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Special Issue Reprint

Sports Science in Children

Edited by
Diogo Coutinho, Sara Santos, Bruno Travassos, Pedro Figueiredo
and Adam Leigh Kelly

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Editors

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Preface

In recent years, the dynamic interplay between research and technology has provided unprecedented opportunities for sports science to lead a transformative impact on the health and well-being of children. While technological advancements offer enhancements in daily activities, they simultaneously introduce challenges, such as diminishing opportunities for street play during childhood and an increase in screen time, leading to discernible negative effects on personal and social aspects (e.g., obesity and depression). These contemporary challenges present novel issues for modern society, and sports science emerges as a crucial ally in effectively addressing them. Indeed, sports science assumes a pivotal role by adeptly designing, implementing, and evaluating diverse sport-related strategies that significantly contribute to fostering long-term sport performance, participation, and personal development.

Sport serves as a conduit that connects people and contributes to the development of physical and mental well-being, which is increasingly at risk in today's society. However, if sporting environments do not contribute to enriching lives and offer appropriate learning experiences, they may, instead of promoting a sense of well-being, emphasize negative emotional states. Thus, this Special Issue has emerged with the mission of bringing together sports scientists from around the world to contribute scientific evidence that supports the creation of enriching environments for personal and social development through sport. Evolution in sport (and society) requires new guidelines on strategies that best promote children's ability to adapt to such complex environments. Taking a holistic view of children's behavior, this special issue aims to provide guidance on the importance of considering factors related with the individual (e.g., maturation or growth), the environment (e.g., relative age effects), and the task (e.g., design, implementation, and monitoring of training scenarios).

Advancements in scientific knowledge in this area increase the possibilities for all sports agents to implement interventions that promote sustainable and healthy long-term development for children. However, the effectiveness of interventions can only be achieved when adequately monitored, and this Special Issue also focuses on the development of instruments and methods for assessing human behavior. The core focus is to support stakeholders and organizational frameworks in refining their methods, creating environments that excel in both effectiveness and efficiency. Overall, we believe that the diverse authorship, samples, and developmental-related factors have resulted in a unique research topic, which has significantly advanced the field through its various approaches and should facilitate thoughtful discussion about sports science in children.

Diogo Coutinho, Sara Santos, Bruno Travassos, Pedro Figueiredo, and Adam Leigh Kelly
Editors

children

Editorial

Special Issue "Sports Science in Children"

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1. Introduction

In recent times, research and technological advancements have opened an unprecedented window of opportunity for sports science to play a pivotal role in the holistic well-being of children [1]. By harnessing the power of sports science, we can not only design, implement, and evaluate sports programs for young athletes but also address broader aspects of their health [2]; therefore, the contemporary role of sports scientists in nurturing young talent cannot be understated, as they promote the most effective and efficient methods to support long-term sport and personal development [3]. By integrating sports science principles into children's health initiatives, we not only contribute to long-term sustained athletic performance but also foster comprehensive health outcomes [4–6]. With appropriate immediate, short-, and long-term interventions, we can enhance athletes' adaptability to navigate the complex and ever-changing competitive landscape.

In the spirit of knowledge dissemination, a diverse range of sports science topics was encouraged as a part of this Special Issue. This included topics such as understanding the various constraints of the performer (e.g., growth and maturation) [7,8], task (e.g., boundary conditions during small-sided games) [9,10], and environment (e.g., Relative Age Effects) [11,12] that coaches should consider in crafting dynamic learning environments; exploring innovative tools and instruments to assess athletes' potential, development, and performance; and the influence of selection, training, and competition environments. Additionally, we sought perspectives and reviews capable of synthesizing knowledge, with a specific emphasis on enhancing our understanding of children's health. This approach was intended to contribute not only to the refinement of youth sports practices but also to the development of comprehensive guidelines that encompass the broader spectrum of children's well-being. Based on these objectives and as a conclusion to this Special Issue, this Editorial provides a general review of the studies and topics included, along with recommendations for future research and practice. In an attempt to view this research through the lens of knowledge mobilization (see [13,14]), we present this Editorial by exploring: (a) knowledge creation (i.e., the refinement of studies into knowledge tools or products through synthesizing our new knowledge), and (b) the shift from knowledge to action (i.e., the application of our new knowledge and skills through informing future policy and systemic change).

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2. Knowledge Creation

This Special Issue features 18 manuscripts, including 14 empirical studies, two reviews, and two conceptual manuscripts. More than 9000 participants were included in the studies, which covered a variety of contexts, including team sports (soccer, n = 4; basketball, n = 2; rugby, n = 1; and volleyball, n = 1), individual sports (judo, n = 1, and tennis, n = 1), multiple sports (basketball, soccer, water polo, volleyball, and handball), and physical education (n = 2). This Special Issue stands as a notable catalyst for advancements within the field, stimulating and enriching meaningful discussions pertaining to the intersection of sports science and youth.

A central focus of this Special Issue was the Relative Age Effect (RAE) in sports. One study by Brustio et al. (1) demonstrated that relatively older players in the rugby union tend to achieve a high-level performance than their later-born counterparts, particularly in the positions of backs and forwards. Interestingly, this effect was more pronounced in players from southern regions, underscoring the impact of sociocultural influences on players' career trajectories. The RAE was also observed by García-Rubio et al. (2) in soccer, spanning from under-17 (U17) to U21 players representing the youth national teams of Spain. Similar patterns were found by Andrew et al. (3), who investigated the RAE in soccer players of both genders across 55 associations under the UEFA governing body. They revealed an over-representation of male players born in the first quartile (January to March) in both the U17 and U19 categories, although these effects did not persist at the senior level. In opposition, no RAE was identified among female players at any level, which highlights that this phenomenon should be considered based on gender, age, competition level, and sport type.

A conceptual paper by Sweeney, Taylor, and MacNamara (4) offered an analysis of the RAE, emphasizing the importance of considering relative age and biological maturation from a holistic and individual perspective. There was an argument for the need for strategies to mitigate the effects of relative age and maturation that prioritize individual considerations, such as grouping players based on specific performance levels (e.g., technical skills) through approaches such as bio-banding rather than employing macro and meso methods. Regarding players' biological maturation, Rüeger et al. (5) reviewed ultrasound-imaging-based methods for assessing biological maturation. While the study highlighted promising results, particularly in wrist and knee measurements due to their non-ionizing nature, affordability, and rapid results, the authors noted the diversity of methods used across studies, making it challenging to establish a "gold standard". The study emphasized the need for further research standardizing procedures, given the potential impact of maturation on selection and career progression opportunities in sport. Collectively, these studies show how the RAE and maturity remain important topics in the sports science literature in children and helped to further understand the two different constructs and its applications.

Another central area of research in sports science involves the examination of young athletes' anthropometric and physical capabilities. Larkin et al. (6) conducted a study comparing children's height, body mass, sprinting, and jumping ability among talented youth athletes (identified at around 13 years old; n = 136) with the general youth population (n = 250). Their findings revealed that both male and female high-level athletes exhibited superior sprinting and jumping abilities compared to their counterparts at lower skill levels. Coincidentally, Pavlinovic et al. (7) suggest that the capacity to jump and sprint has been linked to reactive agility in early pubescent boys and girls (around 11 to 12 years old), a trait identified as pivotal for sporting success. In order to foster the development of reactive agility, pre-pubescent and early pubescent children must be exposed to diverse activities that enhance their fundamental movement skills (7).

Athletes' physical performance, encompassing attributes such as speed, jumping abilities, and reactive agility, has emerged as a critical indicator of talent and a key factor in achieving a high performance (6, 7). In order to develop such physical skills, Xiao et al. (8) investigated the effects of a 12-week functional training intervention on adolescent Chinese tennis players. The authors documented significant enhancements in athletes' strength and power, evidenced by improvements in exercises such as push-ups, medicine ball throws, and standing long jumps, favoring the group that underwent functional training over a control group. Taken together, these studies emphasize the value of implementing fitness testing in youth sports settings to monitor individuals' physical development, as well as the importance of employing strength and conditioning coaches within youth sports environments (as part of an interdisciplinary team) to ensure that young athletes are adequately measured, trained, and developed. Indeed, these approaches should be considered based on the biological age of young athletes as well as their chronological age.

A comprehensive understanding of players' developmental trajectories often requires a retrospective analysis of their career. In this context, Coutinho et al. (9) conducted an in-depth retrospective analysis of 546 young male athletes (aged 13.87 $\pm$ 1.9 years) across a range of sports who belong to regional sports clubs (n = 42). The study revealed that soccer players tended to specialize early despite engaging in a broader spectrum of team sports. Conversely, water polo players demonstrated a higher weekly training volume than soccer and handball by the age of 10 years. Despite this, these findings provide valuable insights to identify the specificities of each sport and unravel the complex factors that shape athletes' pathways toward expertise.

In light of these multifaceted determinants that impact youth development, researchers have designed, implemented, and evaluated interventions to outline ways to nurture athletes' progression in sports. For example, Côté et al. (10) examined the impact of the 1616 Story-Based Youth Development program in ice hockey. The results from the pilot study were encouraging, indicating that strategies of knowledge mobilization from other role models allow for the introduction of principles to sustain positive youth development. Practitioners should consider similar knowledge mobilization initiatives to enhance sports participation, reduce dropout rates, and foster positive attitudes toward sports among young athletes. Another approach to nurture athletes' development involves exposing them to heightened levels of training and competition, such as playing with and against chronologically older opponents and participating in a greater number of competitions, e.g., [15]. Simenko (11) suggested that "playing-up", commonly adopted in youth judo, may contribute to producing young medalists; however, they cautioned that this tactic should be viewed through a short-term lens, as in the long-term, it has been shown to elevate dropout rates in some instances. These findings underscore the importance of multifaceted interventions and holistic approaches in sports science to help shape and support the developmental pathways of young athletes.

As part of this Special Issue, some studies delved into strategies to better understand players' technical and tactical skills in team sports. In this regard, Davids et al. (12) developed a paper describing the intricate interplay between individual, task, and environmental constraints, offering valuable insights into shaping learning opportunities. The work deepens the theoretical understanding and provides practical examples that coaches can employ to guide players' interactions during practice. Additionally, the interaction between player performance and task conditions was extensively explored by Birrento Aguiar et al. (13), who conducted a review of various boundary condition manipulations in youth basketball players' technical and tactical performances. While the research showcased diverse outcomes based on different manipulations, the authors highlighted the need for more studies with youth players to draw robust conclusions. They also emphasized the importance of studies comparing different age groups to offer crucial insights for training design.

In line with that, Tannoubi et al. (14) explored the impact of a video-modeling strategy on enhancing basketball skills in both open and closed tasks for youth players. Their findings indicated marked improvements in analytical drills (such as basketball skill tests) and small-sided games (three vs. three) among the group exposed to video modeling. This underscores the importance of coaches employing such methods to augment players' learning experiences. Examining the nature of training tasks, Coutinho et al. (15) demonstrated that employing tasks grounded in cooperation and opposition led to superior outcomes in decision making and execution for U14 players when compared to more prescriptive tasks or those lacking opposition. Consequently, designing relevant learning environments is dependent on the strategies adopted by coaches as well as the type or interactions promoted by the training tasks.

Now, regarding the variation in individual constraints in players' performance, Coito et al. (16) investigated the impact of players' age (U15, U17, and U19) on the capacity of passing distances in soccer according to pitch zones (e.g., Z1 to Z6, in which Z1 refers to the areas closest to the team's own goal, while Z6 refers to zones closest to the opponents' goal). The research revealed that players tend to employ medium-distance passes close to their opponents' targets and shorter passes in the midfielder zone of the pitch. Notably, older players demonstrated a propensity for medium and longer passes to more distant teammates, reflecting their heightened game knowledge. These findings shed light on the nuanced decision-making processes influenced by age and pitch positioning, guiding coaches in optimizing players' strategic choices on the field.

To enhance the design of training tasks and facilitate continuous improvement among athletes, it is crucial to implement regular performance assessments. A study conducted with U13 female volleyball players demonstrated the effectiveness of adjusting the training focus based on a flexible periodization, tailored to players' assessments during four vs. four small-sided game (SSG) formats, creating a more encouraging learning environment (Loureiro et al., 17). In contrast, adhering to a rigid planning structure whereby adjustments were only made monthly failed to align with the learners' developmental needs. These findings emphasize the necessity for coaches and technical staff to consistently measure and assess players' performance across all dimensions, enabling the creation of appropriate training tasks. In this context, the emergence of new instruments supporting the assessment of players' technical and tactical skills during game-based situations is paramount. González-Rodenas et al. (18) developed the Observational Framework to Evaluate Individual Offensive Behavior in Youth Soccer (INDISOC). This instrument focuses on individual ball possession by evaluating players' performance based on their ability to receive the ball, process, and execute the final action. The INDISOC serves as a valuable tool for coaches to measure players' performance, enabling them to fine-tune the training process and enhance the overall training experience. Taken together, the technical and tactical development of athletes should be carefully considered by both researchers and practitioners and considered part of multidimensional training and research methodologies, respectively.

3. From Knowledge to Action

In this Special Issue, significant attention was given to the RAE and biological age in children's sports, shedding light on the significant impact of birthdate on selection, development, and performance outcomes (1, 3, 4). Multifaceted interventions will play a pivotal role in nurturing athletes' development and progression and ultimately will be crucial in moderating such effects. Practical implementation involves creating, adopting, and measuring strategies that tailor training and development programs based on specific ability levels rather than chronological age (4). This nuanced approach aims to mitigate the challenges posed by relative age and maturation differences and create a fairer and more individualized development pathway for young athletes that reflects the culture, sports, and individual differences.

Anthropometric and physical capabilities also emerged as critical indicators of talent in youth athletes (6–8) To translate this knowledge into practice, youth sports programs should incorporate regular fitness testing to monitor individual physical development. Additionally, emphasizing diverse activities for pre-pubescent and early pubescent children, can enhance fundamental movement skills, laying the foundation for improved sprinting, jumping, and agility abilities. It is noteworthy that the study of (7) revealed that change-of-direction abilities were significant predictors in both boys and girls, whereas jumping skills proved to be a determining factor exclusively in girls. These disparities appear to be linked to gender-specific patterns of sports involvement, with boys more frequently participating in team sports. Indeed, such gender-specific differences were noted by many authors across other disciplines in this Special Issue (e.g., differences in RAEs and maturation); therefore, sport scientists and other youth sport practitioners should be cautious of "copy–pasting" the norms of many male domains and ensure they meet the needs of the female athlete, particularly as both research and professional practice continue to rapidly grow in women's and girls' sport [16].

Technical and tactical skills in team sports can be effectively enhanced through thoughtful training task design and proper feedback strategies. Coutinho et al. (15) highlight the significance of training tasks that emphasize dynamic and unpredictable situations. This emphasizes the need for coaches to carefully consider the conditions introduced during practice sessions, ensuring a well-rounded approach to skill development; mainly when considering team sports in which the information that guides players' actions is continuously changing as a result of the interaction between players and the environment. Complementarily, the introduction of new assessment instruments, such as INDISOC, provides coaches with valuable tools to measure, assess, and prescribe relevant training interventions that enhance players' technical and tactical skills during soccer-game-based situations. In fact, coaches and sports scientists may use video-modeling strategies to augment players' learning experiences (14). For example, coaches may use videos from role-models and high-level players to act as priming strategies that contributes to inspire players' performance. For instance, the continuous performance assessment is critical for creating a conducive learning environment for young athletes. Accordingly, coaches should adjust training focus based on regular assessments by adopting a flexible periodization aligning with the developmental needs of players (17).

4. Future Directions

Building on the contemporary knowledge in sports science related to youth athletes, this Special Issue significantly contributes to the understanding of the pathways for talent development and the effective design of learning environments that concomitantly improves children health and well-being. While the insights provided are valuable, there is a need to continue exploring the evolution of sports coinciding with the mounting pressure on athletes to excel. For example, the potential negative impact of RAEs on numerous young athletes requires further research to mitigate such effects and help widen the pool of potential talent [17,18]. The negative effects of RAEs are also observed in school contexts, where children manifest lower satisfaction with their own life and lower health [19]. Although the impact of RAEs may be more pronounced in sports environments [18], these contexts simultaneously provide fertile ground for the development of strategies to alleviate their negative effects on children and youth [20]. Moreover, they offer an opportunity to enhance young individuals' capacity to perceive and understand individual differences effectively. For that purpose, further studies may explore more individualized and holistic approaches (4). Incorporating assessments of players' biological maturation and action capacities might offer part of the solution; however, despite promising results with ultrasound-image-based methods, the absence of standardized guidelines prevents these techniques from becoming the gold standard procedure (5). It is imperative for researchers to persistently emphasize and advance studies on biological maturity, recognizing the complex specificities inherent to each sport and acknowledging the diverse cultural backgrounds of the individuals involved, as this nuanced understanding is crucial for tailoring training programs and interventions that resonate with the unique physiological and sociocultural aspects of athletes [21].

While physical prowess is a paramount across sports, team sports also heavily rely on players' technical and tactical capabilities. Recent research has explored how different boundary conditions influence player performance (13, 15, 16). However, many of these studies have taken a short-term perspective and focused on specific sample groups (such as amateur players, U19 players, or national-level athletes), limiting the generalizability of their findings. Future research endeavors should adopt medium- and long-term approaches, incorporating participants from diverse skill levels and age groups. Moreover, these interventions should include instruments for continuously monitoring players' development, enabling the formulation of adaptable short-term plans that prioritize fostering positive and conducive learning environments. This holistic and inclusive approach promises to yield more comprehensive and actionable insights, propelling the field of youth sports science into a more nuanced and impactful future.

To our surprise, no studies on artificial intelligence (AI) were included. Indeed, AI (e.g., machine learning approaches and Generative AI) are becoming increasingly common in applied sport science environments, e.g., [22], thus capturing some of these stories and evaluating good practice will be important moving forward. For instance, the emergence of chatbots has played a significant role in facilitating interactions between AI and individuals [23]. One notable interaction involves requesting personalized training interventions, where AI provides suggestions and assistance at a personal level [24], potentially contributing to improved health and wellbeing [25]. This presents a realm of new opportunities to explore how AI can contribute to reducing the high prevalence of sedentary behavior among children [26] and addressing issues such as relative energy deficiency in sports (REDS) [27]. Consequently, there is a call to action to inspire researchers and stakeholders to intensify their efforts in developing experimental studies. These studies can contribute to the establishment of normative guidelines that assist children, youth, coaches, and parents in utilizing AI to promote an active lifestyle and enhance health and well-being.

It was also surprising to note that no study focused on children's health nor well-being. In recent years, we have witnessed an unprecedented increase in childhood obesity [28]. This surge is compounded by elevated levels of sedentary behavior [29], extensive screen time [30] and decreased social interaction [31]. Collectively, these factors have contributed to a rise in issues related to mental health [32]. Indeed, mental health has garnered significant attention from researchers, particularly following the onset of the COVID-19 pandemic [33–35]. While it is well established that sports can positively impact mental health outcomes [36], additional research is needed to comprehend how children of various age groups and genders may respond to distinct training interventions from both micro- and macroscale perspectives. Consequently, future studies must delve into the ways in which sports sciences can actively contribute to the well-being of children, with a specific focus on mental health. This exploration should involve sharing insights from clinical, epidemiological, and translational science that are particularly relevant to children's health.

Lastly, during sports science research and practice related to youth, we feel it is pertinent to highlight the need to ensure that we put the child before the athlete in all circumstances. More specifically, we encourage both researchers and practitioners to recognize the growing research in this field, as well as (and more importantly) the rapid increase in the professionalization of talent development systems (e.g., soccer academies), should not compromise children's rights [37]. For instance, talent pathways are inherently judicious and discriminate due to the often subjective and selective nature of these processes, and thus, athletes regularly face various setbacks (e.g., deselection) and mistreatment (e.g., biases in selection). Researchers can negate this by ensuring organizations possess a clear and coherent children's rights policy prior to engaging in research activities, whilst practitioners must respect and promote children's rights, health, and wellbeing during applied activities.

5. Summary

This Special Issue was designed with the dual purpose of advancing youth sports science research to provide theoretical and practical insights. These insights not only contribute to enhancing the understanding of youth sports but also play a crucial role in promoting the health, both physical and mental, of children. The aim is to assist stakeholders and organizational structures in adapting their practices to foster more effective and efficient environments, with a specific emphasis on the significant impact these practices can have on the overall health and well-being of youth. Beyond expanding the knowledge in specific domains, research efforts have also aimed to raise new questions, inspiring future advancements in this field. Moving forward, researchers and practitioners are encouraged to co-create research projects to facilitate greater knowledge mobilization across children's sports science. We extend heartfelt gratitude to all the contributing authors and reviewers whose dedication and expertise have made this research topic possible. Their invaluable contributions have enriched our understanding of sports science in youth and paved the way for innovative approaches and progressive developments in this crucial area. Thank you for your unwavering commitment to advancing the world of sports science and nurturing the talents of young athletes.

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List of Contributions

1. Brustio, P.R.; Kelly, A.L.; Lupo, C.; Ungureanu, A.N. The Influence of Contextual Factors on the Relative Age Effect in Male International Rugby Union: The Impact of Sociocultural Influences and Playing Position. *Children* **2022**, *9*, 1941.
2. García-Rubio, J.; García-Vallejo, A.; Arenas-Pareja, M.d.l.Á.; López-Sierra, P.; Ibáñez, S.J. From Junior to Elite in Soccer: Exploring the Relative Age Effect and Talent Selection in Spanish Youth National Teams. *Children* **2022**, *9*, 1543.
3. Andrew, M.; Finnegan, L.; Datson, N.; Dugdale, J.H. Men Are from Quartile One, Women Are from? Relative Age Effect in European Soccer and the Influence of Age, Success, and Playing Status. *Children* **2022**, *9*, 1747.
4. Sweeney, L.; Taylor, J.; MacNamara, Á. Push and Pull Factors: Contextualising Biological Maturation and Relative Age in Talent Development Systems. *Children* **2023**, *10*, 130.
5. Rüeger, E.; Hutmacher, N.; Eichelberger, P.; Löcherbach, C.; Albrecht, S.; Romann, M. Ultrasound Imaging-Based Methods for Assessing Biological Maturity during Adolescence and Possible Application in Youth Sport: A Scoping Review. *Children* **2022**, *9*, 1985.
6. Larkin, P.; Carlon, T.; Sortino, B.; Greer, S.; Cuttiford, T.; Wijekulasuriya, G.; Pane, C. Anthropometry and Physical Performance in 13-Year-Old Australian Talent-Identified Male and Female Athletes Compared to an Age-Matched General Population Cohort. *Children* **2023**, *10*, 212.
7. Pavlinovic, V.; Foretic, N.; Versic, S.; Sekulic, D.; Liposek, S. Predictors of Reactive Agility in Early Puberty: A Multiple Regression Gender-Stratified Study. *Children* **2022**, *9*, 1780.
8. Xiao, W.; Bai, X.; Geok, S.K.; Yu, D.; Zhang, Y. Effects of a 12-Week Functional Training Program on the Strength and Power of Chinese Adolescent Tennis Players. *Children* **2023**, *10*, 635.
9. Coutinho, P.; Ramos, A.; Afonso, J.; Bessa, C.; Ribeiro, J.; Davids, K.; Fonseca, A.M.; Mesquita, I. To Sample or to Specialise? Sport Participation Patterns of Youth Team Sport Male Players. *Children* **2023**, *10*, 729.
10. Côté, J.; Coletti, J.; McGuire, C.S.; Erickson, K.; Saizew, K.; Maw, A.; Primeau, C.; Wolff, M.; Ladd, B.; Martin, L.J. A Proof-of-Concept Evaluation of the 1616 Story-Based Positive Youth Development Program. *Children* **2023**, *10*, 799.
11. Simenko, J. Youth Judokas Competing in Higher Age Groups Leads to a Short-Term Success. *Children* **2022**, *9*, 1737.
12. Davids, K.; Rothwell, M.; Hydes, S.; Robinson, T.; Davids, C. Enriching Athlete—Environment Interactions in Youth Sport: The Role of a Department of Methodology. *Children* **2023**, *10*, 752.
13. Birrento Aguiar, R.A.; Giménez Egido, J.M.; Palao Andrés, J.M.; Ortega-Toro, E. Influence of Rule Manipulation on Technical—Tactical Actions in Young Basketball Players: A Scoping Review. *Children* **2023**, *10*, 323.
14. Tannoubi, A.; Ouergui, I.; Srem-Sai, M.; Hagan, J.E.; Quansah, F.; Azaiez, F. Effectiveness of Video Modeling in Improving Technical Skills in Young Novice Basketball Players: A Quasi-Experimental Study. *Children* **2023**, *10*, 687.
15. Coutinho, D.; Kelly, A.L.; Santos, S.; Figueiredo, P.; Pizarro, D.; Travassos, B. Exploring the Effects of Tasks with Different Decision-Making Levels on Ball Control, Passing Performance, and External Load in Youth Football. *Children* **2023**, *10*, 220.

16. Coito, N.; Folgado, H.; Monteiro, D.; Travassos, B. How Football Players' Age Affect Passing Patterns of Play According to Field Location. *Children* **2023**, *10*, 157.
17. Loureiro, M.; Mesquita, I.; Ramos, A.; Coutinho, P.; Ribeiro, J.; Clemente, F.M.; Nakamura, F.Y.; Afonso, J. Flexible Training Planning Coupled with Flexible Assessment: A 12-Week Randomized Feasibility Study in a Youth Female Volleyball Team. *Children* **2023**, *10*, 29.
18. González-Rodenas, J.; Villa, I.; Tudela-Desantes, A.; Aranda-Malavés, R.; Aranda, R. Design and Reliability of an Observational Framework to Evaluate the Individual Offensive Behavior in Youth Soccer—The INDISOC Tool. *Children* **2022**, *9*, 1311.

References

1. Radovic, A.; Badawy, S.M. Technology Use for Adolescent Health and Wellness. *Pediatrics* **2020**, *145*, S186–S194. [CrossRef] [PubMed]
2. Smedegaard, S.; Christiansen, L.B.; Lund-Cramer, P.; Bredahl, T.; Skovgaard, T. Improving the well-being of children and youths: A randomized multicomponent, school-based, physical activity intervention. *BMC Public Health* **2016**, *16*, 1127. [CrossRef]
3. Côté, J.; Turnnidge, J.; Vierimaa, M. A Personal Assets Approach to Youth Sport. In *Handbook of Youth Sport*; Smith, A., Green, K., Eds.; Routledge: Oxfordshire, UK, 2016; pp. 243–256.
4. Moeijes, J.; van Busschbach, J.T.; Bosscher, R.J.; Twisk, J.W.R. Sports participation and psychosocial health: A longitudinal observational study in children. *BMC Public Health* **2018**, *18*, 702. [CrossRef]
5. Kokko, S. Sports clubs as settings for health promotion: Fundamentals and an overview to research. *Scand. J. Public Health* **2014**, *42*, 60–65. [CrossRef]
6. Pate, R.R.; Hillman, C.H.; Janz, K.F.; Katzmarzyk, P.T.; Powell, K.E.; Torres, A.; Whitt-Glover, M.C. Physical Activity and Health in Children Younger than 6 Years: A Systematic Review. *Med. Sci. Sports Exerc.* **2019**, *51*, 1282–1291. [CrossRef]
7. Malina, R.M.; Cumming, S.P.; Rogol, A.D.; Coelho, E.S.M.J.; Figueiredo, A.J.; Konarski, J.M.; Kozieł, S.M. Bio-Banding in Youth Sports: Background, Concept, and Application. *Sports Med.* **2019**, *49*, 1671–1685. [CrossRef]
8. Towlson, C.; MacMaster, C.; Gonçalves, B.; Sampaio, J.; Toner, J.; MacFarlane, N.; Barrett, S.; Hamilton, A.; Jack, R.; Hunter, F.; et al. The effect of bio-banding on technical and tactical indicators of talent identification in academy soccer players. *Sci. Med. Footb.* **2022**, *6*, 295–308. [CrossRef]
9. Clemente, F.M.; Ramirez-Campillo, R.; Sarmento, H.; Praça, G.M.; Afonso, J.; Silva, A.F.; Rosemann, T.; Knechtle, B. Effects of Small-Sided Game Interventions on the Technical Execution and Tactical Behaviors of Young and Youth Team Sports Players: A Systematic Review and Meta-Analysis. *Front. Psychol.* **2021**, *12*, 667041. [CrossRef]
10. Silva, A.F.; Ramirez-Campillo, R.; Sarmento, H.; Afonso, J.; Clemente, F.M. Effects of Training Programs on Decision-Making in Youth Team Sports Players: A Systematic Review and Meta-Analysis. *Front. Psychol.* **2021**, *12*, 663867. [CrossRef] [PubMed]
11. Wattie, N.; Schorer, J.; Baker, J. The relative age effect in sport: A developmental systems model. *Sports Med.* **2015**, *45*, 83–94. [CrossRef] [PubMed]
12. Bozděch, M.; Agricola, A.; Zháněl, J. The Relative Age Effect at Different Age Periods in Soccer: A Meta-Analysis. *Percept. Mot. Ski.* **2023**, *130*, 2632–2662. [CrossRef] [PubMed]
13. Graham, I.D.; Logan, J.; Harrison, M.B.; Straus, S.E.; Tetroe, J.; Caswell, W.; Robinson, N. Lost in knowledge translation: Time for a map? *J. Contin. Educ. Health Prof.* **2006**, *26*, 13–24. [CrossRef] [PubMed]
14. Kelly, A.L.; Turnnidge, J. From Knowledge to Action: Bridging the Gap Between Research and Practice in Youth Soccer. In *Talent Identification and Development in Youth Soccer*; Routledge: Oxfordshire, UK, 2023.
15. Kelly, A.; Wilson, M.R.; Jackson, D.T.; Goldman, D.E.; Turnnidge, J.; Côté, J.; Williams, C.A. A multidisciplinary investigation into "playing-up" in academy football according to age phase. *J. Sports Sci.* **2021**, *39*, 854–864. [CrossRef]
16. Kelly, A.L.; Brown, T.; Reed, R.; Côté, J.; Turnnidge, J. Relative Age Effects in Male Cricket: A Personal Assets Approach to Explain Immediate, Short-Term, and Long-Term Developmental Outcomes. *Sports* **2022**, *10*, 39. [CrossRef] [PubMed]
17. Kelly, A.L.; Calvo, A.L.; dos Santos, S.D.; Jiménez Sáiz, S.L. Special Issue "Talent Identification and Development in Youth Sports". *Sports* **2022**, *10*, 189. [CrossRef]
18. Jones, B.D.; Lawrence, G.P.; Hardy, L. New evidence of relative age effects in "super-elite" sportsmen: A case for the survival and evolution of the fittest. *J. Sports Sci.* **2018**, *36*, 697–703. [CrossRef]
19. Fumarco, L.; Baert, S.; Sarracino, F. Younger, dissatisfied, and unhealthy—Relative age in adolescence. *Econ. Hum. Biol.* **2020**, *37*, 100858. [CrossRef]
20. Webdale, K.; Baker, J.; Schorer, J.; Wattie, N. Solving sport's 'relative age' problem: A systematic review of proposed solutions. *Int. Rev. Sport Exerc. Psychol.* **2020**, *13*, 187–204. [CrossRef]
21. Malina, R.M.; Rogol, A.D.; Cumming, S.P.; Coelho e Silva, M.J.; Figueiredo, A.J. Biological maturation of youth athletes: Assessment and implications. *Br. J. Sports Med.* **2015**, *49*, 852–859. [CrossRef]
22. Kelly, A.L.; Williams, C.A.; Cook, R.; Sáiz, S.L.J.; Wilson, M.R. A Multidisciplinary Investigation into the Talent Development Processes at an English Football Academy: A Machine Learning Approach. *Sports* **2022**, *10*, 159. [CrossRef]
23. Maher, C.A.; Davis, C.R.; Curtis, R.G.; Short, C.E.; Murphy, K.J. A Physical Activity and Diet Program Delivered by Artificially Intelligent Virtual Health Coach: Proof-of-Concept Study. *JMIR Mhealth Uhealth* **2020**, *8*, e17558. [CrossRef]

24. Zhang, J.; Oh, Y.J.; Lange, P.; Yu, Z.; Fukuoka, Y. Artificial Intelligence Chatbot Behavior Change Model for Designing Artificial Intelligence Chatbots to Promote Physical Activity and a Healthy Diet: Viewpoint. *J. Med. Internet Res.* **2020**, *22*, e228452020. [CrossRef]
25. Oh, Y.J.; Zhang, J.; Fang, M.-L.; Fukuoka, Y. A systematic review of artificial intelligence chatbots for promoting physical activity, healthy diet, and weight loss. *Int. J. Behav. Nutr. Phys. Act.* **2021**, *18*, 160. [CrossRef] [PubMed]
26. Rodriguez-Ayllon, M.; Cadenas-Sánchez, C.; Estévez-López, F.; Muñoz, N.E.; Mora-Gonzalez, J.; Migueles, J.H.; Molina-García, P.; Henriksson, H.; Mena-Molina, A.; Martínez-Vizcaíno, V.; et al. Role of Physical Activity and Sedentary Behavior in the Mental Health of Preschoolers, Children and Adolescents: A Systematic Review and Meta-Analysis. *Sports Med.* **2019**, *49*, 1383–1410. [CrossRef] [PubMed]
27. Ackerman, K.E.; Stellingwerff, T.; Elliott-Sale, K.J.; Baltzell, A.; Cain, M.; Goucher, K.; Fleshman, L.; Mountjoy, M.L. #REDS (Relative Energy Deficiency in Sport): Time for a revolution in sports culture and systems to improve athlete health and performance. *Br. J. Sports Med.* **2020**, *54*, 369–370. [CrossRef] [PubMed]
28. Lanigan, J.; Barber, S.; Singhal, A. Prevention of obesity in preschool children. *Proc. Nutr. Soc.* **2010**, *69*, 204–210. [CrossRef] [PubMed]
29. Saunders, T.J.; Chaput, J.P.; Tremblay, M.S. Sedentary behaviour as an emerging risk factor for cardiometabolic diseases in children and youth. *Can. J. Diabetes* **2014**, *38*, 53–61. [CrossRef] [PubMed]
30. Robinson, T.N.; Banda, J.A.; Hale, L.; Lu, A.S.; Fleming-Milici, F.; Calvert, S.L.; Wartella, E. Screen Media Exposure and Obesity in Children and Adolescents. *Pediatrics* **2017**, *140*, S97–S101. [CrossRef] [PubMed]
31. Kraut, R.; Patterson, M.; Lundmark, V.; Kiesler, S.; Mukopadhyay, T.; Scherlis, W. Internet paradox. A social technology that reduces social involvement and psychological well-being? *Am. Psychol.* **1998**, *53*, 1017–1031. [CrossRef]
32. Membride, H. Mental health: Early intervention and prevention in children and young people. *Br. J. Nurs.* **2016**, *25*, 552–557. [CrossRef]
33. Westrupp, E.M.; Bennett, C.; Berkowitz, T.; Youssef, G.J.; Toumbourou, J.W.; Tucker, R.; Andrews, F.J.; Evans, S.; Teague, S.J.; Karantzas, G.C.; et al. Child, parent, and family mental health and functioning in Australia during COVID-19: Comparison to pre-pandemic data. *Eur. Child Adolesc. Psychiatry* **2023**, *32*, 317–330. [CrossRef] [PubMed]
34. Ravens-Sieberer, U.; Erhart, M.; Devine, J.; Gilbert, M.; Reiss, F.; Barkmann, C.; Siegel, N.A.; Simon, A.M.; Hurrelmann, K.; Schlack, R.; et al. Child and Adolescent Mental Health During the COVID-19 Pandemic: Results of the Three-Wave Longitudinal COPSY Study. *J. Adolesc. Health* **2022**, *71*, 570–578. [CrossRef] [PubMed]
35. Elharake, J.A.; Akbar, F.; Malik, A.A.; Gilliam, W.; Omer, S.B. Mental Health Impact of COVID-19 among Children and College Students: A Systematic Review. *Child Psychiatry Hum. Dev.* **2023**, *54*, 913–925. [CrossRef] [PubMed]
36. Belcher, B.R.; Zink, J.; Azad, A.; Campbell, C.E.; Chakravartti, S.P.; Herting, M.M. The Roles of Physical Activity, Exercise, and Fitness in Promoting Resilience During Adolescence: Effects on Mental Well-Being and Brain Development. *Biol. Psychiatry Cogn. Neurosci. Neuroimaging* **2021**, *6*, 225–237. [CrossRef]
37. Jayanthi, N.A.; Post, E.G.; Laury, T.C.; Fabricant, P.D. Health Consequences of Youth Sport Specialization. *J. Athl. Train.* **2019**, *54*, 1040–1049. [CrossRef]

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Article

Anthropometry and Physical Performance in 13-Year-Old Australian Talent-Identified Male and Female Athletes Compared to an Age-Matched General Population Cohort

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Abstract: Talent-identified male and female athletes are assumed to have greater speed and power than the general population at a given age. However, a comparison of the jump and sprint performance of an Australian cohort of male and female youth athletes from various sports to age-matched controls has not occurred. Therefore, the aim of this study was to compare anthropometric and physical performance markers between ~13-year-old talent-identified youth athletes and general population Australian youth. The anthropometry and physical performance in talent-identified youth athletes (n = 136, 83 males) and general population youth (n = 250, 135 males) were tested during the first month of the school year in an Australian high school within a specialized sports academy. Talent-identified females were taller ($p < 0.001$; d = 0.60), sprinted faster (20 m: $p < 0.001$; d = −1.16), and jumped higher ($p < 0.001$; d = 0.88) than general population youth females. Similarly, talent-identified males sprinted faster (20 m: $p < 0.001$; d = −0.78) and jumped higher ($p < 0.001$; d = 0.87) than general population youth males, but were not taller ($p = 0.13$; d = 0.21). Body mass was not different between groups for males ($p = 0.310$) or females ($p = 0.723$). Overall, youth, particularly females, who are trained in a variety of sports, exhibit greater speed and power during early adolescence compared to their age-matched peers, with anthropometric differences only occurring in females at 13 years of age. Whether talented athletes are selected because they exhibit these traits or whether speed and power are developed through sport participation requires further investigation.

Keywords: physical fitness; performance data; speed; power; youth athletic development

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1. Introduction

There are well-known health-related benefits associated with youth physical activity [1], including cardiorespiratory fitness [2], muscular fitness [3], bone health [4], and cardiometabolic health [5]. Furthermore, evidence suggests that physical activity reduces depressive symptoms in children and adolescents [6], and can have a positive effect on cognitive function and academic outcomes (e.g., school performance, memory and executive function) [7]. While researchers have examined the level and types of physical activity youth undertake to inform guidelines and recommendations [8], few have reported the physical profile of the general Australian youth population; in particular, speed (i.e., 20-m sprint) and power (i.e., vertical jump) measures. When anthropometric and physical performance profiles have been reported, it has generally been to highlight "at risk" groups and the potential impact of a lack of physical activity on health and well-being [9,10]. Therefore, it is important to develop benchmarks of anthropometry and physical performance which can be used to inform practitioners, such as medical professionals, physical education teachers, and youth sport coaches, when prescribing physical activity in the general population.

While there has been limited research investigating the general youth population, there has been extensive research profiling the anthropometric and physical performance measures of talented youth athletes [11,12]. By definition, talented youth athletes have been described as individuals with a special ability in a specific domain which places them in the top 10% of their peers, and have the potential for high-level performance in adulthood [13–16]. Profiling of anthropometric and physical performance measures has been used to inform performance benchmarks, talent identification, health and well-being, and return-to-play protocols for youth athletes [17,18]. For example, the ability to perform high-speed running actions [19] and jump higher [20] are important prerequisites for successful performance in many sports. To assess the sprint capacity of a youth athlete, maximum linear acceleration assessments have been used, with the most common being a maximal 20 metre (m) sprint [21–23]. Further, to measure lower limb power, countermovement jump (CMJ) performance has been shown to provide youth athletes with a competitive advantage [24]. A limitation of the current knowledge is that performance benchmarks and age-related differences are based on studies which focused on specific sports, and typically observed males [25]. Therefore, there is a need to explore these factors in both generally trained and female populations.

While studies have explored physical activity and performance levels in the general youth population and sport-specific contexts, there are still limited normative anthropometric and physical performance data for the Australian youth general population and talent-identified youth athletes. To the authors' knowledge, there are no studies available that provide sex-specific anthropometric and physical fitness normative data for a trained and untrained Australian youth population (i.e., 13-year-olds). Therefore, the purpose of this cross-sectional study was to present sex-specific anthropometric (i.e., body height, body mass) and physical performance (i.e., CMJ; 5 m, 10 m, and 20 m sprint) reference values for Australian talent-identified and general population youths. A further aim of this study was to determine anthropometric and physical differences between these two populations. These findings will provide benchmark values and identify specific anthropometric and physical performance characteristics for the relevant population, and potentially inform physical activity recommendations.

2. Materials and Methods

2.1. Participants

A total of 386 individuals participated in this cross-sectional study. Participants were recruited from a single Australian public high school (Year 7 and 8). When considered by sex, there were 168 females (talent-identified: n = 53, age = 12.92 $\pm$ 0.60 years; general population: n = 115, age = 12.96 $\pm$ 0.65 years) and 218 males (talent-identified: n = 83, age = 13.15 $\pm$ 0.56 years; general population: n = 135, age = 13.04 $\pm$ 0.63 years) who participated in the study.

Participants were included in the study if they met the following inclusion criteria: (1) attending the partner school, (2) being in Year 7 and Year 8 school grades, and (3) participating in physical education classes during the testing period (Term 1 2022, February–March). Within this group, 136 were talent-identified youth athletes who were selected for and attended the sports academy within the high school. Participants were selected for the academy based on coach expert opinion of their sporting ability at the age of selection (~12 years old). The aim of the academy is to provide a training environment which accelerates an individual's progress within their nominated sports national talent pathway. The training environment of the academy included three 45 min formal strength and conditioning sessions per week with nationally accredited strength and conditioning coaches. Further, participants completed between two to three 90 min sport-specific training sessions. This school-based training environment (i.e., strength and conditioning; sport-specific training) complemented the external sport-specific national talent pathway training (i.e., club training; national training camps) the participants were undertaking. The other 250 individuals were regular high school students from the general population.

These individuals were not a part of the academy and completed regular Australian high school curriculum, including Physical Education classes.

The sole exclusion criterion was injury which prevented participation in the testing session. Therefore, any individual who had an injury which impeded their ability to perform the physical assessments on the testing day were excluded from the study. Ethical approval was gained from the lead institution's research ethics board (HRE 21-064) which abides by the guidelines of the Declaration of Helsinki. Consent was obtained for all participants and parents of all participants prior to data collection.

2.2. Experimental Design

All participants completed a range of anthropometric (i.e., standing height; body mass) and physical performance measures (i.e., CMJ; 5 m, 10 m, and 20 m sprint), which were completed in one session and conducted by tertiary educated strength and conditioning coaches with over 5 years' experience conducting this testing battery. The testing occurred in the same indoor venue with standardised environmental conditions for all participants. Prior to testing all electronic testing equipment was calibrated according to manufacturer standards. The height and body mass of participants were recorded, followed by a standardised 10-min warm up, led by a qualified strength and conditioning coach, which included familiarisation to the CMJ and 20 m sprint procedures. Participants then completed a CMJ followed by the 20 m sprint [26].

2.3. Measures

Height was measured using a wall-mounted stadiometer (Wedderburn, Sydney, Australia), with each participant removing socks and shoes. The stretch–stature method [27] was used to minimise technical error, with each participant instructed to inhale and hold a deep breath during the measurement. All measurements of height were taken at the end of the inhale with the headboard placed firmly on the vertex of the head and heels together and on the ground. Height was measured in centimetres (cm), with typical error of 1.0 cm [28].

Portable force plates (ForceDecks FD4000, VALD Performance, Brisbane, Australia) were used to measure body mass and CMJ [29]. Participants stood with their hands on their hips and feet shoulder width apart on each of the force places. After calibration, participants were instructed to step onto the plates and stand as still as possible to determine body mass. The participant was then instructed to perform a CMJ to a self-selected depth "as quickly and explosively as possible" on "GO" after a 3-2-1-GO countdown. Participants had to start and land on the force plates, keep their hands on their hips and have their knees extended during flight. If this did not occur, the jump was ruled as invalid and repeated. One familiarisation jump occurred before three jumps were completed in total, with the maximum jump height (cm) and body mass (kg) recorded for analysis.

A 20 m straight-line course on a basketball court was used to measure sprint performance. Electronic timing gates (Swift Performance Equipment, Lismore, Australia) were positioned at the start line as well as at 5 m, 10 m, and 20 m intervals. All participants started in a crouched position with the front foot touching the start line, back heel up, and no hands on the ground. Participants had to start from a stationary position and could not use a 3-point start position. Participants began whenever they were ready and were instructed to "run as fast as they could" until they reached cones placed at the 25 m mark. Three maximal sprints were undertaken with a 2 min recovery in between. The best split times for 5 m, 10 m, and 20 m were recorded in seconds, with typical error of measurement being 0.03 s [26].

2.4. Statistical Analysis

Descriptive statistics were used to summarise the data, with the mean, standard deviation (SD), minimum, and maximum for all measures (i.e., standing height; body mass; CMJ; 5 m, 10 m, and 20 m sprint performance across each group relative to sex).

The assumptions of normality were assessed visually using a histogram for all outcome variables. As there were no deviations from a normal distribution, parametric statistical analyses were conducted. Due to the difference in population size between the talent-identified athletes and general population groups, a Welch's *t*-test were used to determine between-group differences in physical performance measures. R Studio version 4.1.2 (RStudio, Boston, USA) was used for all data management and analysis, with the "rstatix" package providing the integrated *t*-test function (*t*_test(), with argument "var.equal = False" for Welch's *t*-test). For the independent *t*-test, each of the physical performance measures were the dependent variable. These measures were: stand height (cm), body mass (kg), CMJ (cm), and 5 m, 10 m, and 20 m sprint (seconds). For each analysis, the independent variable was the participant group (i.e., talent-identified athletes; general population). Point estimates for mean difference in populations, along with 95% confidence intervals, were calculated. Results were considered statistically significant for $p < 0.05$. Effect sizes were calculated by Cohen's d [30] and the magnitude was described by Sawilowsky's [31] rules of thumb (very small, d = 0.01; small, d = 0.20; medium, d = 0.50; large, d = 0.80; very large, d = 1.20; huge, d = 2.00).

3. Results

Tables 1 and 2 present the mean and standard deviation values of the physical fitness tests for the talent-identified and general population relative to sex. In particular, female talent-identified athletes were taller ($p < 0.001$; d = 0.60), jumped higher (CMJ; $p < 0.001$; d = 0.88) and sprinted faster (5 m $p < 0.001$; d = −0.69; 10 m $p < 0.001$; d = −1.05; 20 m $p < 0.001$; d = −1.16) than their general population counterparts. There was no significant difference in body mass between the female groups ($p = 0.723$; d = −0.06).

Table 1. Descriptive statistics with group difference for female talent-identified athletes and the general population counterparts for the physical performance measures.

	Talent-Identified Athletes (n = 53)			General Population (n = 115)							
	Mean (SD)	Maximum	Minimum	Mean (SD)	Maximum	Minimum	Mean Difference	Lower 95% CI	Upper 95% CI	*p*-value	Effect Size
Stand Height (cm)	160.93 (7.40)	142.7	180.19	156.91 (5.89)	144.4	170.7	4.02	1.72	6.32	<0.001 *	Medium
Body Mass (kg)	51.27 (8.71)	32.35	74.99	51.84 (11.59)	31.50	105.70	−0.57	−3.76	2.62	0.723	Very Small
CMJ (cm)	24.86 (4.02)	17.10	32.60	20.70 (4.96)	6.50	32.10	3.98	2.55	5.40	<0.001 *	Large
5 m Sprint (s)	1.26 (0.07)	1.12	1.44	1.32 (0.11)	1.12	1.71	−0.07	−0.10	−0.04	<0.001 *	Medium
10 m Sprint (s)	2.08 (0.11)	1.90	2.35	2.24 (0.18)	1.95	2.92	−0.15	−0.20	−0.11	<0.001 *	Large
20 m Sprint (s)	3.61 (0.19)	3.29	4.09	3.94 (0.36)	3.16	5.38	−0.34	−0.42	−0.25	<0.001 *	Large

* denotes a significant ($p < 0.05$) difference between groups, SD: standard deviation.

In relation to males, talent-identified athletes were found to jump higher (CMJ; $p < 0.001$; d = 0.87) and sprint faster (10 m; $p < 0.001$; d = −0.62; 20 m; $p < 0.001$; d = −0.78) than their general population counterparts. There were no significant statistical differences for stand height ($p = 0.13$; d = 0.21), 5 m sprint ($p = 0.07$; d = −0.25), and body mass ($p = 0.31$; d = −0.13) between the groups.

Table 2. Descriptive statistics with group difference for male talent-identified athletes and the general population counterparts for the physical performance measures.

	Talent-Identified Athletes (n = 83)			General Population (n = 135)							
	Mean (SD)	Maximum	Minimum	Mean (SD)	Maximum	Minimum	Mean Difference	Lower 95% CI	Upper 95% CI	*p*-value	Effect Size
Stand Height (cm)	163.1 (10.66)	145.4	190.44	160.93 (9.85)	136.6	191.6	−1.86	−0.68	5.03	0.134	Small
Body Mass (kg)	52.43 (10.46)	32.19	81.84	54.29 (16.67)	26.10	121.20	2.18	−5.49	1.76	0.311	Very Small
CMJ (cm)	29.32 (6.26)	16.10	43.30	24.08 (5.77)	8.70	37.10	5.24	3.57	6.92	<0.001 *	Large
5 m Sprint (s)	1.22 (0.09)	1.03	1.48	1.25 (0.10)	1.02	1.71	−0.02	−0.05	0.00	0.069	Small
10 m Sprint (s)	2.01 (0.13)	1.71	2.37	2.11 (0.17)	1.76	2.92	−0.10	−0.14	−0.05	<0.001 *	Medium
20 m Sprint (s)	3.49 (0.24)	2.94	4.08	3.72 (0.36)	3.08	5.20	−0.24	−0.32	−0.16	<0.001 *	Medium

* denotes a significant ($p < 0.05$) difference between groups, SD: standard deviation.

4. Discussion

The aim of this study was to present sex-specific anthropometry and physical performance normative data for 13 year olds and to determine the difference between talent-identified and general population youth in anthropometry, speed, and power. Male and female youth talent-identified athletes exhibited greater speed over 10 m and 20 m and lower body power compared to age-matched general population youth. Female youth talent-identified athletes were taller than the general population, and body mass was not different between groups for both sexes. Therefore, speed and power are physical characteristics which discriminate talent-identified athletes from the general population in a heterogenous sample of youth. Anthropometric characteristics carry greater importance in differentiating talented females than talented males at ~13 years of age.

Our data suggest that speed and power are discriminating factors between talent-identified male and female youth athletes and the general population. There are limited studies which compare the speed and power of trained and untrained youth male and female populations. Estonian girls (10 to 17 years old) who participated in track and field were found to have greater 30 m sprint speed and CMJ jump height for all chronological age groups than a recreationally active control group [32]. Russian girls trained in judo and volleyball aged 12 to 14 years were faster and had a longer standing broad jump compared with untrained youth [33], and male swimmers (~14 years old) had greater upper body strength compared to age-matched controls [34]. The principle of training specificity can explain the differences of previous studies, as youth competing in sports which require speed [32], lower body power [32,33], and upper body strength [34] had greater performance of these physical characteristics compared to untrained youth. However, the results of the current study show that differences in speed and lower body power exist between the general population and a heterogenous sample of youth talent-identified athletes. Further work is required to determine whether improvements in speed and power are caused by participation in sport alone and the extent that these potential adaptations may have on the health of athletes and youth in general.

Previous research has shown that despite no resistance training, male 14-year-old recreational and talent-identified soccer players have greater strength during high- and low-velocity concentric contractions of lower limb muscles compared to untrained controls [35]. For youth aged ~13 years, predominantly neuromuscular adaptations increase speed and power [36]. Specifically, greater motor unit activation, neuromuscular coordination and neural drive is purported to increase strength and power in youth aged between 12 and 14 years [37]. This is because increases in muscle size and mass and strength gains associated with these morphological changes typically occur after the period of peak growth (peak height velocity) in youth [37,38]. Resistance training is a modality which increases strength, speed, and lower body power in youth athletes [39,40]. The talent-identified population within this study participated in resistance training based program within the sports academy; therefore, training adaptation to this stimulus may explain the differences in speed and lower body power. However, testing occurred in Term 1 of the school calendar, with participants also having had limited structured resistance training during the 12 months prior to testing due to COVID-19 lockdown restrictions, and had limited structured resistance training for the 6 weeks prior to testing. Since resistance training history was not collected within each cohort, there is no way of knowing the extent that residual strength, speed, and power gains from previous training explained the differences in speed and power in the cohorts of talent-identified and general population youth studied. A previous study of ~16-year-old male youth athletes have suggested that resistance training age predicts lower body power but sport training age predicts strength and athletic qualities like change of direction ability [41]. Further research is required to determine the extent to which sport exposure and/or resistance training exposure affects speed and power, given that these physical characteristics discriminate between talent-identified youth and the general population.

The magnitude of difference between the anthropometric and physical characteristics of talent-identified and untrained male and female 13-year-olds was sex-specific. Talent-identified females were taller than their sex-matched general population counterparts, whilst height was not different between male cohorts. Furthermore, there were consistent differences and effect sizes between male and female cohorts for the CMJ, whilst the difference in sprinting was greater in magnitude between trained and untrained females compared to males. This is the first study, to the authors' knowledge, to observe the differences in anthropometric and physical characteristics between trained and untrained male and female youth. Taller talent-identified females compared to the general population may be due to the talent identification practices in certain sports. For example, there is a general understanding that height is a consideration when identifying and selecting athletes for sports such as netball [42], basketball [43], and volleyball [44]. Therefore, as there were a large number of female athletes from these sports, the identified difference may be due to an over-representation of taller female athletes selected for these sports, rather than a consistency across the female youth athlete population.

In contrast, while male talent-identified athletes also participate in sports (e.g., basketball, volleyball, Australian Rules Football) where height is an advantage, there was no difference in height between talent-identified and general population young males. Whilst the heterogeneity of the sports within the sports academy improves the generalisability of the results to the wider cohort of "talent-identified youth" and reduces the likelihood of biased athletic profiling, the physical performance and anthropometric variables in the athlete cohorts may be influenced by the distribution of athletes between different sports. Furthermore, females experience peak height velocity (PHV) at an earlier age than males [36], and talent-identified females may experience this at an even younger age; therefore, they may be within or even past this period by the age of 13, which may also explain the greater difference in height. This would also explain the greater magnitude of speed differential between general population and talent-identified females compared to similar cohorts of males, who would most likely be pre-PHV, and the greater speed and power of talented youth compared to the general population. A major limitation of the study design is that maturation status was not assessed in either population; therefore, it is unknown whether biological maturity affected speed and power measures. Future studies comparing talent-identified and/or trained youth should collect and report biological maturation using common field-based measures [45] to help elucidate whether maturation or training status is the predominant predictor of speed and power in 13-year-olds, as well as other cohorts of age-matched talent-identified and untrained youth [46].

The results also highlighted a similar increase in CMJ performance between groups in the male and female populations; however, the reasoning for this large effect is more difficult to explain. Males and females have similar lower body power until they are ~13 years old, when the rate of increase in lower body power changes in a sex-dependent manner [47]. Accordingly, males of matched-talent groups have greater CMJ scores compared to females. The similarity in effect may be a statistical anomaly, as the cross-sectional design of this study limits its generalisability. Using a longitudinal study design where male and female general population and talent-identified youth are monitored for numerous years may also overcome this limitation and help determine whether a global difference in lower body power exists between trained and untrained youth, or whether these effects change over time.

While a strength of the study is the collection of a large heterogeneous sample, interpretation of the results should, however, be considered with respect to methodological limitations. Specifically, as the current study is cross-sectional in nature, data were only based on current performance. Future studies should consider using a more longitudinal design to not only confirm current results, but also assess for potential anthropometrical and physical performance changes over several time periods. Additionally, the study does not consider the participants' maturation status; therefore, the data only provide a generalized view of the populations. Future studies should consider incorporating measures of maturation, such as peak height velocity [48] and the impact of this on the individual measures. Additionally, replication of this study in cohorts of youth of different ages, in different training environments, and of different ethnicities, is warranted. More studies assessing the effect of resistance training on the speed and power of talent-identified and general population youth would help determine the efficacy of resistance training modalities in bridging the gap in physical fitness between untrained and trained young people.

5. Conclusions

Overall, male and female talent-identified youth (~13 years old) athletes are faster and have greater lower body power than age-matched general population youth. Female talent-identified youth are taller, and there is no difference in body mass between talented and non-talent-identified youth. The extent that training and competing in sport and/or biological maturation modulate these population differences is unknown. Physical performance and anthropometric normative data about talent-identified and general population male and female youth are presented for strength and conditioning coaches, physiotherapists, and other allied health professionals to use to guide their interpretation of the results of similar assessments in similar cohorts. Future research should replicate this study design with different age groups, or utilise a longitudinal design to develop a greater understanding of the relationship between training, maturation, and physical performance of talent-identified athletes and the general population.

6. Practical Applications

- Speed and power discriminate male and female talent-identified youth athletes (~13 years old) from the general population.
- Youth strength and conditioning coaches, allied health professionals, and physical educators who facilitate the development of youth athletes now have physical performance benchmarks which can be used to guide training prescription.
- The development of speed and power prior to the age of 13 years may be beneficial to improve athletic and sports performance for males and females.

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References

1. Chaput, J.P.; Willumsen, J.; Bull, F.; Chou, R.; Ekelund, U.; Firth, J.; Jago, R.; Ortega, F.B.; Katzmarzyk, P.T. 2020 WHO guidelines on physical activity and sedentary behaviour for children and adolescents aged 5–17 years: Summary of the evidence. *Int. J. Behav. Nutr. Phys. Act.* **2020**, *17*, 141. [CrossRef]
2. Raghuveer, G.; Hartz, J.; Lubans, D.R.; Takken, T.; Wiltz, J.L.; Mietus-Snyder, M.; Perak, A.M.; Baker-Smith, C.; Pietris, N.; Edwards, N.M. Cardiorespiratory Fitness in Youth: An Important Marker of Health: A Scientific Statement from the American Heart Association. *Circulation* **2020**, *142*, e101–e118. [CrossRef]
3. Evaristo, S.; Moreira, C.; Lopes, L.; Oliveira, A.; Abreu, S.; Agostinis-Sobrinho, C.; Oliveira-Santos, J.; Póvoas, S.; Santos, R.; Mota, J. Muscular fitness and cardiorespiratory fitness are associated with health-related quality of life: Results from labmed physical activity study. *J. Exerc. Sci. Fit.* **2019**, *17*, 55–61. [CrossRef] [PubMed]
4. Boreham, C.A.G.; McKay, H.A. Physical activity in childhood and bone health. *Br. J. Sports Med.* **2011**, *45*, 877–879. [CrossRef] [PubMed]
5. Gralla, M.H.; McDonald, S.M.; Breneman, C.; Beets, M.W.; Moore, J.B. Associations of Objectively Measured Vigorous Physical Activity with Body Composition, Cardiorespiratory Fitness, and Cardiometabolic Health in Youth: A Review. *Am. J. Lifestyle Med.* **2019**, *13*, 61–97. [CrossRef]
6. Dale, L.P.; Vanderloo, L.; Moore, S.; Faulkner, G. Physical activity and depression, anxiety, and self-esteem in children and youth: An umbrella systematic review. *Ment. Health Phys. Act.* **2019**, *16*, 66–79. [CrossRef]
7. Donnelly, J.E.; Hillman, C.H.; Castelli, D.; Etnier, J.L.; Lee, S.; Tomporowski, P.; Lambourne, K.; Szabo-Reed, A.N. Physical activity, fitness, cognitive function, and academic achievement in children: A systematic review. *Med. Sci. Sports Exerc.* **2016**, *48*, 1197. [CrossRef] [PubMed]
8. King, A.C.; Whitt-Glover, M.C.; Marquez, D.X.; Buman, M.; Napolitano, M.A.; Jakicic, J.; Fulton, J.E.; Tennant, B.L. Physical Activity Promotion: Highlights from the 2018 Physical Activity Guidelines Advisory Committee Systematic Review. *Med. Sci. Sports Exerc.* **2019**, *51*, 1340–1353. [CrossRef]
9. Hasselstrøm, H.; Hansen, S.E.; Froberg, K.; Andersen, L.B. Physical fitness and physical activity during adolescence as predictors of cardiovascular disease risk in young adulthood. Danish Youth and Sports Study. An eight-year follow-up study. *Int. J. Sports Med.* **2002**, *23*, 27–31. [CrossRef]
10. Hermassi, S.; Van den Tillaar, R.; Bragazzi, N.L.; Schwesig, R. The associations between physical performance and anthropometric characteristics in obese and non-obese schoolchild handball players. *Front. Physiol.* **2021**, *11*, 580991. [CrossRef]
11. Lesinski, M.; Schmelcher, A.; Herz, M.; Puta, C.; Gabriel, H.; Arampatzis, A.; Laube, G.; Büsch, D.; Granacher, U. Maturation-, age-, and sex-specific anthropometric and physical fitness percentiles of German elite young athletes. *PLoS ONE* **2020**, *15*, e0237423. [CrossRef]
12. Larkin, P.; Sortino, B.; Carlon, T.; Saunders, T.; Pane, C. Gender- and Sport-specific Normative Anthropometric and Physical Values in Talent-Identified High School Athletes. *J. Strength Cond. Res.* **2022**, *10*, 1519. [CrossRef]
13. Gagné, F. Understanding the Complex Choreography of Talent Development Through DMGT-Based Analysis. *Int. Handb. Gift. Talent.* **2000**, *2*, 67–79.
14. Güllich, A.; Cobley, S. On the efficacy of talent identification and talent development programmes. In *Routledge Handbook of Talent Identification and Talent Development in Sport*; Baker, J., Cobley, S., Schorer, J., Wattie, N., Eds.; Routledge: London, UK, 2017; pp. 80–98.
15. Johansson, A.; Fahlén, J. Simply the best, better than all the rest? Validity issues in selections in elite sport. *Int. J. Sports Sci. Coach.* **2017**, *12*, 470–480. [CrossRef]
16. Larkin, P.; Reeves, M.J. Junior-elite football: Time to re-position talent identification? *Soccer Soc.* **2018**, *19*, 1183–1192. [CrossRef]
17. Risberg, M.A.; Steffen, K.; Nilstad, A.; Myklebust, G.; Kristianslund, E.; Moltubakk, M.M.; Krosshaug, T. Normative Quadriceps and Hamstring Muscle Strength Values for Female, Healthy, Elite Handball and Football Players. *J. Strength Cond. Res.* **2018**, *32*, 2314–2323. [CrossRef]
18. Smpokos, E.; Mourikis, C.; Tsikakis, A.; Katsikostas, N.; Linardakis, M. Reference performance values of pre-seasonal physical fitness in elite youth male football players in Greece. *J. Public Health* **2020**, *30*, 1307–1318. [CrossRef]
19. Reilly, T.; Bangsbo, J.; Franks, A.L. Anthropometric and physiological predispositions for elite soccer. *J. Sports Sci.* **2000**, *18*, 669–683. [CrossRef] [PubMed]

20. Woods, C.T.; Cripps, A.; Hopper, L.; Joyce, C. A comparison of the physical and anthropometric qualities explanatory of talent in the elite junior Australian football development pathway. *J. Sci. Med. Sport* **2017**, *20*, 684–688. [CrossRef] [PubMed]
21. Dobbin, N.; Highton, J.; Moss, S.L.; Twist, C. The discriminant validity of a standardized testing battery and its ability to differentiate anthropometric and physical characteristics between youth, academy, and senior professional rugby league players. *Int. J. Sports Physiol. Perform.* **2019**, *14*, 1110–1116. [CrossRef]
22. Haycraft, J.A.; Kovalchik, S.; Pyne, D.B.; Robertson, S. Relationships between Physical Testing and Match Activity Profiles Across the Australian Football League Participation Pathway. *Int. J. Sports Physiol. Perform.* **2019**, *14*, 771–778. [CrossRef] [PubMed]
23. Robertson, S.; Woods, C.; Gastin, P. Predicting higher selection in elite junior Australian Rules football: The influence of physical performance and anthropometric attributes. *J. Sci. Med. Sport* **2015**, *18*, 601–606. [CrossRef]
24. Jennings, J.; Wundersitz, D.W.; Sullivan, C.J.; Cousins, S.D.; Tehan, G.; Kingsley, M.I. Physical testing characteristics better explain draft outcome than in-game movement profile in junior elite Australian rules football players. *J. Sci. Med. Sport* **2021**, *24*, 1284–1289. [CrossRef] [PubMed]
25. Paul, D.J.; Nassis, G.P. Physical fitness testing in youth soccer: Issues and considerations regarding reliability, validity, and sensitivity. *Pediatr. Exerc. Sci.* **2015**, *27*, 301–313. [CrossRef] [PubMed]
26. Woolford, S.M.; Polglaze, T.; Rowsell, G.; Spencer, M. Field testing principles and protocols. In *Physiological Tests for Elite Athletes*, 2nd ed.; Tanner, R.K., Gore, C.J., Eds.; Human Kinetics: Champaign, IL, USA, 2013; pp. 231–248.
27. Marfell-Jones, M.; Olds, T.; Stewart, A.; Carter, J.E.L. *International Standards for Anthropometric Assessment*; International Society for the Advancement of Kinathropometry: Adelaide, Australia, 2006.
28. Pyne, D.B.; Gardner, A.S.; Sheehan, K.; Hopkins, W.G. Fitness testing and career progression in AFL football. *J. Sci. Med. Sport* **2005**, *8*, 321–332. [CrossRef] [PubMed]
29. Heishman, A.D.; Daub, B.D.; Miller, R.M.; Freitas, E.D.; Frantz, B.A.; Bemben, M.G. Countermovement jump reliability performed with and without an arm swing in NCAA division 1 intercollegiate basketball players. *J. Strength Cond. Res.* **2020**, *34*, 546–558. [CrossRef] [PubMed]
30. Cohen, J. A power primer. *Psychol. Bull.* **2016**, *112*, 155–159. [CrossRef]
31. Sawilowsky, S. New effect size rule of thumb. *J. Mod. Appl. Stat. Methods* **2009**, *8*, 467–474. [CrossRef]
32. Loko, J.; Aule, R.; Sikkut, T.; Ereline, J.; Viru, A. Age differences in growth and physical abilities in trained and untrained girls 10–17 years of age. *Am. J. Hum. Biol.* **2003**, *15*, 72–77. [CrossRef]
33. Iadreev, V.; Cherkashin, I.; Vujkov, S.; Drid, P. Differences in anthropometric, motoric and cognitive abilities between athletically trained and untrained girls. *Biomed. Hum. Kinet.* **2015**, *7*, 73–77. [CrossRef]
34. McNarry, M.A.; Lester, L.; Brown, J.; Mackintosh, K.A. Investigating the Modulatory Role of Chronological and Biological Age on Performance Predictors in Youth Swimmers. *J. Sci. Sport Exerc.* **2020**, *2*, 349–358. [CrossRef]
35. Iga, J.; George, K.; Lees, A.; Reilly, T. Cross-sectional investigation of indices of isokinetic leg strength in youth soccer players and untrained individuals. Scand. *J. Med. Sci. Sports* **2009**, *19*, 714–719. [CrossRef]
36. Lloyd, R.S.; Oliver, J.L. The youth physical development model: A new approach to long-term athletic development. *Strength Cond. J.* **2012**, *34*, 61–72. [CrossRef]
37. Faigenbaum, A.D.; Lloyd, R.S.; Myer, G.D. Youth Resistance Training: Past Practices, New Perspectives, and Future Directions. *Pediatr. Exerc. Sci.* **2013**, *25*, 591–604. [CrossRef]
38. Chaouachi, A.; Ben Othman, A.; Makhlouf, I.; Young, J.D.; Granacher, U.; Behm, D.G. Global Training Effects of Trained and Untrained Muscles with Youth Can be Maintained During 4 Weeks of Detraining. *J. Strength Cond. Res.* **2019**, *33*, 2788–2800. [CrossRef] [PubMed]
39. Meylan, C.M.P.; Cronin, J.B.; Oliver, J.L.; Hopkins, W.G.; Contreras, B. The effect of maturation on adaptations to strength training and detraining in 11–15-year-olds. *Scand. J. Med. Sci. Sports* **2014**, *24*, e156–e164. [CrossRef] [PubMed]
40. Moran, J.; Sandercock, G.R.H.; Ramírez-Campillo, R.; Meylan, C.; Collison, J.; Parry, D.A. A meta-analysis of maturation-related variation in adolescent boy athletes' adaptations to short-term resistance training. *J. Sports Sci.* **2017**, *35*, 1041–1051. [CrossRef]
41. Booth, M.; Cobley, S.; Halaki, M.; Orr, R. Is training age predictive of physiological performance changes in developmental rugby league players? A prospective longitudinal study. *Int. J. Sports Sci. Coach.* **2020**, *15*, 306–315. [CrossRef]
42. Simpson, M.J.; Jenkins, D.G.; Leveritt, M.D.; Kelly, V.G. Physical profiles of elite, sub-elite, regional and age-group netballers. *J. Sports Sci.* **2019**, *37*, 1212–1219. [CrossRef]
43. Joseph, J.; McIntyre, F.; Joyce, C.; Scanlan, A.; Cripps, A. A comparison of multidimensional qualities discriminant of selection in elite adolescent Australian basketball athletes. *PLoS ONE* **2021**, *16*, e0256032. [CrossRef]
44. Mostaert, M.; Pion, J.; Lenoir, M.; Vansteenkiste, P. A Retrospective Analysis of the National Youth Teams in Volleyball: Were They Always Faster, Taller, and Stronger? *J. Strength Cond. Res.* **2022**, *36*, 2615–2621. [CrossRef] [PubMed]
45. Mirwald, R.L.; Baxter-Jones, A.D.; Bailey, D.A.; Beunen, G.P. An assessment of maturity from anthropometric measurements. *Med. Sci. Sports Exerc.* **2002**, *34*, 689–694.
46. Malina, R.M.; Cumming, S.P.; Rogol, A.D.; Coelho-E-Silva, M.J.; Figueiredo, A.J.; Konarski, J.M.; Kozieł, S.M. Bio-Banding in Youth Sports: Background, Concept, and Application. *Sports Med.* **2019**, *49*, 1671–1685. [CrossRef] [PubMed]

47. Quatman, C.E.; Ford, K.R.; Myer, G.D.; Hewett, T.E. Maturation Leads to Gender Differences in Landing Force and Vertical Jump Performance: A Longitudinal Study. *Am. J. Sports Med.* **2006**, *34*, 806–813. [CrossRef]
48. Mills, K.; Baker, D.; Pacey, V.; Wollin, M.; Drew, M.K. What is the most accurate and reliable methodological approach for predicting peak height velocity in adolescents? A systematic review. *J. Sci. Med. Sport* **2017**, *20*, 572–577. [CrossRef] [PubMed]

children

Article

Predictors of Reactive Agility in Early Puberty: A Multiple Regression Gender-Stratified Study

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Abstract: Reactive agility (RAG) is a crucial factor of success in sports, but there are practically no studies dealing with RAG among children. The main aim of this study was to identify predictors of RAG among early pubescent boys and girls. The participants were primary school boys (n = 73) and girls (n = 59) aged 11–12. The criterion variable was the originally developed "Triangle" test of reactive agility (Triangle-RAG). Predictors included anthropometric/body composition indices (body height, seated height, body mass, and body fat percentage) and motor abilities (10 and 20 m sprint, broad jump, squat jump, countermovement jump, drop jump, and two tests of change of direction speed—CODS (Triangle-CODS, and 20 yards)). The results of the univariate analysis showed that anthropometric/body composition indices were not significantly correlated to TRAG (0–4% of the common variance), while all motor abilities were significantly associated with TRAG (7–43% of the common variance) in both genders. Among boys, 64% of the TRAG variance was explained by multiple regression, with TCODS as the only significant predictor. Among girls, multiple regression explained 59% of the TRAG-variance with TCODS, countermovement jump, and drop jump as significant predictors. Differences in multivariate results between genders can be explained by (i) greater involvement in agility-saturated sports (i.e., basketball, tennis, soccer) in boys, and (ii) advanced maturity status in girls. The lack of association between anthropometric/body built and TRAG was influenced by the short duration of the TRAG (3.54 ± 0.4 s). Our findings suggest that pre-pubescent and early pubescent children should be systematically trained on basic motor abilities to achieve fundamentals for further developing RAG. Since in this study we observed predictors including only athletic abilities and anthropometric/body composition, in future studies, other motor abilities, as well as cognitive, perceptual, and decision-making parameters as potential predictors of RAG in children should be investigated.

Keywords: non-planned agility; pre-planned agility; anthropometry; children

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1. Introduction

Agility is often defined as the ability to quickly and efficiently change the speed and direction of movement [1,2]. It belongs to the domain of speed-explosives abilities that are determined by training status and genetic potential [3]. Agility is a complex motor ability, and in the background of the manifestation of agility are numerous other abilities, such as speed, power, coordination, balance, and even cognitive and perceptual capacities [4]. In general, the existence of two basic types of agility is widely accepted and scientifically proven; (1) change of direction speed or pre-planned, non-reactive agility (CODS) and (2) reactive, non-planned agility (RAG) [5,6]. CODS is evident in situations where the movement pattern is known in advance, while on the other side, in the RAG, agile movement is performed based on some external stimuli and cannot be pre-planned [7,8]. It is generally accepted that different factors influence these two agility manifestations. Briefly, while CODS is mainly determined by morphological and motor parameters, perceptual and cognitive skills are crucial in RAG [3,9].

Both facets of agility are present in sports, and their importance to situational efficiency and performance is confirmed [10,11]. Although it represents one of the most important motor skills in athletes, recently, its importance has been highlighted outside the competitive context [12,13]. In particular, agile movements are presented in professional activities (i.e., military, police), in everyday life, regardless of age, while performing unexpected reactions, overcoming obstacles, and, more specifically, solving perceptual-motor tasks during playing time [14–16].

Agility measurements among children are important for one specific reason. In particular, when performing agility tasks, a specific movement technique that differs from sport to sport plays a significant role [3,17]. This technique is developed through systematic, sport-specific training and will play a significant role in the performance of agility when testing adult athletes. Consequently, this will not give a precise picture of the abilities and skills that affect agility, regardless of movement efficiency. For this reason, it is necessary to analyze the predictors of the agile movement in the population of children, especially among the ones who do not engage in agility-saturated sports.

Several studies investigated the predictors of non-reactive, pre-planned agility in children not involved in specific sports [4,18,19]. For example, the study on early pubescent girls identified reactive strength as the most significant predictor, while body composition and anthropometrics had weak-to-medium correlations with reactive agility performance [18]. More recently, a study on early pubescent boys and girls analyzed the influence of balance, jumping, speed capacities, and several morphological variables on three different agility tests [19]. Results highlighted sprinting at 10 m, body mass, and high jumps as the most important predictors [19]. Additionally, a study on early pubescent boys investigated predictors in five different agility performances [4]. Predictors explained between 47% and 62% of the variance, with the two-leg lateral jumps recognized as the single best predictor [4].

Although studies already analyzed predictors of CODS, there is an evident lack of studies exploring the predictors of RAG among children. Meanwhile, RAG is known to be an important determinant of success in agility-saturated sports [7,20,21]. A better understanding of the background of RAG in children will hopefully result in a more accurate orientation of talented children toward agility-saturated sports (i.e., basketball, soccer, handball, tennis). Therefore, the main aim of this study was to determine the association between anthropometric/body composition indices, motor abilities (predictors), and RAG in early pubescent boys and girls. Knowing the differences in fitness status between prepubescent boys and girls, we tried to avoid the potential influence of gender as a covariate of established associations; therefore, a gender-stratified approach was applied. We hypothesized that the studied predictors would be significantly associated with RAG with some gender specifics.

2. Materials and Methods

2.1. Participants

Primary school boys (n = 73) and girls (n = 59) aged 11–12 years were involved in this study. In the first phase of the study, a sub-sample consisting of 21 participants was tested on newly developed tests throughout the test–retest procedure in order to evaluate the reliability of the tests (for details on reliability, please see the first part of the Results section). All participants were in good health and were regularly attending physical education classes (PE), while some of them were included in out-of-school sports. The inclusion criteria were: no evident motor aberrations and health-related issues (as indicated by school medical staff), no locomotor injury over a period of two weeks before testing, and regular participation in PE. Exclusion criteria were: recent musculoskeletal disorders, sickness over the previous two weeks, the current prevalence of pain, and/or overall sense of weakness, and three participants were excluded from the study accordingly.

The Ethical Board of the Faculty of Kinesiology University of Split, Split, Croatia, administered approval for the investigation (Ethical board number: 2181-205-02-05-22-0021).

The participants were informed of the purpose of the study, and the written consent was signed by their parents or custodians.

2.2. Measures and Procedures

Variables in this study included predictors and criteria. The predictors consisted of anthropometric/body-built indices (body height, seated height, body mass, and body fat percentage), motor abilities (10 m sprint—S10M, and 20 m sprint—S20M, broad jump—BJ, squat jump—SJ, countermovement jump—CMJ, and drop jump—DJ, triangle test of change of direction speed—TCODS and 20 Yard shuttle agility test—20Y). The criterion variable was the originally developed "Triangle" test of reactive agility (TRAG).

Body height was measured using a Seca Instruments stadiometer. Body mass and body fat were assessed using a Tanita Pro MC-780U body composition analyzer (Tanita Corp., Tokyo, Japan), which provides a print-out of the measured body mass and calculated body fat. Information about the participants' gender, age, and body height was inserted into the device, and the participants had to stand barefoot in an upright, stable position. The device provided body mass and used an algorithm incorporating impedance, age, and height, to estimate the percentage of the total body fat.

A Brower timing system (Salt Lake City, UT, USA) was used for the assessment of S10 and S20, which is a commonly used and previously validated system [22]. Two electronic timing gates were placed 1, 11, and 21 m from the starting line. These photocells were mounted 1 m above floor level, which is the maximal height of the manufacturer's standard tripods. The participants ran as fast as possible for the required distance, with the self-chosen preferred leg placed on the starting marking.

For the 20Y, TCODS, and TRAG agility tests, BlazePod was used (Play Coyotta Ltd., Tel Aviv, Israel).

For TCODS and TRAG, three lighting pods were mounted on 50 cm cones in an equilateral triangle formation—equal sides, equal angles of 60° (Figure 1).

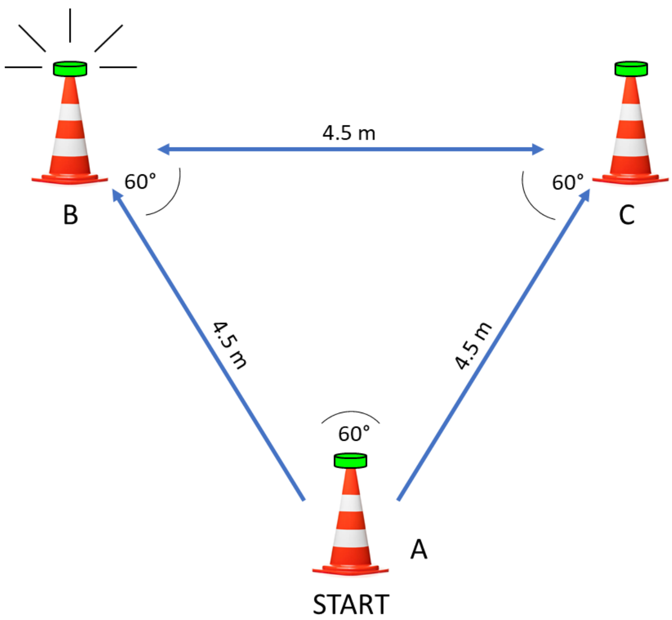

Figure 1. Scheme of the TRAG and TCODS testing.

To set the angles, a universal plastic goniometer with a 360° conveyor was used (1° accuracy, European Product). The distance between the cones was set at 4.5 m. In the TCODS test, the participants knew the scenario in advance (first trial: A–B–C, second trial: A–C–B), and after starting, they had to run from one cone to another and touch the lighting pods to turn off the lights. For the TRAG test, the participants did not have advanced knowledge of the scenario. However, all participants were tested by the same templates (first trial: A–C–B, second trial: A–B–A, third trial: A–C–A, fourth trial: A–B–C). The participants were instructed to begin the test with their preferred foot forward placed next to the starting cone. To start the TRAG, students should tap the first lighting pod (cone A), run to the next lighted cone, and touch the designated pod, which triggers the last cone. TRAG scenarios were applied in random order, but all participants were tested in all four scenarios. The testing was arranged in groups of 4–5 participants, which allowed for appropriate rest intervals between the tests and trials. The rest interval was not less than 20 s between trials.

For the 20Y test, three 50 cm cones, with lighting pods on top, were positioned along a line 4.57 m (5 yd) apart. Students would start with a two-point stance after touching the middle pod to run fast as possible, 4.57 m to the left. The subjects then ran 9.14 m to touch the illuminated cone on the right and finally finished by running back, touching the middle pod.

SJ, CMJ, and DJ testing were performed using the OptoGait system (Microgate, Bolzano, Italy). The software platform allows for the easy storage of all tests carried out and the ability to recall them instantly if necessary. Before the test, the participants were familiarized (the test procedure has been explained to the participants) with the procedure and had three attempts of each test. The students had to use maximal effort to achieve the best possible result. During the broad jump test, the participants stood on the starting line with their legs parallel and feet shoulder-width apart. They were instructed to bend their knees (the degree of flexion was determined by the participant) and bring their arms behind their bodies. A powerful drive was then used to propel them forward.

All measurements were performed on an indoor gymnasium with a wooden floor. Before testing, the participants completed a 10 min warm-up including jogging, skipping, lateral running drills, dynamic stretching, and light jumping. The testing protocol was the same for all participants. All of the tests were performed at the same time of day (9 to 11 a.m.) to prevent variations in the biorhythm and fitness abilities. The participants had one practice trial for familiarization with each test and performed it with self-chosen sports shoes. For the tests measured automatically by the Brower timing system, Optogait, and the Blazepod system, the same examiner assessed all participants.

2.3. Statistics

Statistical calculations included several groups of analysis. First of all, a Kolmogorov–Smirnov test was used to check the normality of distribution, and means and standard deviations were calculated for all observed variables. The reliability of the agility tests was checked by calculating Intra Class Coefficients (ICC). Student's T-test was used to evaluate the differences between the genders. To examine the univariate associations between the variables, the Pearson correlation coefficient was calculated. In the last phase, all significantly correlated variables were included in the multiple regression analysis to identify the predictors of the TRAG, separately for boys and girls. For all the analyses, Statistica 14.0 (TIBCO Software Inc., Palo Alto, CA, USA) was used, with a p-level of 95% in all calculations.

3. Results

The TRAG and TCODS tests showed appropriate inter-testing and intra-testing reliability (TRAG: ICC = 0.69 and 0.76, TCODS: 0.77 and 0.80 for inter-testing and intra-testing reliability, respectively).

The descriptive statistics and results of the Kolmogorov–Smirnov test of the normality of distributions for all variables are presented in Supplementary Tables S1 and S2 (for boys and girls, respectively).

Table 1 presents the results of univariate correlations for boys. Apart from the small and negligible correlation between BF and TRAG (less than 5% of the common variance), anthropometric/body-built indices were not significantly correlated to TRAG. However, practically all motor variables were significantly correlated to TRAG (6% to 60% of the common variance).

Table 1. Pearson's moment correlation coefficients between the studied variables for boys.

Var	AGE	BH	SH	BM	BF	BJ	S10	S20	20Y	TCODS	T RAG	SJ	CMJ	DJ
BH	0.36 *													
SH	0.41 *	0.66 *												
BM	0.18	0.66 *	0.53 *											
BF	−0.26 *	0.06	0.06	0.64 *										
BJ	0.36 *	0.18	0.20	−0.11	−0.52 *									
S10	−0.22	0.03	−0.02	0.34 *	0.54 *	−0.73 *								
S20	−0.21	0.03	−0.02	0.34 *	0.53 *	−0.74 *	0.98 *							
20Y	−0.26 *	−0.05	−0.02	0.23	0.42 *	−0.62 *	0.73 *	0.77 *						
TCODS	−0.22	−0.08	−0.12	0.23	0.47 *	−0.67 *	0.79 *	0.82 *	0.82 *					
TRAG	−0.18	−0.00	−0.07	0.21	0.27 *	−0.51 *	0.62 *	0.64 *	0.66 *	0.74 *				
SJ	0.27 *	0.20	0.26 *	−0.07	−0.50 *	0.78 *	−0.67 *	−0.67 *	−0.49 *	−0.56 *	−0.28 *			
CMJ	0.34 *	0.12	0.22	−0.18	−0.54 *	0.83 *	−0.73 *	−0.73 *	−0.51 *	−0.60 *	−0.35 *	0.92 *		
DJ	0.36 *	0.18	0.23	−0.10	−0.45 *	0.83 *	−0.81 *	−0.81 *	−0.55 *	−0.64 *	−0.46 *	0.87 *	0.91 *	
RSI	0.09	−0.00	0.04	−0.29 *	−0.50 *	0.69 *	−0.70 *	−0.68 *	−0.46 *	−0.54 *	−0.43 *	0.66 *	0.72 *	0.72 *

Legend: BH—body height, SH—seated height, BM—body mass, BF—body fat, BJ—broad jump, S10—10 m sprint, S20—20 m sprint, 20Y—20-yard shuttle agility test, TCODS—"Triangle" change of direction, TRAG—"Triangle" reactive agility, SJ—squat jump, CMJ—countermovement jump, DJ—drop jump, RSI—reactive strength index, * indicates the statistical significance of $p < 0.05$.

Among girls, anthropometric/body composition indices were not correlated with TRAG, while all motor indices except 20Y were significantly correlated with TRAG (10–39% of the common variance) (Table 2).

Table 2. Pearson's moment correlation coefficients between the studied variables for girls.

Var	AGE	BH	SH	BM	BF	BJ	S10	S20	20Y	TCODS	T RAG	SJ	CMJ	DJ
BH	0.19													
SH	0.38 *	0.79 *												
BM	0.23	0.59 *	0.57 *											
BF	0.15	0.19	0.25	0.81 *										
BJ	0.09	0.37 *	0.38 *	−0.11	−0.39 *									
S10	0.01	−0.14	−0.21	0.29	0.50 *	−0.74 *								
S20	0.11	−0.13	−0.17	0.28	0.52 *	−0.70 *	0.89 *							
20Y	−0.23	−0.43 *	−0.38 *	−0.02	0.24	−0.54 *	0.51 *	0.49 *						
TCODS	−0.20	−0.08	−0.30	0.14	0.33 *	−0.43 *	0.49 *	0.44 *	0.42 *					
TRAG	0.12	0.05	−0.13	0.13	0.27	−0.33 *	0.43 *	0.39 *	0.28	0.63 *				
SJ	0.04	−0.05	0.17	−0.27	−0.46 *	0.46 *	−0.50 *	−0.51 *	−0.38 *	−0.51 *	−0.50 *			
CMJ	0.02	−0.13	0.14	−0.22	−0.36 *	0.45 *	−0.54 *	−0.56 *	−0.41 *	−0.47 *	−0.54 *	0.93 *		
DJ	0.03	−0.01	0.19	−0.27	−0.41 *	0.46 *	−0.53 *	−0.54 *	−0.42 *	−0.50 *	−0.41 *	0.89 *	0.90 *	
RSI	0.00	0.01	0.08	−0.33 *	−0.47 *	0.48 *	−0.51 *	−0.59 *	−0.45 *	−0.45 *	−0.36 *	0.75 *	0.75 *	0.86 *

Legend: BH—body height, SH—seated height, BM—body mass, BF—body fat, BJ—broad jump, S10—10 m sprint, S20—20 m sprint, 20Y—20-yard shuttle agility test, CODS—"Triangle" change of direction, TRAG—"Triangle" reactive agility, SJ—squat jump, CMJ—countermovement jump, DJ—drop jump, RSI—reactive strength index, * indicates the statistical significance of $p < 0.05$.

When multiple regressions were calculated for boys, 64% of the variance was attributed to the TRAG, with TCODS as a single partial significant regressor (Table 3).

Table 3. Results of the multiple regression analysis for boys for TRAG as a criterion.

Predictor	β	SE of β	b	SE of b	t (64)	*p*-Value
TCODS	0.59	0.18	0.63	0.19	3.4	0.001
R = 0.80; R^2 = 0.64; Adjusted R^2 = 0.56; F (10.50) = 8.9; $p < 0.001$; St. Error of estimate: 0.35						

Legend: TCODS—"Triangle" change of direction speed, R—coefficient of the multiple correlation; R^2—coefficient of the determination; β—standardized regression coefficient; b—nonstandardized regression coefficient.

When the multivariate relationship between the predictors and TRAG was calculated for girls, 59% of the variance in the TRAG performance was explained. The significant partial predictors were TCODS, CMJ, and DJ, with better reactive agility in girls who perform better in CODS and jumping tests (Table 4).

Table 4. Results of the multiple regression analysis for girls with TRAG as a criterion.

Predictor	β	SE of β	b	SE of b	t (50)	*p*-Value
TCODS	0.66	0.13	0.97	0.20	4.9	0.001
CMJ	−0.86	0.31	−0.08	0.03	−2.8	0.01
DJ	−0.71	0.28	0.07	0.03	2.5	0.01
R = 0.76; R^2 = 0.59; Adjusted R^2 = 0.52; F (8.49) = 8.81; $p < 0.001$; St. Error of estimate: 0.39						

Legend: TCODS—"Triangle" change of direction speed, CMJ—countermovement jump, DJ—drop jump, R—coefficient of the multiple correlation; R^2—coefficient of the determination; β—standardized regression coefficient; b—nonstandardized regression coefficient.

4. Discussion

This study aimed to identify predictors of reactive agility among early pubescent boys and girls. There are several very important findings. First, anthropometric/body built indices were not correlated with TRAG in the studied children. Second, multivariate analysis evidenced TCODS as the only significant multivariate predictor of TRAG in boys. Meanwhile, in girls, in addition to TCODS, leg power was highlighted as a significant multivariate predictor. Therefore, our initial study hypothesis was confirmed.

4.1. Anthropometric/Body Composition Indices and Reactive Agility

Anthropometric/body built indices were already studied as being potential predictors of facets of agility in children, but almost exclusively in relation to pre-planned agility (e.g., CODS), and the findings were not consistent [4,19]. For example, in the study on early pubescent boys, Sekulić et al. found no significant correlation between observed anthropometry indices and five different pre-planned agility tests except for body mass and the Zig-zag test [4]. On the other hand, Pavlinović et al. reported a significant correlation between body mass and body fat with pre-planned agility in both boys and girls [19]. Meanwhile, to the best of our knowledge, this is the first study where anthropometric/body-built indices were observed as predictors of reactive agility. In short, apart from the negligible correlation between body fat and TRAG in boys (less than 5% of the common variance), anthropometric/body-built indices were not associated with TRAG in early pubescent children.

The first reason for the absence of an association between anthropometric/body composition and TRAG can probably be found in the duration of the test applied in our study. Namely, the test duration was very short (approximately 3 s). It, therefore, did not contain a significant energetic component, for which a higher body and fat mass would represent an important factor of influence. Second, it is widely accepted that reactive agility is more a complex ability than CODS, being under the influence not only of conditioning capacities and corresponding anthropometric/body built indices but also cognitive-perceptual abilities (REFS). As a result, simply mathematically/statistically, the percentage of the RAG variance which could be explained by anthropometrics/body built is reduced, resulting in negligible correlations observed herein. It is also important to highlight that our study observed participants (both boys and girls), who were mostly in the pre-peak high velocity (PHV) age. As a result, there was no significant difference between them in anthropometric indices that could affect RAG performance [23,24]. Consequently, we have found no evidence that anthropometric/body-built indices should be observed as significant predictors of RAG in this age group.

4.2. Motor Abilities and Reactive Agility

Analyzing the results of univariate correlation analyses, it is evident that all power-related variables significantly correlate with reactive agility in boys. The correlation coefficients ranged from 0.28 to 0.51 for jumping performance, 0.62 to 0.64 for sprinting, and

0.66 to 0.74 for TCODS and 20Y performances. However, multivariate analysis revealed TCODS as the only significant predictor of TRAG. Thus, we can confirm that TCODS in the here-studied boys was an indicator of "overall motor status". Actually, this is in accordance with previous studies where authors examined predictors of RAG in competitive athletes, where significant correlations between the sport-specific CODS and RAG performances were reported of professional futsal players, young soccer players, young tennis players, and rugby league professional players [25–27]. Another important element additionally explains the importance of TCODS in predicting TRAG. In brief, TCODS and TRAG had similar scenarios and consisted of similar movement patterns (please see Methods for details). While strong correlations between pre-planned and non-planned agility tests with the same movement patterns were well documented in previous studies, we have no doubt that it additionally contributed to the finding that TCODS was the only significant predictor of TRAG in this study [27–29].

While TCODS was a significant predictor of TRAG in girls as well, we have no doubts that the background of its influence on TRAG for girls is almost certainly very similar to the one previously discussed for boys. However, the indicators of lower body power (e.g., CMJ and DJ) were also significantly multivariately associated with TRAG among girls. The explanation of these associations should be found in the characteristics of the CMJ and DJ.

These two types of jumping are characterized by slow (CMJ) or fast (DJ) short-stretching cycles, during which, the muscle goes through the phases of eccentric, isometric, and, finally, concentric contraction [30]. In that context, the finding of significant influence on TRAG is not surprising as the same pattern of different types of muscle contraction is characteristic of agile stop-and-go movements, distinct for TRAG [31,32]. In particular, when performing such a movement, sudden deceleration with eccentric muscle contraction occurs first. After that, there is a short period of isometric contraction when the movement is stopped and, finally, concentric contraction occurs in the acceleration phase [3].

4.3. Gender Differences in the Prediction of the Reactive Agility Performance

From the perspective of our study, it is essential to discuss the differences in the prediction of TRAG between the genders. Specifically, lower body power significantly predicted TRAG among girls but not among boys. There are two possible explanations for such findings. The first one is "contextual" (i.e., differences in sports involvement between genders), while the second explanation is related to differences in the maturation process between boys and girls at that age.

In early puberty, boys are more involved in sports, specifically team sports that are saturated with agile movements [33–35]. For example, a study on a large sample of Australian adolescents from 12 to 16 years old, found that 78.5% of boys participate in organized sports compared to 66.1% of girls [35]. This is not only related to organized participation in competitive sports but also to "free play", where boys more often than girls participate in different team sports [36,37]. Consequently, it is reasonable to expect that the boys in our sample have a higher level of specific motor skills which are (systematically and non-systematically) developed throughout participation in team sports [38]. It will help them in agility tests structured as in this study (TCODS and TRAG had the same movement patterns). On the other hand, girls (who are not as engaged in sports as boys, and therefore are relatively less skilled than boys of the same age) will probably conduct TRAG while exploiting their power capacities.

Second, the differences in biological maturity can potentially have a significant role in our findings regarding gender differences in predictors of TRAG. Namely, it is known that girls mature earlier and enter accelerated growth and development phases before boys [39,40]. Consequently, differences in power capacities such as jumping and sprinting among girls are greater than among boys, i.e., they have a greater variance in power than boys. As a result, stronger girls exploited their capacities even in RAG.

Indeed, studies have shown a more significant influence of physical capacity on agility in relatively older and more mature participants [41,42]. For example, in the study on youth football players, Krolo et al. analyzed predictors of sport-specific agility [42]. The results showed that the observed predictors, i.e., sprinting and power capacities, explained the larger percentage of agility variance in older than in younger participants [42]. Additionally, a study on pubertal handball male players showed that in older players (post-peak height velocity (PHV) group), a more considerable proportion of handball-specific agility was explained with physical capacities compared to the pre-PHV group [41]. It was explained by the fact that early maturers experienced more dynamic morphological changes and were able to generate more force than their late-maturing peers [41]. It is also important to note that changes also occur in the cognitive aspect of maturation with neural adaptations, which are an essential part of reactive agility. This not only explains our findings but also directs future studies to include cognitive parameters as agility predictors. Supportively, recent studies undertaken in other sports highlighted the applicability of the Stroop test (i.e., a test that measures the delay in reaction time between congruent and incongruent stimuli) as an important determinant of various facets of success in sports, indicating the potential usefulness of such measurement tools in determining the predictors of RAG as well [43].

4.4. Predictors of Reactive Agility in Children in Comparison to Predictors of Reactive Agility in Athletes

When observing all previously discussed associations between predictors and RAG, and comparing them with previous reports on athletes, certain differences in correlations should be highlighted. First, previous studies performed with athletes reported RAG as being more influenced by sprinting and jumping capacities than we have found herein. Second, the correlation between CODS and RAG in children was evidently higher than the correlation between CODS and RAG in athletes. With regard to the objectives of our study, these issues are specifically discussed.

In our study (specifically for boys), sprinting and jumping were not multivariately associated with RAG, which was not the case in previous studies performed with athletes [7,42,44] However, this is at least partially a consequence of the selection of variables in our multivariate regression. Namely, in previous studies, anthropometric indices, sprinting and jumping capacities were most often analyzed separately for both RAG and CODS, while CODS tests were not involved in the analyses as predictors of RAG [7,42,44]. For example, a study with young soccer players highlighted power capacities, manifested through slow and fast short-stretching cycles as the factors contributing to RAG [42]. Additionally, a study on a sample of top-level futsal players evidenced anthropometric indices and reactive strength as predictors of performance on the futsal-specific reactive agility test [44]. However, as we said previously, CODS was not included as a predictor of RAG in these studies, which naturally increased the percentage of the variance that was explained by other observed characteristics and capacities. However, we must not ignore the fact that RAG and CODS are more correlated in the here-studied children than in athletes observed previously, and this will also be shortly discussed.

Indeed, the correlations between the same-scenario CODS and RAG in our study are much higher (0.63 for girls and 0.74 for boys) than the correlations between the same capacities in competitive athletes. For example, Sheppard et al. (2006) reported less than 10% of the shared variance between sport-specific CODS and RAG in Australian football players, while Scanlan evidenced a negligible correlation between RAG and CODS in basketball players [45,46]. In explaining such relatively small correlations between CODS and RAG in professional athletes, authors regularly concluded that RAG performance in professional, highly trained athletes is more influenced by perceptual and cognitive abilities than by athletic parameters (i.e., anthropometric/body built indices and conditioning capacities), which are known to be determinants of CODS [45,46]. This is mostly explained by the fact that highly trained athletes have already reached a high level of conditioning status throughout systematic training, and/or sport-selection process, while perceptual and cognitive capacities are mostly "inherited" and/or at least are not systematically and specifically trained throughout sports training. Our study indirectly supports such considerations. In brief, it seems that RAG is more influenced by basic motor abilities in children than in professional athletes, at least partially due to the greater variance of these abilities in the relatively untrained population compared to highly trained athletes involved in professional sports.

4.5. Limitations and Strengths of the Study

One of the study's limitations is the cross-sectional design. Therefore, a longitudinal approach and interventions are needed in future studies to obtain a clearer picture of the relations between the observed capacities. Additionally, we evidenced only a limited number of variables while not including some theoretically significant predictors of RAG (i.e., strength, flexibility, and cognitive and perceptive parameters). Finally, the sample of participants in this study was heterogenous; it included boys and girls from different sports. Thus, in the future, it is recommended to analyze agility predictors only on children that do not participate in agility-saturated sports.

To the best of our knowledge, this is the first study to evaluate the predictors of RAG among early pubescent boys and girls while evaluating the evidently important factors of RAG performance. Knowing the importance of RAG in competitive sports, we hope that our results will initiate further research.

5. Conclusions

Although the results of the correlation analysis showed a significant and relatively high association between all the observed motor parameters and RAG, multivariate analysis extracted CODS in both genders and sprinting/jumping among girls as the most significant predictors. Anthropometric indices were not factors of influence on RAG, which is most likely a consequence of the short duration of the RAG test applied herein and the participants' age (pre-pubescent children).

High correlations between CODS and RAG and a relatively high proportion of the explained variance of RAG indicate that RAG in this age group is probably more related to motor abilities than cognitive factors. However, it is clear that RAG should be observed as a complex, multifactorial ability. Therefore, future studies must include other abilities that could influence agility performance, primarily cognitive, perceptual, and decision-making parameters. Finally, our findings suggest that pre-pubescent and early pubescent children should be systematically trained on basic motor abilities to achieve fundamentals for further developing RAG.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/children9111780/s1, Table S1. Descriptive statistics for boys' sample (N = 72); Table S2. Descriptive statistics for girls' sample (N = 58); Table S3. *t*-Test for independent samples between boys and girls.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Ethics Committee of the University of Split, Faculty of Kinesiology (Ethical board number: 2181-205-02-05-22-0021).

Informed Consent Statement: Informed consent was obtained from all participants involved in the study. Parents provided written consent for the inclusion of their children in the research.

Data Availability Statement: The authors will provide data to all interested parties upon reasonable request.

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References

1. Lazić, A.; Bratić, M.; Stamenković, S.; Andrašić, S.; Stojiljković, N.; Trajković, N. Knee Pads Do Not Affect Physical Performance in Young Female Volleyball Players. *Children* **2021**, *8*, 748. [CrossRef] [PubMed]
2. Hojka, V.; Stastny, P.; Rehak, T.; Gołas, A.; Mostowik, A.; Zawart, M.; Musálek, M. A systematic review of the main factors that determine agility in sport using structural equation modeling. *J. Hum. Kinet.* **2016**, *52*, 115–123. [CrossRef] [PubMed]
3. Sheppard, J.M.; Young, W.B. Agility literature review: Classifications, training and testing. *J. Sport. Sci.* **2006**, *24*, 919–932. [CrossRef] [PubMed]
4. Sekulic, D.; Spasic, M.; Esco, M.R. Predicting agility performance with other performance variables in pubescent boys: A multiple-regression approach. *Percept. Mot. Ski.* **2014**, *118*, 447–461. [CrossRef] [PubMed]
5. Horníková, H.; Jeleň, M.; Zemková, E. Determinants of reactive agility in tests with different demands on sensory and motor components in handball players. *Appl. Sci.* **2021**, *11*, 6531. [CrossRef]
6. Gabbett, T.; Benton, D. Reactive agility of rugby league players. *J. Sci. Med. Sport* **2009**, *12*, 212–214. [CrossRef]
7. Veršić, S.; Foretić, N.; Spasić, M.; Uljević, O. Predictors of agility in youth soccer players: Contextualizing the influence of biological maturity. *Kinesiol. Slov.* **2020**, *26*, 31–47. [CrossRef]
8. Morral-Yepes, M.; Moras, G.; Bishop, C.; Gonzalo-Skok, O. Assessing the Reliability and Validity of Agility Testing in Team Sports: A Systematic Review. *J. Strength Cond. Res.* **2022**, *36*, 2035–2049. [CrossRef]
9. Horička, P.; Šimonek, J.; Paška, Ľ. Relationship between reactive agility, cognitive abilities, and intelligence in adolescents. *J. Phys. Educ. Sport* **2020**, *20*, 2263–2268.
10. Šimonek, J.; Horička, P.; Hianik, J. Differences in pre-planned agility and reactive agility performance in sport games. *Acta Gymnica* **2016**, *46*, 68–73. [CrossRef]
11. Ozen, G.; Atar, O.; Koc, H. The effects of a 6-week plyometric training programme on sand versus wooden parquet surfaces on the physical performance parameters of well-trained young basketball players. *Montenegrin J. Sport. Sci. Med.* **2020**, *9*, 27. [CrossRef]
12. Gildenhuys, G.; Toriola, A.; Fourie, M.; Shaw, I.; Witthuhn, J.; Shaw, B. Evaluation of Pilates training on agility, functional mobility and cardiorespiratory fitness in elderly women and fitness. *Afr. J. Phys. Health Educ. Recreat. Danc.* **2013**, *19*, 505–512.
13. Andrašić, S.; Gušić, M.; Stanković, M.; Mačak, D.; Bradić, A.; Sporiš, G.; Trajković, N. Speed, Change of Direction Speed and Reactive Agility in Adolescent Soccer Players: Age Related Differences. *Int. J. Environ. Res. Public Health* **2021**, *18*, 5883. [CrossRef]
14. Zemková, E.; Hamar, D. Age-related changes in agility time in children and adolescents. *Int. J. Sci. Res.* **2014**, *3*, 280–285.
15. Johnstone, J.A.; Ramon, M. *Perceptual-Motor Activities for Children: An Evidence-Based Guide to Building Physical and Cognitive Skills*; Human Kinetics: Champaign, IL, USA, 2011.
16. Klymovych, V.; Oderov, A.; Romanchuk, S.; Korchagin, M.; Chernozub, A.; Olkhovyi, O.; Zolochevskyi, V. The influence of professionally oriented physical training means on the operator's physical ability level. *Sport Mont* **2020**, *18*, 19–23.
17. Wheeler, K.W.; Sayers, M.G. Modification of agility running technique in reaction to a defender in rugby union. *J. Sport. Sci. Med.* **2010**, *9*, 445.
18. Spasic, M.; Uljevic, O.; Coh, M.; Dzelalija, M.; Sekulic, D. Predictors of agility performance among early pubescent girls. *Int. J. Perform. Anal. Sport* **2013**, *13*, 480–499. [CrossRef]
19. Pavlinović, V.; Spasić, M.; Foretić, N.; Kontić, D.; Zenić, N. Differential Influence of General Anthropometric and Motor Predictors on Pre-planned Agility in Pubescent Boys and Girls: A Multiple Regression Study. *Sport Mont* **2022**, *20*, 75–81. [CrossRef]
20. Hoffman, J.R. Evaluation of a reactive agility assessment device in youth football players. *J. Strength Cond. Res.* **2020**, *34*, 3311–3315. [CrossRef]
21. Lima, R.; Rico-González, M.; Pereira, J.; Caleiro, F.; Clemente, F. Reliability of a reactive agility test for youth volleyball players. *Pol. J. Sport Tour.* **2021**, *28*, 8–12. [CrossRef]
22. Haugen, T.A.; Tønnessen, E.; Seiler, S.K. The difference is in the start: Impact of timing and start procedure on sprint running performance. *J. Strength Cond. Res.* **2012**, *26*, 473–479. [CrossRef] [PubMed]
23. Malina, R.M.; Kozieł, S.M.; Králik, M.; Chrzanowska, M.; Suder, A. Prediction of maturity offset and age at peak height velocity in a longitudinal series of boys and girls. *Am. J. Hum. Biol.* **2021**, *33*, e23551. [CrossRef] [PubMed]
24. Iuliano-Burns, S.; Mirwald, R.L.; Bailey, D.A. Timing and magnitude of peak height velocity and peak tissue velocities for early, average, and late maturing boys and girls. *Am. J. Hum. Biol. Off. J. Hum. Biol. Assoc.* **2001**, *13*, 1–8. [CrossRef]
25. Fiorilli, G.; Iuliano, E.; Mitrotasios, M.; Pistone, E.M.; Aquino, G.; Calcagno, G.; di Cagno, A. Are change of direction speed and reactive agility useful for determining the optimal field position for young soccer players? *J. Sport. Sci. Med.* **2017**, *16*, 247–253.
26. Serpell, B.G.; Ford, M.; Young, W.B. The development of a new test of agility for rugby league. *J. Strength Cond. Res.* **2010**, *24*, 3270–3277. [CrossRef]
27. Sinkovic, F.; Foretic, N.; Novak, D. Reliability, Validity and Sensitivity of Newly Developed Tennis-Specific Reactive Agility Tests. *Sustainability* **2022**, *14*, 13321. [CrossRef]
28. Inglis, P.; Bird, S.P. Reactive agility tests: Review and practical applications. *J. Aust. Strength Cond.* **2016**, *24*, 62–69.
29. Oliver, J.L.; Meyers, R.W. Reliability and generality of measures of acceleration, planned agility, and reactive agility. *Int. J. Sport. Physiol. Perform.* **2009**, *4*, 345–354. [CrossRef]
30. Turner, A.N.; Jeffreys, I. The stretch-shortening cycle: Proposed mechanisms and methods for enhancement. *Strength Cond. J.* **2010**, *32*, 87–99. [CrossRef]

31. Thomas, K.; French, D.; Hayes, P.R. The effect of two plyometric training techniques on muscular power and agility in youth soccer players. *J. Strength Cond. Res.* **2009**, *23*, 332–335. [CrossRef]
32. Sahin, H.M. Relationships between acceleration, agility, and jumping ability in female volleyball players. *Eur. J. Exp. Biol.* **2014**, *4*, 303–308.
33. Wickel, E.E.; Eisenmann, J.C. Maturity-related differences in physical activity among 13-to 14-year-old adolescents. *Pediatr. Exerc. Sci.* **2007**, *19*, 384–392. [CrossRef]
34. Soares, J.; Antunnes, H.; van den Tillaar, R. A comparison between boys and girls about the motives for the participation in school sport. *J. Phys. Educ. Sport* **2013**, *13*, 303.
35. Slater, A.; Tiggemann, M. Gender differences in adolescent sport participation, teasing, self-objectification and body image concerns. *J. Adolesc.* **2011**, *34*, 455–463. [CrossRef]
36. Hjelmér, C. Free play, free choices?—Influence and construction of gender in preschools in different local contexts. *Educ. Inq.* **2020**, *11*, 144–158. [CrossRef]
37. Harten, N.; Olds, T.; Dollman, J. The effects of gender, motor skills and play area on the free play activities of 8–11 year old school children. *Health Place* **2008**, *14*, 386–393. [CrossRef]
38. Gréhaigne, J.-F.; Richard, J.-F.; Griffin, L.L. *Teaching and Learning Team Sports and Games*; Routledge: London, UK, 2012.
39. Malina, R.M.; Rogol, A.D.; Cumming, S.P.; E Silva, M.J.C.; Figueiredo, A.J. Biological maturation of youth athletes: Assessment and implications. *Br. J. Sport. Med.* **2015**, *49*, 852–859. [CrossRef]
40. Beunen, G.; Malina, R.M. Growth and biologic maturation: Relevance to athletic performance. *Young Athl.* **2008**, *1*, 3–17.
41. Hammami, R.; Sekulic, D.; Selmi, M.A.; Fadhloun, M.; Spasic, M.; Uljevic, O.; Chaouachi, A. Maturity status as a determinant of the relationships between conditioning qualities and preplanned agility in young handball athletes. *J. Strength Cond. Res.* **2018**, *32*, 2302–2313. [CrossRef]
42. Krolo, A.; Gilic, B.; Foretic, N.; Pojskic, H.; Hammami, R.; Spasic, M.; Uljevic, O.; Versic, S.; Sekulic, D. Agility testing in youth football (soccer) players; evaluating reliability, validity, and correlates of newly developed testing protocols. *Int. J. Environ. Res. Public Health* **2020**, *17*, 294. [CrossRef]
43. Kovacevic, N.; Mihanovic, F.; Lusic Kalcina, L.; Hrbic, K.; Poklepovic Pericic, T.; Matijas, T.; Galic, T. Influence of cognitive performance and swimming capacities on selection of youth water polo players to national team. *J. Sport. Med. Phys. Fit.* **2022**. [CrossRef]
44. Zeljko, I.; Spasic, M.; Sekulic, D. Predicting futsal specific change of direction speed and reactive agility; analysis of specific correlates in top-level players. *Sport Qual. Life* **2020**, *2019*, 147.
45. Sheppard, J.; Young, W.B.; Doyle, T.; Sheppard, T.; Newton, R.U. An evaluation of a new test of reactive agility and its relationship to sprint speed and change of direction speed. *J. Sci. Med. Sport* **2006**, *9*, 342–349. [CrossRef] [PubMed]
46. Scanlan, A.; Humphries, B.; Tucker, P.S.; Dalbo, V. The influence of physical and cognitive factors on reactive agility performance in men basketball players. *J. Sport. Sci.* **2014**, *32*, 367–374. [CrossRef]

children

Article

Effects of a 12-Week Functional Training Program on the Strength and Power of Chinese Adolescent Tennis Players

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Abstract: Background: Functional training is any type of training designed to improve a specific movement or activity for fitness or high performance sports. This study examined the effect of functional training on the strength and power of young tennis players. Methods: 40 male tennis players were assigned to the functional training group (n = 20; age, 16.7 ± 0.4 years) or the conventional training group (n = 20; age, 16.5 ± 0.6 years). The functional training group received three 60 min sessions per week for 12 weeks, while the conventional training group participated in three sessions per week of mono-strength exercise for 12 weeks. Strength and power were measured according to the International Tennis Federation protocol at baseline, 6 weeks after the intervention, and 12 weeks after the intervention. Results: Both forms of training increased ($p < 0.05$) push-ups, wall squat test, over medicine ball throw, and standing long jump after 6 weeks of training, and the effect improved further as the 12-week mark approached. Except for the wall squat test (left) at 6 weeks, functional training showed no advantage over conventional training. After an additional 6 weeks of training, all measures of strength and power were better ($p < 0.05$) in the functional training group. Conclusions: Improvements in strength and power could occur after as little as 6 weeks of functional training, and 12-week functional training could outperform conventional training in male adolescent tennis players.

Keywords: youth; resistance training; motor development; musculoskeletal adaptation; physical fitness

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1. Introduction

For many sports, strength and power are foundational qualities [1]. Modern tennis has evolved from a primarily technical sport dominated by sport-specific technical skills [2] to a dynamic, advanced sport characterized by stroke and serve speed, higher physical speed, and movement demands that are both strategic and explosive [3]. Therefore, modern tennis players must be physically fit to execute more complex shots and compete against increasingly formidable opponents. In addition, tennis requires a high level of muscle and joint strength for performance (ball velocity) and injury prevention (joint protection), while a sufficient range of motion in the major joints (e.g., rotator cuff muscles) is necessary for strokes and on-court movement [4]. Various training strategies have been developed to improve the strength and power of tennis players [5,6]. Similar to many other sports, there is no one-size-fits-all training method and no universally accepted method in tennis that can be recommended as the best way to improve the strength and power of tennis players.

Functional training is a trending method for enhancing the strength and power of athletes [7]. Functional training refers to the training of partial chains and connections in the human motion chain, which includes multi-dimensional motion trajectory acceleration, deceleration, and stability training activities that meet the characteristics of specific target actions [8]. The essence of functional training is goal-directed exercise, meaning it could consist of any exercise designed to improve a particular movement or activity [9]. In other words, if balance training is included in a functional training program, the training intervention aims to improve sport-specific balance performance. Unlike mono-strength exercise, functional training introduces a variety of movements and stimulates all of the major muscle groups in the body, hence its growing popularity in professional tennis training [10].

Functional training that emphasizes the development of strength and power differs from conventional resistance training, which focuses on increasing the strength and endurance of a specific muscle group [11]. Functional training, on the other hand, is designed to isolate and develop individual muscles through the use of body weight, stable positions, and fixed training equipment [12]. Moreover, conventional training often relies on high loads and duration to develop or enhance muscular performance [12]. However, tennis requires the simultaneous use of multiple muscle groups and joints across multiple axes [13], rendering conventional training inadequate for achieving the desired improvement in tennis players' specific physical fitness.

Functional training has shown promise for enhancing the physical fitness of diverse populations. Green and colleagues conducted a cross-sectional study on male athletes with backgrounds in either strength, endurance, or high-intensity functional training [14]. It was observed that the functional training group had comparable power outputs and absolute strength to the strength-focused group. Interestingly, the functional training group exhibited fatigue resistance and mitochondrial capacity comparable to endurance training participants. Similarly, another study comparing the physiological profiles of trained athletes found that athletes who participated in high-intensity functional training attained aerobic levels comparable to those of endurance athletes and power and strength output comparable to those of power athletes [15]. It is possible for functional training to simultaneously improve multiple facets of physical fitness. These findings of Green et al. [14] and Adami et al. [15] have now been replicated in a randomized controlled trial. Compared to endurance training or strength training alone, functional training improved the counter-movement jump, 20 m sprint, 3-repetition maximum back squat, and yo-yo test in an untrained population after 6 weeks of training twice per week for 60–75 min per session [16].

Compared to adult populations, there are limited studies on functional training for children and adolescents. Previous studies focused on youth soccer players [17], martial artists [18], and handball players [19], whereas research on youth tennis players is scant [13]. For example, Zrhl and Demirci reported that 8 weeks of functional training improved the 10 m sprint, vertical leap, flexibility, hand gripping force, and T agility test in 10–12-year-old female tennis players [20]. However, the effects of functional training on other age groups of youth tennis players remain unknown. The effect of functional training on the strength and power performance of young tennis players, especially, is not yet backed up by research [12]. Furthermore, due to insufficient data, there is no consensus regarding how long a functional training intervention has to last to increase the strength and power of trained youth athletes. Given its potential in sports with a high demand for strength and power, it would be interesting to determine if young tennis players, who are in a crucial stage of physical fitness development, could reap the same benefits observed in other sports and adult populations.

Therefore, this study investigated the effect of 12-week functional training on the strength and power of young tennis players. The results are intended to assist coaches in optimizing their training methods, especially in developing countries where young players often lack access to advanced resistance training equipment.

2. Materials and Methods

2.1. Design

This research was approved by the Ethics Committee of Universiti Putra Malaysia (protocol number JKEUPM-2020-283) and parental consent was obtained. The participant's legal guardian provided informed consent, and participants could withdraw from the study at any time.

The study protocol is summarized in Figure 1. The design and reporting of the study followed the CONSORT statement [21] and a cluster-randomized approach. The sample size was determined using G*Power 3.1. The effect size was calculated using data from previous studies (effect size = 0.24). The sample size was calculated to be 30 (15 for each group) based on an alpha of 0.05 and a power of 0.80. To achieve the required statistical power in cluster randomized trials, the presumptive individual randomization sample size may be amplified by a design effect [22]. Taking into account the design effect and a potential dropout rate of 20% of the total sample size [23], the final sample size was determined to be 42.75, which was rounded to 44 tennis players.

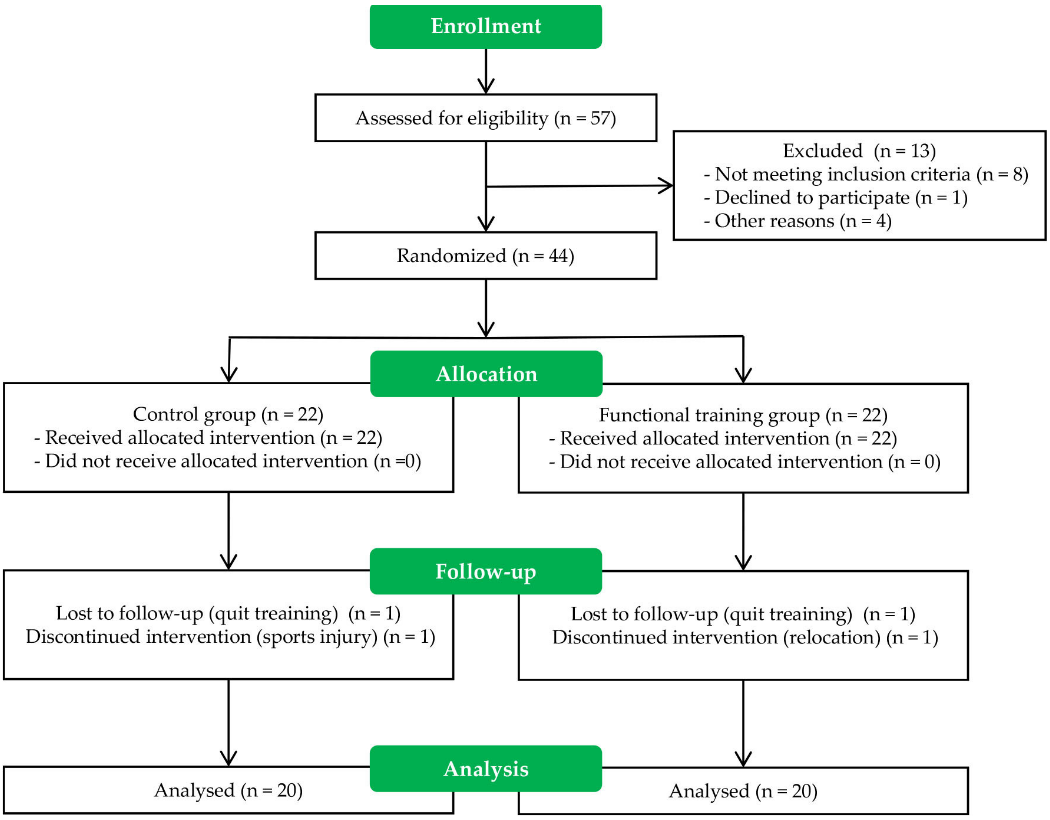

Figure 1. CONSORT flow diagram.

Tennis players from the Youth Tennis Reserve Training Base in Jiaxing, Zhejiang province were recruited. Given that the majority of tennis players were male during the study period, only 14- to 18-year-old male tennis players were recruited for this study. Participants were removed from the final list if any of the following conditions were met: recent (i.e., less than one year) history of knee, elbow, or shoulder injury; history of rheumatoid disease or neurological damage for which treatment is ongoing [24]; prior experience with functional training in the 12 months before the present study; and players who are about to discontinue tennis training due to uncertain factors. Table 1 summarizes the participants' demographics.

Table 1. Participants' demographics.

Variables	CT	FT	p
	M (SD)	M (SD)	
Age (year)	16.5 (0.6)	16.7 (0.4)	0.360
Height (cm)	176.4 (2.4)	176.2 (2.6)	0.836
Weight (kg)	71.8 (3.2)	71.6 (3.0)	0.830
Training experience (month)	58.0 (4.2)	57.9 (4.4)	0.971

Note: CT: conventional training group; FT: functional training group.

2.2. Intervention

During the study's planning phase, seven experts familiar with tennis training assessed the content validity of the training intervention and outcome evaluation [25]. Specifically, the items content validity index (I-CVI) and modified Kappa coefficient factor were used to determine the content validity using a 4-point ordinal scale (1, 'not relevant'; 2, 'somewhat relevant'; 3, 'quite relevant'; 4, 'highly relevant') [26]. Items with I-CVI values below 0.78 were adjusted or removed, and Kappa values above 0.75 indicate excellent content validity, between 0.40 and 0.75 indicate fair to good content validity, and below 0.40 indicate poor content validity. In addition, an open-ended questionnaire was provided to solicit expert feedback for micro-adjustments to the training intervention.

The functional training group and the conventional training group were trained every Monday, Wednesday, and Friday from 4–5 p.m. The functional training group received a program based on Santana's Racket Sport Program [27], whereas the conventional training group followed the conventional training program. The functional training program details are presented in Table 2. Researchers collected the participants' training logbooks weekly and encouraged them to adhere to the intervention. The definition of intervention adherence was attendance at 80% of prescribed sessions.

Table 2. A detailed description of the 12-week functional training.

Type of Exercise	Week 1	Week 2	Week 3	Week 4
MB wood chop Side T plank BP compound row	2 sets × 10 reps	3 sets × 10 reps	3 sets × 15 reps	4 sets × 10 to 15 reps
MB ABC squat BP staggered-stance fly BP staggered-stance CLA row	2 sets × 10 reps	3 sets × 10 reps	3 sets × 15 reps	2 sets × 10 to 15 reps
Rope circles (clockwise and counterclockwise) Vibration blade throw (per side)	2 sets × 10 to 15 s 2 sets × 10 s			
Frequency, times, intensity, and rest	3 times/weeks, 60 min, 60–75% 1RM, 30–60 s			
Type of Exercise	**Week 5**	**Week 6**	**Week 7**	**Week 8**
BP low-to-high chop DB single-arm diagonal fly rotation BP staggered-stance CLA compound row	1 set × 6 reps	2 sets × 6 reps	3 sets × 4 reps	4 sets × 4 reps
DB or KB lateral reaching lunge T push-up DB or KB staggered-stance bent-over single-arm row	1 set × 6 reps	2 sets × 6 reps	3 sets × 4 reps	4 sets × 4 reps
X-up SB rollout Rope circles (clockwise and counterclockwise) Vibration blade throw (per side)	2 sets × 10 reps 2 sets × 10 reps 2 sets × 20 s 2 sets × 15 s			
Frequency, times, intensity, and rest	3 times/weeks, 60 min, 75–90% 1RM, 30–60 s			
Type of Exercise	**Week 9**	**Week 10**	**Week 11**	**Week 12**
DB or KB lateral reaching lunge Skater	2 sets × 5 + 5 reps	3 sets × 5 + 5 reps	3 or 4 sets × 5 + 5 reps	4 sets × 5 + 5 reps

Table 2. *Cont.*

Type of Exercise	Week 1	Week 2	Week 3	Week 4
BP low-to-high chop MB rotational throw: perpendicular	2 sets × 5 + 5 reps	3 sets × 5 + 5 reps	3 or 4 sets × 5 + 5 reps	4 sets × 5 + 5 reps
Biplex 3				
BP high-to-low chop MB overhead side-to-side slam	2 sets × 5 + 5 reps	3 sets × 5 + 5 reps	3 or 4 sets × 5 + 5 reps	4 sets × 5 + 5 reps
BP swim MB overhead slam	2 sets × 5 + 5 reps	3 sets × 5 + 5 reps	3 or 4 sets × 5 + 5 reps	4 sets × 5 + 5 Reps
Single-leg CLA anterior reach (per leg)	3 sets × 10 reps			
Rope circles (clockwise and counterclockwise)	3 sets × 10 to 15 s			
Vibration blade throw (per side)	3 sets × 10 s			
Frequency, times, intensity, and rest	3 times/weeks, 60 min, 95–100% 1RM, 1–2 min			

Note: 1RM: one repetition maximum; 5 + 5: 60 s of rest between the first and second exercise; BP: bands or pulleys; CLA: contralateral arm; DB: dumbbell; KB: kettlebells; MB: medicine balls; SB: stability balls.

2.3. Evaluation

The evaluation of strength and power followed the International Tennis Federation (ITF) standard test protocol [28]. For this study, the ITF's strength (push-ups and wall squat test) and power (over medicine ball throw and standing long jump) test batteries were utilized.

One week before the baseline evaluation, all participants and their coaches attended an orientation session. The participants were instructed to maintain their daily diet in the dining hall of the training base and to avoid alcoholic beverages. All participants were required to eat food in the dining hall 24 h before each evaluation. During this meeting, they were also given a familiarization trial with the ITF test batteries. To ensure optimal recovery, their coaches were instructed to refrain from assigning strenuous workouts 24 h before each evaluation.

All the data collection took place between 8 and 11 a.m. After completing a tennis-specific warm-up, each participant completed the tests. After the baseline evaluation, the test batteries were administered again after 6 and 12 weeks of the intervention. All of the testers majored in physical education, and two of them are certified ITF level-2 coaches.

2.4. Statistics

Data were analyzed using the IBM SPSS version 23. The homogeneity of two groups for demographics and outcome variables at baseline were examined using a two-tailed *t*-test. To determine the efficacy of the intervention, a generalized estimating equation analysis was conducted, followed by Bonferroni correction for pairwise comparison. Given that the average training experience of the sample was less than 5 years, the effect size (Cohen d) was interpreted as follows: trivial, 0.35; small, 0.35 to 0.80; moderate, 0.80 to 1.50; and large, >1.50 [29]. A p-value less than 0.05 was considered statistically significant.

3. Results

Based on the experts' evaluation, both the relevancy (training intervention: I-CVI = 0.857–1.000, Kappa = 0.588–1.000; strength: I-CVI = 0.857–1.000, Kappa = 0.682–1.000; power: I-CVI = 0.857, Kappa = 0.682–0.741) and clarity (training intervention: I-CVI = 0.857–1.000, Kappa = 0.696–1.000; strength: I-CVI = 0.857–1.000, Kappa = 0.682–1.000; power: I-CVI = 0.857–1.000, Kappa = 0.588–0.741) met the acceptable thresholds, indicating that the content validity was satisfactory.

Table 3 summarizes the results of the ITF test batteries. Briefly, both forms of training improved strength and power, but the 12-week functional training showed greater promise among 14- to 18-year-old tennis players.

Table 3. Tennis-specific performance following 12-week training.

Test Battery		Time	Measurement		Between-Group		Within-Group d (T0 vs. T12)	
			CT	FT	p	d	CT	FT
Strength	PU (#)	T0	38.9 (1.7)	38.9 (1.7)	1.000	<0.001	1.62	3.44
		T6	41.0 (3.6) *	41.2 (2.8) *	0.802	0.08		
		T12	44.8 (4.9) †	48.3 (3.5) †	0.008	0.82		
	WSTL (sec)	T0	36.0 (2.5)	37.2 (2.4)	0.136	0.46	1.93	4.40
		T6	38.5 (2.4) *	43.3 (2.8) *	<0.001	1.85		
		T12	41.2 (2.8) †	47.8 (2.4) †	<0.001	2.51		
	WSTR (sec)	T0	57.5 (2.9)	57.1 (3.6)	0.683	0.13	0.98	1.59
		T6	59.4 (2.9) *	60.1 (3.5) *	0.444	0.24		
		T12	60.3 (2.9) †	62.7 (3.5) †	0.017	0.73		
Power	OMBT (m)	T0	8.9 (1.4)	9.4 (1.6)	0.249	0.36	0.45	0.65
		T6	9.2 (1.4) *	9.8 (1.5) *	0.202	0.39		
		T12	9.5 (1.3) †	10.4 (1.4) †	0.033	0.66		
	SLJ (m)	T0	2.52 (0.11)	2.54 (0.12)	0.469	0.22	0.92	1.51
		T6	2.56 (0.11) *	2.61 (0.10) *	0.132	0.46		
		T12	2.62 (0.10) †	2.72 (0.12) †	0.002	0.95		

Note: CT, conventional training; FT, functional training; T0, pre-intervention test; T6, 6-week post-intervention test; T12, 12-week post-intervention test; PU, push-ups; WSTL, wall squat test (left); WSTR, wall squat test (right); OMBT, over medicine ball test; SLJ, standing long jump. * T0 vs. T6, $p < 0.05$; † T6 vs. T12, $p < 0.05$.

First, there was a significant time effect. At 6 weeks, both forms of training improved the push-ups, wall squat test, over medicine ball throw, and standing long jump. All measures of strength and power improved following an additional 6-week training. Overall, after 12 weeks, both forms of training had a large training effect on the push-ups and wall squat test (left); functional training had a large training effect on the wall squat test (right) and standing long jump; conventional training had a moderate training effect on the wall squat test (right) and standing long jump, and both forms of training had a small training effect on the over medicine ball throw.

Second, there was a significant group effect. At 6 weeks, only the wall squat test (left) was different between the two forms of training. At 12 weeks, the functional training group outperformed the conventional training group on all measures of strength and power. Compared to conventional training, 12-week functional training had a large training effect on the wall squat test (left), a moderate training effect on the push-ups and standing long jump, and a small training effect on the wall squat test (right) and over medicine ball throw.

4. Discussion

This study demonstrates that functional training for as little as 6 weeks can improve the strength and power of adolescent male tennis players. These results are expected and consistent with the population studied. Children's strength can increase by 30% to 50% after just 8 to 12 weeks of a well-designed strength training program [30]. Nonetheless, when considering the use of functional training to replace conventional training on strength and power development, our results suggest that training may require 12 weeks to yield superior results. These findings are essential for guiding the coaching of adolescent tennis players, whose motor development is crucial at this age.

Existing evidence suggests that functional training can enhance strength and power in a variety of sports. Oliver and Brezzo [31] found that the strength (single-leg squat) of female volleyball players increased following 13 weeks of functional training. Alonso-Fernández et al. [19] reported that 8 weeks of functional training improved the repeated sprint ability of female handball players. Park [32] found that 6 weeks of functional training increased the back strength of elite taekwondo athletes. Fernandez-Fernandez et al. [33] found that 8 weeks of neuromuscular warm-up before and after tennis-specific training increased muscular strength and power as measured by counter-movement jump, medicine ball throw, and shoulder strength. Collectively, this study not only adds additional evidence to the growing body of literature on functional training for youth but also demonstrates that a 6-week functional training program is effective in increasing both strength and power in trained male adolescent tennis players.

The notable point seemed to be that 6 weeks of functional training cannot lead to higher strength and power than conventional training. At the 6-week mark, the functional training group only performed better on the wall squat test (left). This difference could be because the dominant hand of the participants is the right hand (forehand) and their support foot is the left foot. In this sample, all athletes hold the tennis racket with their right hand (forehand shot). In professional tennis, the forehand shot is the most used and essential for offensive scoring [34]. Accordingly, when the tennis ball is struck, the typical supporting foot is left [35]. In addition, the left foot is the foot that lands after striking the tennis ball, which can help strengthen the left lower body [36]. Therefore, this condition may account for the significant difference observed after 6 weeks of functional training, indicating that functional training may be an efficient method for enhancing underdeveloped strength. This finding, however, does not support the notion that 6 weeks of functional training improved other strength and power components more than conventional training.

According to previous research, as little as 4 weeks of functional training is sufficient to produce greater gains in strength and power than conventional training. For example, Yildiz et al. [13] reported that a 4-week functional training improved the functional movement screen in comparison to conventional training. Likewise, Tomljanovi et al. [37] found that 5 weeks of functional training improved the strength (standing overarm and lying medicine ball throw) of moderately trained male athletes (aged from 22 to 25 years). This inconsistency may be attributable to a variety of confounding variables, including training experience, the volume of functional training, and evaluation objectives. It is important to note that in the aforementioned studies, the movement patterns in the functional training were similar to their sports-specific tests, which could help athletes adapt to training. This might explain why 1 month of functional training could have a noticeable effect.

In this study, an additional 6 weeks of functional training outperformed in all measures of strength and power. This is consistent with the findings obtained by Yildiz et al. [13] from a group of school-aged tennis players. Although their functional training group demonstrated significant improvement on the functional movement screen at the 4-week mark compared to the conventional training group, their functional training showed the most promise after an additional 4 weeks of training. Specifically, functional training outperformed conventional training in terms of flexibility, counter-movement jump, T-test agility, dynamic balance (both left and right), static balance, and the functional movement screen over an 8-week duration. Our results not only corroborate these preliminary findings but also demonstrate that 12-week functional training could provide larger advantages than conventional training for adolescents who are engaging in systematic tennis training. In terms of effect size, functional training demonstrates remarkable advantages in tennis-specific lower-limb strength and power, which could be particularly beneficial for enhancing on-court performance and reducing injury risks [38]. Particularly, the wall squat test (left) revealed an exceptionally large effect size, indicating that functional training may be especially useful in developing the supporting foot strength of young tennis players.

The difference in subsequent gains in strength and power between functional and conventional training after 6 weeks may be attributable to the plateau effect in sports training [39]. Resistance training induces changes in motor unit recruitment during voluntary contractions. The onset of training adaptation is associated with corticospinal signaling neural adaptations [40], and significant changes in motor unit behavior, such as a concurrent increase in discharge rate and decrease in the recruitment-threshold force of motor units, could occur as early as 3 weeks [41]. Nonetheless, such adaptation often moderates [42] or even normalizes over time [43], resulting in a plateau phase following additional training exposure. For example, rapid changes in motor unit discharge rate occurred in the early

3-week phase of strength training compared to later 3-week phases in untrained young adults [41]. Current literature suggests that simple overload in training duration becomes less effective after 3–6 weeks of compensatory adaptations and that introducing controlled overload in training intensity and/or variation is recommended for eliciting additional performance gains. This aligns with the present findings. In the first half of the training program, both strength and power increased substantially. Nevertheless, conventional tennis training does not introduce variation after the onset of adaptation, whereas functional training is exceptional in terms of training variation and intensity (see also Table 2) throughout the second half of the training program, making it superior to conventional training after the entire training program. This study not only provides additional empirical data regarding the development curve of strength and power in trained adolescents, but it also sheds new light on the design of a mixed resistance training program for adolescent tennis players.

While the focus of this study was on the utility of functional training, it is also important to consider the logistics of this type of training. In China, and likely in other developing countries, training facilities for young athletes beginning systematic training may be limited and insufficient. Functional training has the advantage of using inexpensive resistance devices (e.g., dumbbells, medicine balls) in daily training [27], which could be convenient yet highly effective when designing resistance training programs for children and adolescents residing in developing countries.

This study has a few limitations. Only the strength and power components of physical fitness were investigated in this study. Future research should look into the effect of functional training on other sport-specific components of physical fitness. Although the caloric intake of the two groups should be comparable, we did not control for energetic beverages such as coffee consumption during the study period. It should be noted that traditionally, the Chinese population does not consume coffee on a regular basis. However, as coffee popularity increases among the young Chinese generation, it is possible that the lack of caffeine consumption control prior to the evaluation may confound the results. In addition, there was no traditional control group, as it would be unethical to discontinue regular training programs. Consequently, the size of the final effect may be inflated due to the normal physical development of adolescents over 3 months. Notwithstanding only male tennis players being recruited for this study, we are cautiously optimistic about the generalization of its efficacy to female tennis players, though a confirmation study is still needed. Finally, although the present sample population is deemed to be beyond the age-specific maturity status in tennis, future research may consider reporting the peak-height velocity for players younger than 16 years of age [44]. In practice, peak-height velocity would enable coaches and team sports scientists to better select and intervene in the training of youth athletes.

In conclusion, this study provides strong evidence regarding the benefits of a 12-week functional training program for youth tennis players. To maximize the continuous development of strength and power, coaches for this age group could incorporate functional training such as our protocol into their routine training regimens, which could be particularly beneficial for young athletes from developing countries.

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References

1. Trinschek, J.; Zieliński, J.; Kusy, K. Maximal Oxygen Uptake Adjusted for Skeletal Muscle Mass in Competitive Speed-Power and Endurance Male Athletes: Changes in a One-Year Training Cycle. *Int. J. Environ. Res. Public Health* **2020**, *17*, 6226. [CrossRef] [PubMed]
2. Ulbricht, A.; Fernandez-Fernandez, J.; Mendez-Villanueva, A.; Ferrauti, A. Impact of Fitness Characteristics on Tennis Performance in Elite Junior Tennis Players. *J. Strength Cond. Res.* **2016**, *30*, 989–998. [CrossRef] [PubMed]
3. Fernandez-Fernandez, J.; Sanz-Rivas, D.; Mendez-Villanueva, A. A Review of the Activity Profile and Physiological Demands of Tennis Match Play. *Strength Cond. J.* **2009**, *31*, 15–26. [CrossRef]
4. Kovacs, M.S. Applied physiology of tennis performance. *Br. J. Sport. Med.* **2006**, *40*, 381–386. [CrossRef]
5. Fernandez-Fernandez, J.; De Villarreal, E.S.; Sanz-Rivas, D.; Moya, M. The Effects of 8-Week Plyometric Training on Physical Performance in Young Tennis Players. *Pediatr. Exerc. Sci.* **2016**, *28*, 77–86. [CrossRef]
6. Moya-Ramon, M.; Nakamura, F.Y.; Teixeira, A.S.; Granacher, U.; Santos-Rosa, F.J.; Sanz-Rivas, D.; Fernandez-Fernandez, J. Effects of Resisted vs. Conventional Sprint Training on Physical Fitness in Young Elite Tennis Players. *J. Hum. Kinet.* **2020**, *73*, 181–192. [CrossRef]
7. Feito, Y.; Heinrich, K.M.; Butcher, S.J.; Poston, W.S.C. High-Intensity Functional Training (HIFT): Definition and Research Implications for Improved Fitness. *Sports* **2018**, *6*, 76. [CrossRef]
8. Cook, G.; Fields, K. Functional Training for the Torso. *Strength Cond. J.* **1997**, *19*, 14–19. [CrossRef]
9. Pacheco, M.M.; Teixeira, L.A.C.; Franchini, E.; Takito, M.Y. Functional vs. Strength training in adults: Specific needs define the best intervention. *Int. J. Sport. Phys. Ther.* **2013**, *8*, 34–43.
10. Top Level Tennis. 1 HOUR Training Plan with Djokovic's FITNESS Coach! Available online: https://www.youtube.com/watch?v=GlALuivD5Ek&ab_channel=TopLevelTennis (accessed on 2 August 2022).
11. Kovac, D.; Krkeljas, Z.; Venter, R. Effect of six-week traditional resistance and functional training on functional performance in female netball players. *BMC Sport. Sci. Med. Rehabil.* **2022**, *14*, 10. [CrossRef]
12. Xiao, W.; Soh, K.G.; Wazir, M.R.W.N.; Talib, O.; Bai, X.; Bu, T.; Sun, H.; Popovic, S.; Masanovic, B.; Gardasevic, J. Effect of Functional Training on Physical Fitness Among Athletes: A Systematic Review. *Front. Physiol.* **2021**, *12*, 738878. [CrossRef] [PubMed]
13. Yildiz, S.; Pinar, S.; Gelen, E. Effects of 8-Week Functional vs. Traditional Training on Athletic Performance and Functional Movement on Prepubertal Tennis Players. *J. Strength Cond. Res.* **2019**, *33*, 651–661. [CrossRef] [PubMed]
14. Green, E.S.; Williams, E.R.; Feito, Y.; Jenkins, N.T. Physiological and Anthropometric Differences Among Endurance, Strength, and High-Intensity Functional Training Participants: A Cross-Sectional Study. *Res. Q. Exerc. Sport* **2023**, *94*, 131–142. [CrossRef]
15. Adami, P.E.; Rocchi, J.E.; Melke, N.; De Vito, G.; Bernardi, M.; Macaluso, A. Physiological profile comparison between high intensity functional training, endurance and power athletes. *Eur. J. Appl. Physiol.* **2022**, *122*, 531–539. [CrossRef] [PubMed]
16. Gavanda, S.; Isenmann, E.; Geisler, S.; Faigenbaum, A.; Zinner, C. The Effects of High-Intensity Functional Training Compared with Traditional Strength or Endurance Training on Physical Performance in Adolescents: A Randomized Controlled Trial. *J. Strength Cond. Res.* **2022**, *36*, 624–632. [CrossRef] [PubMed]
17. Keiner, M.; Kadlubowski, B.; Sander, A.; Hartmann, H.; Wirth, K. Effects of 10 Months of Speed, Functional, and Traditional Strength Training on Strength, Linear Sprint, Change of Direction, and Jump Performance in Trained Adolescent Soccer Players. *J. Strength Cond. Res.* **2022**, *36*, 2236–2246. [CrossRef] [PubMed]
18. Cherepov, E.A.; Shaikhetdinov, R.G. Effectiveness of functional training during physical conditioning of students practicing martial arts. *J. Phys. Educ. Sport* **2016**, *16*, 510–512. [CrossRef]
19. Alonso-Fernández, D.; Lima-Correa, F.; Gutierrez-Sánchez, Á.; Abadía-García de Vicuña, O. Effects of a high-intensity interval training protocol based on functional exercises on performance and body composition in handball female players. *J. Hum. Sport Exerc.* **2017**, *12*, 1186–1198. [CrossRef]
20. Zırhlı, O.; Demirci, N. The Influence of functional training on biomotor skills in girl tennis players aged 10–12. *Balt. J. Health Phys. Activ.* **2020**, *12*, 33–45. [CrossRef]
21. Moher, D.; Hopewell, S.; Schulz, K.F.; Montori, V.; Gøtzsche, P.C.; Devereaux, P.J.; Elbourne, D.; Egger, M.; Altman, D.G. CONSORT 2010 Explanation and Elaboration: Updated guidelines for reporting parallel group randomised trials. *BMJ* **2010**, *340*, c869. [CrossRef]
22. Donner, A.; Birkett, N.; Buck, C. Randomization by cluster: Sample size requirements and analysis. *Am. J. Epidemiol.* **1981**, *114*, 906–914. [CrossRef] [PubMed]
23. Cramer, H.; Haller, H.; Dobos, G.; Lauche, R. A Systematic Review and Meta-Analysis Estimating the Expected Dropout Rates in Randomized Controlled Trials on Yoga Interventions. *Evid. Based Complement. Altern. Med.* **2016**, *2016*, 5859729. [CrossRef] [PubMed]
24. Barber-Westin, S.D.; Hermeto, A.A.; Noyes, F.R. A Six-Week Neuromuscular Training Program for Competitive Junior Tennis Players. *J. Strength Cond. Res.* **2010**, *24*, 2372–2382. [CrossRef] [PubMed]

25. Mokkink, L.B.; Terwee, C.B.; Knol, D.L.; Stratford, P.W.; Alonso, J.; Patrick, D.L.; Bouter, L.M.; de Vet, H.C.W. The COSMIN checklist for evaluating the methodological quality of studies on measurement properties: A clarification of its content. *BMC Med. Res. Methodol.* **2010**, *10*, 22. [CrossRef]
26. Polit, D.F.; Beck, C.T.; Owen, S.V. Is the CVI an acceptable indicator of content validity? Appraisal and recommendations. *Res. Nurs. Health* **2007**, *30*, 459–467. [CrossRef]
27. Santana, J.C. *Functional Training*; Human Kinetics: Champaign, IL, USA, 2015.
28. International Tennis Federation. Fitness Testing. Available online: https://www.itftennis.com/media/2295/conditioning-fitness-testing.pdf (accessed on 1 November 2019).
29. Fröhlich, M.; Emrich, E.; Pieter, A.; Stark, R. Outcome Effects and Effects Sizes in Sport Sciences. *Int. J. Sport. Sci. Eng.* **2009**, *3*, 175–179.
30. Dahab, K.S.; McCambridge, T.M. Strength Training in Children and Adolescents: Raising the Bar for Young Athletes? *Sport. Health* **2009**, *1*, 223–226. [CrossRef]
31. Oliver, G.D.; Brezzo, R.D. Functional Balance Training in Collegiate Women Athletes. *J. Strength Cond. Res.* **2009**, *23*, 2124–2129. [CrossRef]
32. Park, J.-s. The effect of functional training on the physical strength factor of elite Taekwondo athletes. *Kinesiology* **2019**, *4*, 1–7. [CrossRef]
33. Fernandez-Fernandez, J.; García-Tormo, V.; Santos-Rosa, F.J.; Teixeira, A.S.; Nakamura, F.Y.; Granacher, U.; Sanz-Rivas, D. The Effect of a Neuromuscular vs. Dynamic Warm-up on Physical Performance in Young Tennis Players. *J. Strength Cond. Res.* **2020**, *34*, 2776–2784. [CrossRef]
34. Kovalchik, S.; Reid, M. A shot taxonomy in the era of tracking data in professional tennis. *J. Sport. Sci.* **2018**, *36*, 2096–2104. [CrossRef] [PubMed]
35. Shi, L.; Sun, W. A Comparative Study on the Forehand Offense of the World Outstanding Male Tennis Players. *J. Beijing Sport Univ.* **2010**, *33*, 125–128. [CrossRef]
36. Knudson, D.V.; Blackwell, J. Trunk Muscle Activation in Open Stance and Square Stance Tennis Forehands. *Int. J. Sport. Med.* **2000**, *21*, 321–324. [CrossRef]
37. Tomljanović, M.; Spasić, M.; Gabrilo, G.; Uljević, O.; Foretić, N. Effects of five weeks of functional vs. traditional resistance training on anthropometric and motor performance variables. *Kinesiology* **2011**, *43*, 145–154.
38. Fernandez-Fernandez, J.; Ulbricht, A.; Ferrauti, A. Fitness testing of tennis players: How valuable is it? *Br. J. Sport. Med.* **2014**, *48*, i22–i31. [CrossRef] [PubMed]
39. Gelman, R.; Berg, M.; Ilan, Y. A Subject-Tailored Variability-Based Platform for Overcoming the Plateau Effect in Sports Training: A Narrative Review. *Int. J. Environ. Res. Public Health* **2022**, *19*, 1722. [CrossRef]
40. Aagaard, P. Training-Induced Changes in Neural Function. *Exerc. Sport Sci. Rev.* **2003**, *31*, 61–67. [CrossRef]
41. Vila-Chã, C.; Falla, D.; Farina, D. Motor unit behavior during submaximal contractions following six weeks of either endurance or strength training. *J. Appl. Physiol.* **2010**, *109*, 1455–1466. [CrossRef]
42. Folland, J.P.; Williams, A.G. Morphological and Neurological Contributions to Increased Strength. *Sport. Med.* **2007**, *37*, 145–168. [CrossRef]
43. Patten, C.; Kamen, G.; Rowland, D.M. Adaptations in maximal motor unit discharge rate to strength training in young and older adults. *Muscle Nerve* **2001**, *24*, 542–550. [CrossRef]
44. Myburgh, G.K.; Cumming, S.P.; Malina, R.M. Cross-Sectional Analysis Investigating the Concordance of Maturity Status Classifications in Elite Caucasian Youth Tennis Players. *Sport. Med. Open* **2019**, *5*, 27. [CrossRef] [PubMed]

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Article

Youth Judokas Competing in Higher Age Groups Leads to a Short-Term Success

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Abstract: Coaches of youth judo athletes might be under the influence of some extraordinary elite judo athletes that have won elite competitions at a relatively young age and might put youth athletes under pressure to gain as much fighting experience as fast as possible. The present study aims to present a 5-year competition structure, volume and age competition categories (ACC) range in which youth judokas competed with 10-year dropout status. Data from 46 judokas were collected (M = 24; F = 22) for four categorisation classes (National-NC; Perspective-PC; International-IC; World class-WC). Competitive structure, volume, performance and number of ACC were collected from 2009 to 2013 for all age groups from scores and standings records of the National Federation. Youth judokas competed in 8 (±2) competitions per year and also competed in 3 (±1) ACC. Abroad competitions affect the fighting experience and competitive success (CS). CS showed positive correlations with the number of ACC in the year 2009 (p = 0.01), 2010 (p = 0.01) and 2011 (p = 0.04). The final observed years' CS 2012 (p = 0.009) and 2013 (p = 0.002) showed a negative association with the number of ACC. CS in the final observed year 2013 showed a positive association (p = 0.012) with the dropout status in 2018 and a negative one with the number of abroad competitions in 2013 (p = 0.029). In total, 52% dropout was noted in 10 years. This ''playing-up" approach was shown to be successful in creating youth medalists. However, just in the short term, if implemented for too long, it starts to affect competition success negatively and increases youth athletes' dropout. Therefore, coaches should include more competitions abroad in competitors' primary age group, while training sessions could be done with higher age groups which would allow for gathering additional experience in a more controlled environment in their yearly periodisation.

Keywords: combat sports; dropout; experience; performance; playing-up; periodisation

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1. Introduction

Participation in youth sports is a widely known phenomenon, and through it, youth athletes can increase their physical activity and develop physical, psychological and social skills [1,2]. During the late phases of adolescence or during the beginning of adulthood, we can see the development of technical-tactical [3] and some physiological variables, such as anaerobic capacity [4] and strength [5]. At that time, involvement in elite youth sports is slowly starting to emerge. It was highlighted that recently youth athletes had begun early specialisation in their selected sport at increasingly younger ages [6,7] which might be the consequence of increased pressure from coaches and/or parents on them to achieve top results [8,9]. However, early specialisation is not recommended [7] due to concerns about the potential for injury [10,11] and the development of psychological burnout against a host of other potential sociological issues. Moreover, early specialisation's harmful effects have provoked the American Orthopedic Society for Sports Medicine (AOSSM) to publish an Early Sport Specialisation Consensus Statement [12]. Additionally, the struggle for competitive standings during childhood and youth with highly specialised training has been highly criticised [13,14].

In judo, competitions at the elite youth level were extended in 2009 with the introduction of the World Judo Cadet Championship (WCC) [15]. Additionally, a year later, in 2010, another high-level youth competition was introduced in the form of the Youth Olympic Games (YOG) [16], which could be one of the reasons for the added pressure on high standings at an early age. The consequence of these competitions will be seen in additional attention directed to the specialised development of athletes from 13 to 14 and 15 to 16-year-old groups [17]. Coaches in judo might be under the influence of some extraordinary elite judo athletes that have won gold medals in Senior World Championships and Olympic games at a relatively young age. Like the case of Kye Sun-Hui winning Olympic gold at the age of 16, Ilias Iliadis winning a gold Olympic medal at the age of 17, Teddy Riner, winning the World Senior Championship at the age of 18 and recently the youngest senior World champion Daria Bilodid winning the Senior World championship at the age of 17. Additionally, research shows that Japan, as one of the most successful judo countries in the world, starts the specialisation in female judokas at an average age of 14.2 years, while their male athletes start at an average age of 16.3 years [15]. Research has shown that an essential predictor of success in elite youth judokas of lower weight categories (LWC) is speed, while in LWC females, specific endurance and peak power bench press were identified as more important predictors [18,19]. In heavier weight categories for males and females, overall maximum strength and hand grip strength with body height and arm span was identified as the most vital predictor of success [18,19]. Additionally, factors like technique, tactical–cognitive skills, and visual tracking were highlighted to be essential factors in successful judo performance [20,21]. In youth judo athletes, somatic growth and years of formal training have also contributed to the increased neuromuscular performance of the upper and lower limbs [22], which are essential for a successful contest.

The theory of Ericsson's model or the Theory of Deliberate practice (TODP) [23] highlights the 10,000 h of deliberate practice to achieve elite performance (across various domains, including sports). Presuming the youth athlete starts training judo at the age of 6–9 years old; with training sessions of youth lasting from 60 to 90 min per session and conducted three times per week for the first 3–4 years (936 h in 4 years) and afterwards 4–5 times per week lasting for 90 to 120 min per session (416 h in 1 year), athletes would achieve this number in an average of 25 years. However, this theory and timeline are not in line in the eyes of coaches training their youth judokas to achieve good results in YOG and Cadet World Championships. Additionally, from a critical point of view, early specialisation would be inevitable if the TODP were completely applied to sports practice. Additional criticism was noted in the literature that TODP does not consider early development experiences, creativity developed via play and practice, or the impact of hereditary and environmental factors [24]. It was demonstrated that expert performance could also be achieved with 3000 to 4000 h of sport-specific training in sports where athletes' peak is achieved after the age of 20 years [25].

The tendency is to train and compete more, consequently getting more experience, a good youth result and elite youth performance. However, the literature has shown that successful competitive performance in early judo competition was not associated with success later in adulthood, as only 7% of the male and 5% of the female athletes had maintained their competitive levels [17]. However, the theory and previous research have been challenged by the latest Tokyo 2020 Olympic games, where 41 medalists won medals at the Cadet and/or Junior World Championships, while 12 were medalists in WCC [26,27]. On the other side, high competitive pressure on youth athletes can cause a high dropout as research tracking a 5-year (2017–2021) youth cadet judokas competitive results showed that 70.6% of those youth judokas had finished their sporting carrier [28]. This could also be because judo possesses two High-risk burnout characteristics (1) involved in technical and/or (2) weight-dependent sports [29]. The current status in elite youth sports is concerning as it was reported that about every tenth young elite athlete reported burnout or depressive symptoms of potential clinical relevance [30]. Additionally, lack of time, fatigue and possible entry to the university were also identified as important factors for dropping out of the sport [31].

Therefore, knowing the practices of youth athletes and their yearly competition volume and how this changes as they get older and how they gain competitive experience is of great importance for researchers and coaches. However, there is a lack of studies that have focused on youth judokas competition volume, their structure of home and abroad competitions and competition range regarding youth judokas competing in higher age categories to gain competition experience. Therefore, this study aims to retrospectively analyse and present The present study aims to present a 5-year competition structure, volume and age competition categories (ACC) range in which youth judokas competed with 10-year dropout status.

2. Materials and Methods

This is a retrospective study that collected the competition data from the freely accessible web page of the Slovenian Judo Federation (SJF) and its history of competition backing to the year 2009 (https://judoslo.si/ranking/team/all/2009, accessed on 5 May 2021). Therefore, the year 2009 was selected as a starting year. Afterwards, the competition list was cross-referenced with the list of categorised judo athletes of the Olympic Committee of Slovenia (OCS) for 2009 (https://www.olympic.si/evidenca, accessed on 7 May 2021). The age of birth criterion for inclusion in the analysis was 1990 and younger. The year 1990 was selected as a cut of age because the athletes would have been at a maximum of 19 years old in 2009 and their main age competition category would be juniors-U21. Additionally, from older competitors, we would only be able to observe the competition structure and volume from the senior and/or U23 category. The OCS categorisation levels from which we selected the competitors were: National, Perspective, International and World class sports categorisation level.

2.1. Participants

Data from 46 judokas (Male = 24; Female = 22) were collected. The national class presented 15 judokas (Male = 11, Female = 4), the Perspective class 23 judokas (Male = 11, Female = 12), the International class 5 judokas (Male = 2, Female = 3) and the World class 3 judokas (Female = 3). The records of the Slovenian Judo cup for the years from 2009 to 2013 in all age groups they were competing were used to gather the following variables: Competitive structure and volume via a number of home, abroad and the total number of competitions; Competitive performance as final points in the Cup standing [32]. According to athletes' age in 2009, a primary age competition category was determined and afterwards, all higher age categories were checked from the records. Youth athletes were competing in age competition categories: U12, U14, U16, U18, U21, U23 and seniors. The 10-year dropout was identified by checking the database to see if an athlete competed in 2018. Additionally, the years 2019 and 2020 were also checked. That was done to be sure the athlete was not out in 2018 because of possible injury or other factors and was back competing the following year.

No ethical issues were present in analysing these data as they were obtained in secondary form and not generated by experimentation via open-access websites, and athletes' personal information was not reported [33–35]. Therefore, written informed consent and ethical institutional approval were not needed.

2.2. Statistical Analysis

Data were processed and presented using the SPSS for Windows 28.0 statistical package (SPSS, Inc., Chicago, IL, USA) and descriptive statistics were used. The Shapiro–Wilk test was used to assess the normality of the data. To determine correlations between selected variables, Spearman correlation coefficients was used. The non-parametric Kruskal–Wallis Test was performed to compare selected variables across the 4 categorisation levels with post hoc paired comparisons by a Mann–Whitney U test with Bonferroni adjustment. Additionally, the eta-squared effect size values were calculated: 0.01—small, 0.06—medium, 0.14—large [36]. Statistical significance was set at $p \leq 0.05$.

3. Results

Characteristics of the sample are presented in Table 1. The mean age of the judokas was 19.45 (±2.41) years, with 47.8% male and 52.2% female representatives. Starting age category of participants in 2009 was 5.15 (±1.55), meaning that the sample's primary age competition category was U16. The primary age competition category in the year 2009 for the National class was between U14 and U16 (5.53 ± 1.36), for the Perspective class was between U14 and U16 (5.61 ± 1.37), for the International class was U21 (3.2 ± 0.45) and for the World class was U21 (3 ± 0).

Table 1. Descriptive statistics of the sample.

Variables	Mean ± SD
Age	19.5 ± 2.4
Sex (%)	
Female	47.8
Male	52.2
Categorisation (%)	
1—World Class	6.5
2—International Class	10.9
3—Perspective Class	50.0
4—National Class	32.6
2009 Starting age category National Class	6 ± 1
2009 Starting age category Perspective Class	6 ± 1
2009 Starting age category International Class	3 ± 0.5
2009 Starting age category World Class	3 ± 0
2009 Average Competition category	5 ± 2
U21 participants in 2009 (n)	11
U18 participants in 2009 (n)	8
U14 participants in 2009 (n)	17
U12 participants in 2009 (n)	10
Total Home Competitions in 5 years	30 ± 10
Total Abroad Competitions in 5 years	10 ± 8
Home Competitions per year	6 ± 2
Abroad Competitions per year	2 ± 2
Total Competitions per Year	8 ± 2
CS—Points 2009 (n = 44)	682 ± 843
CS—Points 2010 (n = 44)	941 ± 1324
CS—Points 2011 (n = 46)	1038 ± 1286
CS—Points 2012 (n = 46)	1251 ± 1291
CS—Points 2013 (n = 46)	1753 ± 1550
Competition categories per year	3 ± 1

Legend: 7 age competition categories 7-U12, 6-U14, 5-U16, 4-U18, 3-U21, 2-U23, 1-Seniors; CS—competition success.

Figure 1 presents the distribution of abroad (A), home (H) and the total number of competitions (T) of National, Perspective, International and World class categorised judokas from years 2009 to 2013. The National Class (NC) categorised judokas competition structure was: the year 2009 (A 0 ± 1; H 6 ± 1; T 6 ± 4); the year 2010 (A 1 ± 1; H 5 ± 1; T 6 ± 4); the year 2011 (A 1 ± 2; H 5 ± 2; T 6 ± 3); the year 2012 (A 1 ± 1; H 7 ± 3; T 7 ± 3) and in the year 2013 (A 1 ± 1; H 8 ± 4; T 9 ± 4). The Perspective Class (PC) judokas competition structure was: the year 2009 (A 1 ± 1; H 6 ± 3; T 7 ± 4); the year 2010 (A 1 ± 2; H 7 ± 3; T 8 ± 4); the year 2011 (A 2 ± 2; H 7 ± 3; T 9 ± 4); the year 2012 (A 3 ± 3; H 8 ± 3; T 10 ± 4) and in the year 2013 (A 4 ± 2; H 6 ± 4; T 10 ± 5). The International Class (IC) judokas competition structure was: the year 2009 (A 3 ± 2; H 7 ± 2; T 10 ± 1); the year 2010 (A 4 ± 2; H 8 ± 2; T 12 ± 4); the year 2011 (A 3 ± 1; H 4 ± 1; T 7 ± 2); the year 2012 (A 3 ± 2; H 3 ± 1; T 6 ± 3) and in the year 2013 (A 5 ± 2; H 3 ± 2; T 9 ± 1). The World Class (WC) judokas competition structure was: the year 2009 (A 5 ± 1; H 5 ± 1; T 10 ± 1); the year 2010 (A 5 ± 4; H 3 ± 1; T 8 ± 5); the year 2011 (A 5 ± 5; H 1 ± 1; T 7 ± 6); the year 2012 (A 5 ± 1; H 3 ± 2; T 8 ± 1) and in the year 2013 (A 7 ± 2; H 2 ± 1; T 8 ± 2).

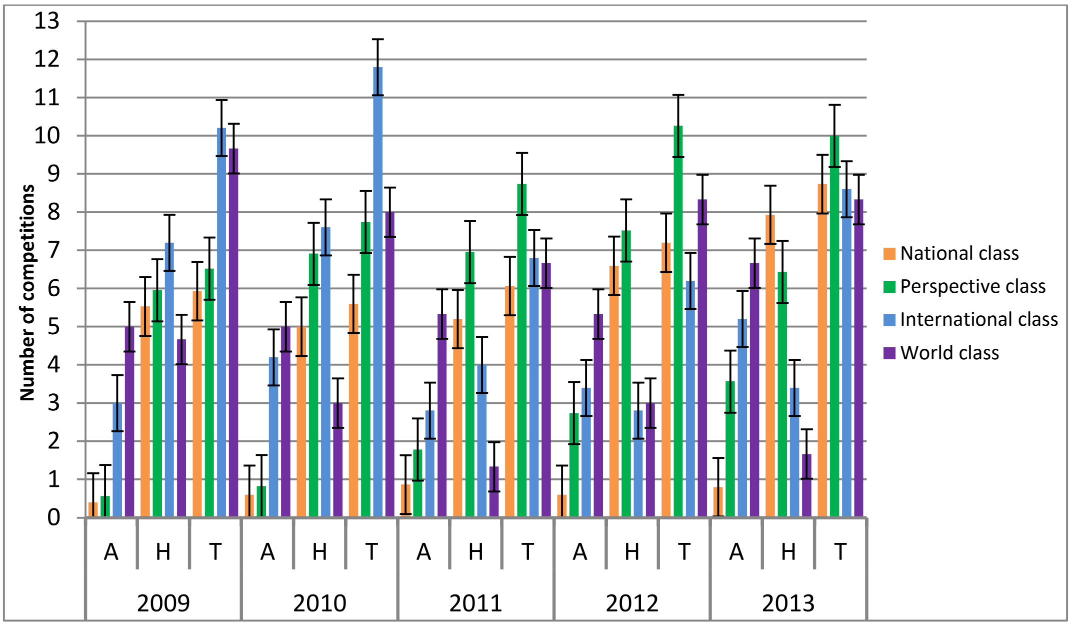

Figure 1. The distribution of abroad (A), home (H) and total number of competitions (T) of different categorisation classes from years 2009 to 2013.

Figure 2 presents the distribution of total achieved points from standings from all age competition categories from 2009 to 2013 for different categorisation classes. The NC judokas achieved the following CS: 2009/361 ± 589 points; 2010/339 ± 396 points; 2011/498 ± 549 points; 2012/529 ± 350 points and in the year 2013/819 ± 502 points. The PC judokas achieved the following CS: 2009/422 ± 528 points; 2010/547 ± 603 points; 2011/900 ± 783 points; 2012/1152 ± 772 points and in the year 2013/1447 ± 962 points. The IC judokas achieved the following CS: 2009/1396 ± 637 points; 2010/2306 ± 1000 points; 2011/1522 ± 473 points; 2012/1797 ± 1392 points and in the year 2013/3428 ± 434 points. The WC judokas achieved the following CS: 2009/2637 ± 946 points; 2010/4076 ± 2749 points; 2011/3982 ± 3456 points; 2012/4717 ± 1848 points and in the year 2013/5980 ± 551 points. In a 5-year period judokas in average accumulated: NC judokas 2545 ± 1832 points, PC judokas 4467 ± 2770 points, IC judokas 10,449 ± 1948 points and WC judokas 21,392 ± 5102 points.

Figure 3 presents how many higher age categories on top of their primary age category (AC) were judokas competing in the years 2009 to 2013. NC judokas competed: 2009/2 ± 1 AC; 2010/2 ± 1 AC; 2011/3 ± 1 AC; 2012/3 ± 1 AC and 2013/3 ± 1AC. PC judokas competed: 2009/2 ± 1 AC; 2010/2 ± 1 AC; 2011/3 ± 1 AC; 2012/3 ± 1 AC and 2013/3 ± 1AC. IC judokas competed: 2009/3 ± 1 AC; 2010/3 ± 0 AC; 2011/2 ± 1 AC; 2012/2 ± 1 AC and 2013/2 ± 1 AC. WC judokas competed: 2009/3 ± 0 AC; 2010/3 ± 1 AC; 2011/2 ± 1 AC; 2012/2 ± 0 AC and 2013/2 ± 0 AC.

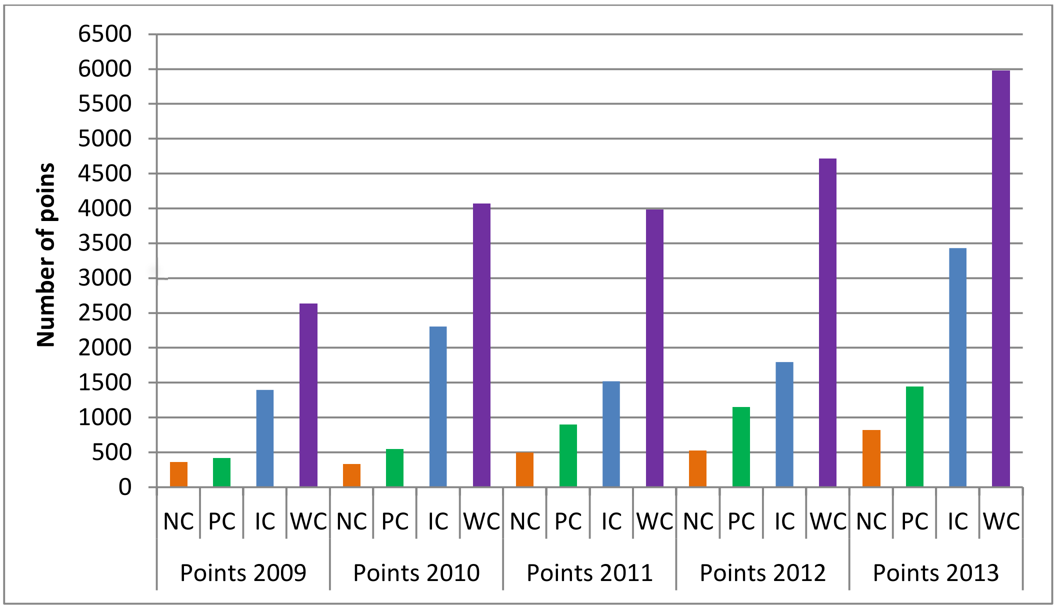

Figure 2. Competition success (CS) as total achieved points from scores and standings from all age competition categories from years 2009 to 2013 for different categorisation classes. NC—National class, PC—Perspective class, IC—International Class, WC—World class.

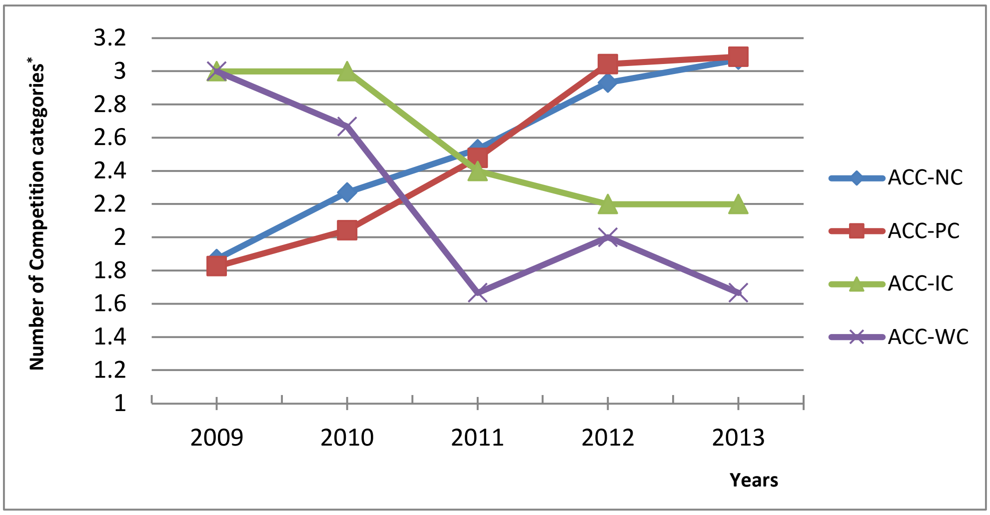

Figure 3. Display of competitions in higher age categories besides judokas primary age category. * 1 = Primary age category; 1 < number of higher age categories. ACC—average number of competitions categories; NC—National class; PC—Perspective class; IC-International Class; WC—World class.

Figure 4 presents the volume and structure of different categorisation levels. On average, NC judokas competed in 7 ± 1 competitions; PC judokas in 9 ± 1 competitions; IC judokas in 9 ± 2 competitions; WC judokas in 8 ± 0 competitions per year, with the majority of abroad competitions in an average of 5.47 competitions and an average of 2.73 home competitions per year.

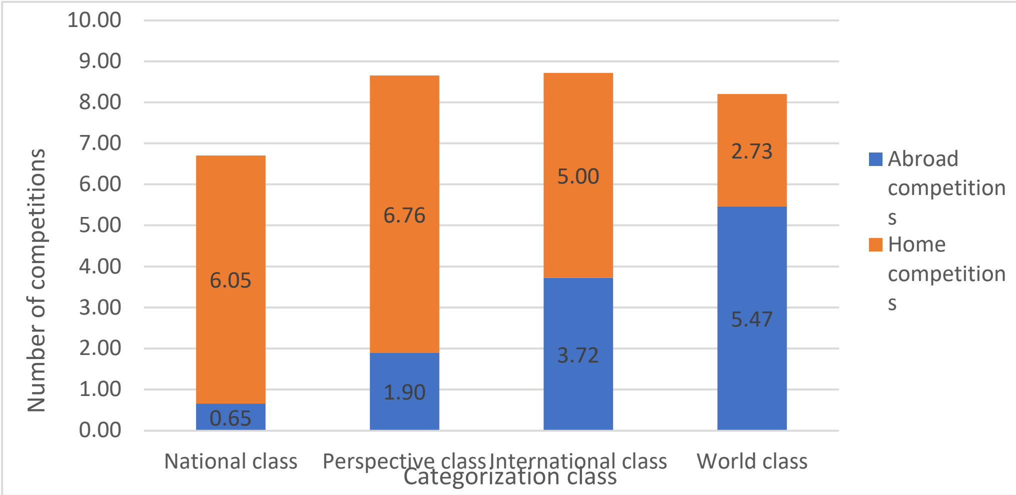

Figure 4. Volume and structure of average total competitions in 5 years per level of categorisation.

Table 2 presents the dropout of judo athletes that stopped competing after 10 years. The Average dropout of all athletes is 52%, with the smallest dropout in the World class categorisation of 33% and the highest in the National class categorisation of 60%.

Table 2. Dropout of athletes in 10 years.

VARIABLES Categorisation Level	Competing in 2018 YES	NO	Dropout %
National	6	9	60
Perspective	11	12	52
International	3	2	40
World Class	2	1	33
TOTAL	22	24	52

Spearman correlation coefficient has shown a significant positive correlation of Competition Success as a sum of all points in 5 years (CS-5Y) with the number of competition categories (CC) in the year 2009 (r = 0.646; p = 0.001); 2010 (r = 0.491; p = 0.001) and 2011 (r = 0.302; p = 0.041). A significant negative correlation was noted between CS-5Y and CC in the year 2012 (r = −0.383; p = 0.009) and year 2013 (r = −0.436; p = 0.002). A significant positive correlation was noted between: CS in the year 2013 and Competition status (dropout) in 2018 (r = 0.369; p = 0.012); Competition status (dropout) in 2018 and number of abroad competitions in 2013 (r = −0.323; p = 0.029). Categorisation level has shown a positive correlation with the number of competitions abroad (r = 0.732; p = 0.001) and the total number of all competitions (r = 0.342; p = 0.020). The age of participants showed a significant negative correlation with categorisation level (r = −0.355; p = 0.015); the number of competitions abroad (r = −0.646; p = 0.001) and a total number of all competitions (r = −0.320; p = 0.030).

Table 3 presents differences between categorisation groups for selected variables with the Kruskal–Wallis test (K-W). The K-W indicated a significant difference between groups in the number of competition categories in the years 2012 (H = 8.8, $p \leq 0.032$, ES = 0.20 [large effect]) and 2013 (H = 10, $p \leq 0.019$, ES = 0.22 [large effect]); however, the no significance was detected between groups after Bonferroni correction for multiple tests. There were also significant differences in the number of competitions between categorisation classes. K-W significant differences were also shown between Total Competitions at Home (H = 12.9, $p \leq 0.005$, ES = 0.29 [large effect]) between WC and PC (p = 0.009) and Total Competitions Abroad (H = 24.7, $p \leq 0.000$, ES = 0.55 [large effect]) between NC and PC (p = 0.023), NC and IC (p = 0.001) and NC and WC (p = 0.001).

Table 3. Difference between Categorisation groups for the number of competition categories and competition distribution in selected years with Kruskal–Wallis test and effect size.

Variable	Group	Mean	SD	Mean Rank	χ^2	Sig	ES
C CAT 2009	WC	2	1	31.50	5.73	0.126	0.133
	IC			31.70			
	PC			19.91			
	NC			21.36			
C CAT 2010	WC	2	1	26.50	5.77	0.123	0.134
	IC			31.00			
	PC			18.52			
	NC			25.35			
C CAT 2011	WC	2	1	12.50	2.47	0.482	0.055
	IC			23.60			
	PC			24.24			
	NC			24.53			
C CAT 2012	WC	3	1	9.50	8.79	0.032 [#]	0.195
	IC			12.90			
	PC			26.48			
	NC			25.27			
C CAT 2013	WC	3	1	7.17	9.99	0.019 [#]	0.222
	IC			13.00			
	PC			26.39			
	NC			25.83			
T C H	WC	30	10	2.33	12.89	0.005 [†]	0.286
	IC			14.20			
	PC			28.33			
	NC			23.43			
T C A	WC	10	8	44.67	24.67	0.000 [‡,T̄,×]	0.548
	IC			38.20			
	PC			24.98			
	NC			12.10			
T C 5Y	WC	40	12	25.33	6.67	0.083	0.148
	IC			28.80			
	PC			26.85			
	NC			16.23			

Legend: ES—effect size; C—competition; CAT—category; T—total; H—home; A—abroad; 5Y—in 5 years; NC—National class; PC—Perspective class; IC—International Class; WC—World class; [#]—no significance between groups after Bonferroni correction for multiple tests; [†]—sig. difference between WC and PC; [‡]—sig. difference between NC and PC; T̄—sig. difference between NC and IC; [×]—sig. difference between NC and WC.

Table 4 presents differences between categorisation groups for selected variables with the K-W. The K-W indicated a significant difference in CS 2009 (H = 15.1, $p \leq 0.002$, ES = 0.35 [large effect]) between NC and IC ($p = 0.039$), NC and WC ($p = 0.010$) and WC and PC ($p = 0.037$); CS 2010 (H = 15.9, $p \leq 0.002$, ES = 0.37 [large effect]) between NC and IC ($p = 0.013$), NC and WC ($p = 0.034$) and PC and IC ($p = 0.026$); CS 2011 (H = 14.7, $p \leq 0.002$, ES = 0.33 [large effect]) between NC and IC ($p = 0.021$), NC and WC ($p = 0.015$); CS 2012 (H = 16.1, $p \leq 0.001$, ES = 0.36 [large effect]) between NC and WC ($p = 0.003$); in CS 2013 (H = 21.3, $p \leq 0.001$, ES = 0.47 [large effect]) between NC and IC ($p = 0.002$), NC and WC ($p = 0.002$) and WC and PC ($p = 0.042$) and Total Competition Success in 5 Years (H = 22.2, $p \leq 0.001$, ES = 0.49 [large effect]) between NC and IC ($p = 0.001$), NC and WC ($p = 0.002$) and WC and PC ($p = 0.047$).

Table 4. Difference between Categorisation groups for Competition Success (CS) for selected years with Kruskal–Wallis test and effect size.

Variable	Group	Mean	SD	Mean Rank	χ^2	Sig	ES
CS 2009	WC IC PC NC	682	843	42.33 34.90 20.66 16.71	15.10	0.002 $^{₸,\times,\dagger}$	0.351
CS 2010	WC IC PC NC	941	1324	40.00 37.90 19.85 17.23	15.93	0.002 $^{₸,\times,\|}$	0.370
CS 2011	WC IC PC NC	1038	1286	41.33 35.90 23.59 15.67	14.68	0.002 $^{₸,\times}$	0.326
CS 2012	WC IC PC NC	1251	1291	44.00 30.50 25.41 14.13	16.13	0.001 $^{\times}$	0.358
CS 2013	WC IC PC NC	1753	1550	45.00 39.70 22.80 14.87	21.25	0.001 $^{₸,\times,\dagger}$	0.472
T CS 5Y	WC IC PC NC	5594	5413	45.00 39.90 23.11 14.33	22.18	0.001 $^{₸,\times,\dagger}$	0.493

Legend: ES—effect size; CS—competition success (points); CAT—category; T—total; 5Y—in 5 years; NC—National class; PC—Perspective class; IC—International Class; WC—World class; †—sig. difference between WC and PC; ₸—sig. difference between NC and IC; $^{\times}$—sig. difference between NC and WC; $^{\|}$—sig. difference between PC and IC.

4. Discussion

Results of the present study demonstrate that youth athletes, on average, compete in 8 ± 2 competitions per year. The structure of abroad competitions is greater for the WC, IC and PC categorised athletes, meaning NC athletes focus more on home competitions. On average, athletes compete in 6 ± 2 home and 2 ± 2 abroad competitions. Additionally, the data showed that youth athletes compete in 3 ± 1 age categories per year. This is also the first study in judo that reports youth judokas involvement in higher age categories and the so-called ''playing-up'' problematic in youth sport. Additionally, a positive association was noted between 5 Years competition success and the number of age categories in years 2009, 2010 and 2011. On the contrary, in the final observed years, 2012 and 2013, the competitions success in 5 years showed a negative association with the number of age categories. Additionally, competition success in the final observed year 2013 showed a positive association with the dropout status in 2018 and a negative one with the number of abroad competitions in 2013. In total, 52% athletes dropout was noted in a 10 year period.

From the current research, it is noted that the youngest athletes were in their primary U12 category, meaning they were under 12 years of age while competing in up to 3 higher age categories (U14, U16, U18). The recommended age limit to start training judo is 10 years [37]. The present study's sample of judokas has undoubtedly started to train judo at an earlier age, as in Slovenia, judo is implemented as the concept of judo kindergarten for children aged from 4 to 6 years. Additionally, in primary school, judo can be chosen as an optional extra-curricular activity in the context of the so-called Little school of judo. As an example, In the Little school of judo in Ljubljana, in the school year 2011/2012, there were 1054 children actively involved in the training process. In the same academic year, four judo competitions were organised for them, with a sum of 1967 children competing and an average of 491.75 (±75.28) children per competition [38].

Early specialisation in sports is generally not recommended [7] based on the potential for injury [10,11] and as well as psychological burnout against the backdrop of a host of other potential sociological issues [39]. In addition, it can lead to dropout from sports because of lack of enjoyment, perceptions of competence, social pressures, competing priorities, pressure from the coaches, not getting along with coaches, anxiety and nervousness due to excessive criticism and physical factors like maturation and injuries [2,40]. Thus, it was highlighted that youth athletes who target high performance and results must engage in deliberate practice in their specialisation years to engage in tasks that will challenge their current performance [41]. Furthermore, it was reported that the road to expertise must constantly focus on improving weaknesses and producing successful outcomes by winning competitions [42]. Data from Figures 1 and 2 show that the number of total competitions and achieved points is steadily increasing each year. This shows that categorised judokas are improving their weaknesses, challenging their performance, steadily producing better outcomes each year, and that their training programs are well planned and executed. In the current study, youth-categorised Slovenian judo athletes competed in 8 (±2) competitions per year. Additionally, differentiation between categorisation classes in the structure of home and abroad competitions was highlighted. In general, coaches need to include on average 8 competitions in their yearly periodisation plan. However, competitions abroad make periodisation even more difficult as they take more time to travel to and back. This especially implies the best judokas in the WC and IC, as it is known that travelling affects performance via numerous factors [43].

According to Barreiros and Fonseca [44] Portuguese judo athletes who started participating internationally at a senior level did not achieve the same high performance as their more successful counterparts. Present study data shows that Slovenian youth judokas start very early with the abroad competitions as some already start competing abroad in the U12 age category. Figure 1 reports that the higher the number of abroad competitions, the higher the competitive success regarding to achieved points, which gives abroad competitions an essential role in the process of gathering necessary experience for a young judoka. This is also supported by the negative correlation between the age of participants and the number of competitions abroad ($r = -0.646$; $p = 0.001$), meaning that the younger judokas competed in more international competitions. Additionally, younger judokas competed more overall ($r = -0.320$; $p = 0.030$) and they also consequently achieved higher categorisation levels ($r = -0.355$; $p = 0.015$). Abroad competitions' importance is also highlighted as the athletes with higher categorisation levels competed more abroad ($r = 0.732$; $p = 0.001$) and had in total, a higher number of overall competitions ($r = 0.342$; $p = 0.020$). Additionally, literature and elite coaches report that youth athletes competing abroad are exposed to all types of fights and that lack of abroad/international competitions may lead to insufficient competition experience, which greatly impacts performance at big competitions [45]. Therefore, the present study findings imply to an intensive early specialisation of youth judokas in Slovenia to achieve high sporting results in youth age groups.

It was discussed that if we want more competent adult athletes, they should have better training conditions and spend more time practising and competing with better teammates and opponents in their youth [46]. This could be seen and supported in Figure 3 where data present NC and PC judokas started competing in 2009 at an average of 1.85 age categories. Competing in more-higher age categories has increased steadily every year, with 2010 1.96 age category, 2011 2.50 age category, 2012 2.99 age category and 2013 3.08 age category. So athletes are gathering more experience by fighting older and possibly better opponents in a short period. This is supported by present study data as Competition Success showed a positive association with the number of competition categories in the years 2009 ($r = 0.646$; $p = 0.001$); 2010 ($r = 0.491$; $p = 0.001$) and 2011 ($r = 0.302$; $p = 0.041$). Furthermore, the following shows that this approach from coaches is an effective way of boosting youth judokas competition success. However, the practice shows that youth judo athletes compete from 2 to 4 years older opponents in 1 to 2 higher age category competitions. Data alarmingly report that some youth judokas were also competing in 4 age categories, exposing them to competing with at least 6 years older opponents from seniors. We know there can be big differences in youth cognitive, physical, emotional and motivational capabilities within 1 year from the relative age effect [47], so we can imagine the differences when youth athletes compete with 2 to 4 years older opponents. In judo relative age effect was clearly identified in elite cadet and junior judo athletes [48]. When adolescent athletes are introduced to competitive events of the senior level, the stressors they encounter and how elite youth athletes cope with them should be understood and managed [49,50]. In the sports science literature, this phenomenon is known as "playing-up" when athletes train and compete with older peers [51]. To the best of our knowledge, this is the first study that would identify and put in context the so-called "playing-up" problematic/topic in judo and could also be terminologically adapted to be more judo-specific to "competing-up." This topic has been briefly addressed in recent years in youth football [52,53] where playing-up has shown positive implications for performance and developmental outcomes in youth football. These findings are in line with our current data in judo. However, the football studies did not explore its association with the possible dropout and performance levels in later years. Nonetheless, the studies have highlighted some important findings where youth athletes playing-up struggled with the intensity of training and competitions and to fit in socially with older peers [53]. However, it was also recomemnded that those younger atheletes had better chances to integrate socially within older competitors when teammates introduced themselves and acively included youth copetitors in sport and their social activities [53]. In practical terms, that would mean that both the competing-up athlete and the older group competitors must be prepared to join or have youth athletes join-in their group. Therefore, coaches play an essential part in preparing both groups and laying the foundations for a smooth transition.

When youth athletes are exposed to numerous hours of deliberate practice without understanding the training context and having a precise aim will not lead to the desired effects in training or competitions [54]. However, the maturation effect on growth and physical performance in young judokas has been highlighted as it seems more relevant than the age effect [55,56]. Additionally, it has been shown that maturation attenuated the age effect and significantly affected upper body and handgrip strength in youth judokas [57]. This phenomenon could explain why we have so many youth judo athletes competing in higher age categories and being successful in them.

Data present that coaches are trying to gain extra experience with their athletes by competing in higher age categories and accumulating an extensive competitive experience with older contestants as fast as possible. Some of them are too concentrated on quick results, which is often associated with their job requirements and elite youth result, which brings possible extra funding to the club or qualifying for an Olympic scholarship program. However, there are no shortcuts to physiological, psychological, technical-tactical and social components of youth athlete development. The coaches should not be short-sighted and focused on the early elite result. Some researchers state that you have to be among the best youth athletes if you want to be a top judoka later in the senior level [44]. However, on the contrary, only 7% of the male and 5% of the female judokas had maintained their competitive levels [17]. Similar findings have been found in Slovenia, where a significant dropout rate was found in athletes achieving top results in junior categories after transitioning to the senior category [58]. The same research reports that 49% of top athletes achieving excellent results in seniors had not been in the top earlier in the junior age category. Moreover, it was reported that 30% of athletes that had their best result at senior-level competitions failed to obtain the categorisation of perspective class when they competed in the junior category [58].

Therefore, successful competitive performance in early judo competition is not associated with success later in adulthood. We can observe that among the Athens 2004

Olympians, 56% made their first international appearance in the senior age category at the age 22.0 (±3.1 years) [59]. Additionally, the present study data showed that competitive success in 5 years was negatively associated with the number of competition categories in the year 2012 ($r = -0.383$; $p = 0.009$) and year 2013 ($r = -.436$; $p = 0.002$). This could imply that the early specialisation and accumulation of competitive performance via competitions in higher age categories is successful in a short period of time. Afterwards, it can have a negative impact on youth athelets and their competitor status. Athletes who were not performing at the highest level and had a high competitive success were also associated with a higher drop out in the year 2018 ($r = 0.369$; $p = 0.012$) and a lower number of abroad competitions ($r = -0.323$; $p = 0.029$). Nonetheless, coaches of elite youth judo athletes should try to focus on competitions abroad and quality training with older age groups to increase the quality and lower the possibility of athletes' burnout and injuries. Additionally, specialisation strategies from Japan could be adopted where specialisation in female judokas starts at an average age of 14.2 years, while Japanese male athletes start specialised trainings at an average age of 16.3 years [11].

From the competitive volume and linear increase in competitive success presented in Figure 2, it can be summarised that the selection process and the training programs in younger age categories are well planned and executed for a good youth result. It was also presented that the Judo Federation of Slovenia had a positive trend and systematically achieved superior results over 2008–2013, both in junior and senior competitions [58]. Nonetheless, the current study showed that this came at a hefty price, with a 52% dropout of youth judokas over the next 10 years. The current analysis also showed that a wider view of the success analysis in sports, especially youth sports, needs to be considered. In this way, the initial research [58], combined with this analysis, could highlight the success and reveal the dropout problem more efficiently. Possibly, this approach could be an organisational effect of smaller countries like Slovenia (with a population of 2.106.215 [60]), which do not have a large pool of competitors and need to rely on a small number of highly talented individuals and hope they do not get injured or drop out for any other reason. This phenomenon of smaller countries' organisations and success in judo needs further research to give us greater insight. The home and abroad competitions structure highlights the importance of abroad competitions in developing youth judo athletes. Therefore, coaches should plan that abroad competitions are attended at an early age in order to achieve elite youth results and have a good foundation for the senior age category. Research has shown [44] that male judokas participating in major events started competing sooner at an international level ($U = 0.266$, $p = 0.007$). Nevertheless, it is recommended that competitions should be implemented inside the primary age category or no more than one age category higher, as this would ensure a systematic development and progressive load of a young body. Judo has been identified as a sport of slow technical maturation and it requires adaptation before its mastery in competition [3]. Therefore, coaches should include more competitions abroad in competitors' primary age groups in their yearly periodisation. Additionally, elite judo coaches highlighted and recommended that competition in training should be widely implemented because it helps in the development of the motor-perceptual, conditional, technical, tactical and psychological potential of judokas [61]. Additionally, training sessions with higher age groups would be a good solution for gathering additional experience in a more controlled environment. Peak performance can also be achieved by exploring various sports in childhood and combining 4000 to 6000 h of deliberate practice in a chosen sport [25]. Early diversification in sports was suggested [62], as it might stimulate physiological and cognitive adaptations, which lay the groundwork for specialised and cognitive capacities necessary for later expertise [63]. Furthermore, fewer hours of training and high health satisfaction characterise low-risk groups for dropping out from sports for elite youth athletes [29], which would, in short translate as "train smarter, not harder".

The current study needs to acknowledge some limitations. The main one is that there was no possibility to identify possible injuries and their impact on competing in higher age categories. Additionally, the reason for the athletes' dropout is unknown. Therefore, further mixed-methods studies are recommended to get the dropout athletes' feedback on how competing in multiple higher age categories impacted them and what later led to their drop out from judo and competitions. Additionally, coaches' feedback and opinion on competing in higher age categories as a tool to fast-track combat experience should be further researched. Finally, the starting age when the athletes started with judo and later with more intensive training was not known as this would give us a better understanding of the early specialisation.

5. Conclusions

Youth judokas are regularly competing in domestic or international competitions. Throughout the years, they gain experience in different patterns. There is a tendency to accumulate youth judoka fighting experience as much as possible and as fast as possible. This is done by competing in more-higher age categories, resulting in youth judokas competing with at least 2 to 6 or more years' older opponents in at least 1 to 3 higher age categories. Additionally, competing abroad significantly affects fighting experience and, consequently, greater competitive success. This approach was shown to be successful in creating youth medalists. However, just as a short-term solution/plan, if implemented for too long, it starts to negatively affect competition success and increases youth athletes' dropout. Therefore, coaches' main focus should be to prepare youth judokas on the senior level through the system of national and international competitions within their age category. They should include more competitions abroad in competitors' primary age group, while training sessions could be done with higher age groups which would allow for gathering additional experience in a more controlled environment in their yearly periodisation. This would ensure adequate muscle-skeletal development of youth judo competitors and steady progress and development of required technical-tactical skills for competing at the senior level.

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Informed Consent Statement: Informed consent was waived because the data were analysed using Public domain audiovisual material, athletes' personal information was not reported, and no ethical issues were present. Therefore, written informed consent was not needed.

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the author upon reasonable request to any qualified researcher.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Allender, S.; Cowburn, G.; Foster, C. Understanding Participation in Sport and Physical Activity among Children and Adults: A Review of Qualitative Studies. *Health Educ. Res.* **2006**, *21*, 826–835. [CrossRef] [PubMed]
2. Crane, J.; Temple, V. A Systematic Review of Dropout from Organized Sport among Children and Youth. *Eur. Phys. Educ. Rev.* **2015**, *21*, 114–131. [CrossRef]
3. Calmet, M.; Ahmaidi, S. Survey of Advantages Obtained by Judoka in Competition by Level of Practice. *Percept. Mot. Skills* **2004**, *99*, 284–290. [CrossRef] [PubMed]
4. Inbar, O.; Bar-Or, O. Anaerobic Characteristics in Male Children and Adolescents. *Med. Sci. Sport. Exerc.* **1986**, *18*, 264–269. [CrossRef] [PubMed]
5. Sale, D.G. Strength Training in Children. In *Perspectives in Exercise Science and Sports Medicine. Vol. 2. Youth, Exercise and Sport*; Gisolfi, C., Lamb, D., Eds.; Benchmark Press: Indianapolis, IN, USA, 1989; pp. 165–222.
6. Morrison, A.B.; Schöffl, V.R. Physiological Responses to Rock Climbing in Young Climbers. *Br. J. Sports Med.* **2007**, *41*, 852–861. [CrossRef] [PubMed]
7. Anderson, B.J.; Griesemer, B.A.; Johnson, M.D.; Martin, T.J.; McLain, L.C.; Rowl, T.W.; Small, E. Intensive Training and Sports Specialization in Young Athletes. *Pediatrics* **2000**, *106*, 154–157. [CrossRef]

8. Washington, R.L.; Bernhardt, D.T.; Gomez, J.; Johnson, M.D.; Martin, T.J.; Rowland, T.W.; Small, E.; LeBlanc, C.; Krein, C.; Malina, R.; et al. Organized Sports for Children and Preadolescents. *Pediatrics* **2001**, *107*, 1459–1462. [CrossRef]
9. David, P. *Human Rights in Youth Sport A Critical Review of Children's Rights in Competitive Sport*; Routledge: London, UK, 2004; ISBN 0415305594/9780415305594.
10. Brenner, J.S. Overuse Injuries, Overtraining, and Burnout in Child and Adolescent Athletes. *Pediatrics* **2007**, *119*, 1242–1245. [CrossRef]
11. DiFiori, J.P. Evaluation of Overuse Injuries in Children and Adolescents. *Curr. Sports Med. Rep.* **2010**, *9*, 372–378. [CrossRef]
12. LaPrade, R.F.; Agel, J.; Baker, J.; Brenner, J.S.; Cordasco, F.A.; Côté, J.; Engebretsen, L.; Feeley, B.T.; Gould, D.; Hainline, B.; et al. AOSSM Early Sport Specialization Consensus Statement. *Orthop. J. Sport. Med.* **2016**, *4*, 2325967116644241. [CrossRef]
13. Weber, R. Protection of Children in Competitive Sport. *Int. Rev. Sociol. Sport* **2009**, *44*, 55–69. [CrossRef]
14. Callender, S.S. The Early Specialization of Youth in Sports. *Athl. Train. Sport. Health Care* **2010**, *2*, 255–257. [CrossRef]
15. Narazaki, N.; Watanabe, R. Differences of Onset and Duration of Judo Specialization between Male and Female Olympic Judo Athletes. *Assoc. Sci. Stud. Judo Kodokan* **2021**, *18*, 55–65.
16. Judge, L.W.; Petersen, J.; Lydum, M. The Best Kept Secret in Sports: The 2010 Youth Olympic Games. *Int. Rev. Sociol. Sport* **2009**, *44*, 173–191. [CrossRef]
17. Julio, U.F.; Takito, M.Y.; Mazzei, L.; Miarka, B.; Sterkowicz, S.; Franchini, E.; Skills, M.; Julio, U.F.; Takito, M.Y.; Mazzei, L.; et al. Tracking 10-Year Competitive Winning Performance of Judo Athletes Across Age Groups. *Percept. Mot. Skills* **2011**, *113*, 139–149. [CrossRef]
18. Kuvačić, G.; Krstulović, S.; Đapić Caput, P. Factors Determining Success in Youth Judokas. *J. Hum. Kinet.* **2017**, *56*, 207–217. [CrossRef]
19. Engwerda, I.M.; Lidor, R.; Elferink-Gemser, M.T. Performance Characteristics of Top-Level Youth Judokas in Light- and Heavy-Weight Categories. *Int. J. Sport. Sci. Coach.* **2020**, *15*, 783–792. [CrossRef]
20. Prieske, O.; Chaabene, H.; Gäbler, M.; Herz, M.; Helm, N.; Markov, A.; Granacher, U. Seasonal Changes in Anthropometry, Body Composition, and Physical Fitness and the Relationships with Sporting Success in Young Sub-Elite Judo Athletes: An Exploratory Study. *Int. J. Environ. Res. Public Health* **2020**, *17*, 7169. [CrossRef]
21. Miarka, B.; Cury, R.; Julianetti, R.; Battazza, R.; Julio, U.F.; Calmet, M.; Franchini, E. A Comparison of Time-Motion and Technical-Tactical Variables between Age Groups of Female Judo Matches. *J. Sport. Sci.* **2014**, *32*, 1529–1538. [CrossRef]
22. Athayde, M.S.d.S.; Kons, R.L.; Fukuda, D.H.; Detanico, D. Body Size Measurements and Physical Performance of Youth Female Judo Athletes with Differing Menarcheal Status. *Int. J. Environ. Res. Public Health* **2021**, *18*, 12829. [CrossRef]
23. Ericsson, K.A.; Krampe, R.T.; Tesch-Römer, C. The Role of Deliberate Practice in the Acquisition of Expert Performance. *Psychol. Rev.* **1993**, *100*, 363–406. [CrossRef]
24. North, J. Project: An Overview and Critique of the '10,000 Hours Rule' and 'Theory of Deliberate Practise'. In *Project Report*. Leeds Metropolitan University: Leeds, UK, 2012; pp. 1–34.
25. Côté, J.; Baker, J.; Abernethy, B. Practice and Play in the Development of Sport Expertise. In *Handbook of Sport Psychology*; Tenenbaum, G., Eklund, R.C., Eds.; Wiley: Hoboken, NJ, USA, 2012; pp. 184–202. ISBN 9780471738114.
26. JudoTraining Previous Results and Age of Medalists at Tokyo 2021. Available online: https://judotraining.info/previous-results-and-age-of-medalists-at-tokyo-2021/ (accessed on 28 August 2022).
27. Agostinho, M.F. Tokyo 2020—Resultados Prévios e Idade Dos(as) Medalhistas. Available online: http://judodebase.blogspot.com/2021/09/tokyo-2020-resultados-previos-e-idade.html (accessed on 28 August 2022).
28. Chobotko, M.; Chobotko, I.; Lastovkin, V.; Schastlyvets, V. Evaluation of the Performances of Judoists (Cadets) of One Weight Category at Competitions of Different Levels for Five Years. *Grail Sci.* **2022**, *12–13*, 670–675. [CrossRef]
29. Granz, H.L.; Schnell, A.; Mayer, J.; Thiel, A. Risk Profiles for Athlete Burnout in Adolescent Elite Athletes: A Classification Analysis. *Psychol. Sport Exerc.* **2019**, *41*, 130–141. [CrossRef]
30. Gerber, M.; Best, S.; Meerstetter, F.; Walter, M.; Ludyga, S.; Brand, S.; Bianchi, R.; Madigan, D.J.; Isoard-Gautheur, S.; Gustafsson, H. Effects of Stress and Mental Toughness on Burnout and Depressive Symptoms: A Prospective Study with Young Elite Athletes. *J. Sci. Med. Sport* **2018**, *21*, 1200–1205. [CrossRef] [PubMed]
31. Sáez, I.; Solabarrieta, J.; Rubio, I. Reasons for Sports-Based Physical Activity Dropouts in University Students. *Int. J. Environ. Res. Public Health* **2021**, *18*, 5721. [CrossRef]
32. Šimenko, J.; Hadžič, V.; Had, V. Bilateral Throw Execution in Young Judokas for a Maximum All Year Round Result. *Int. J. Sports Physiol. Perform.* **2021**, *17*, 720–725. [CrossRef]
33. Calmet, M.; Pierantozzi, E.; Sterkowicz, S.; Challis, B.; Franchini, E. Rule Change and Olympic Judo Scores, Penalties and Match Duration. *Int. J. Perform. Anal. Sport* **2017**, *17*, 458–465. [CrossRef]
34. Calmet, M.; Pierantozzi, E.; Sterkowicz, S.; Takito, M.Y.; Franchini, E. Judo Rules: Searching for a Wind of Changes. *Int. J. Perform. Anal. Sport* **2017**, *17*, 863–871. [CrossRef]
35. Kajmovic, H.; Karpljuk, D.; Kapo, S.; Simenko, J. Comparison of Individual Penalties According to Gender and Weight Categories of Elite Judo Athletes from Four World Championships. *Biology* **2022**, *11*, 1284. [CrossRef]
36. Adam, M.; Sterkowicz-Przybycień, K. The Efficiency of Tactical and Technical Actions of the National Teams of Japan and Russia at the World Championships in Judo (2013, 2014 and 2015). *Biomed. Hum. Kinet.* **2018**, *10*, 45–52. [CrossRef]

37. Kostka, T.; Furgal, W.; Gawroński, W.; Bugajski, A.; Czamara, A.; Klukowski, K.; Krysztofiak, H.; Lewicki, R.; Szyguła, Z.; Tomaszewski, W.; et al. Recommendations of the Polish Society of Sports Medicine on Age Criteria While Qualifying Children and Youth for Participation in Various Sports. *Br. J. Sport. Med.* **2012**, *46*, 159–162. [CrossRef]
38. Šimenko, J. Some Aspects and Advantages of Judo Training for Children and Adolescents. *Sport Rev. Za Teor. Prakt. Vprasanja Sport.* **2013**, *61*, 1–10.
39. Malina, R.M. Early Sport Specialization. *Curr. Sports Med. Rep.* **2010**, *9*, 364–371. [CrossRef]
40. Witt, P.A. Why Children/Youth Drop out of Sports. *J. Park Recreat. Admi.* **2018**, *36*, 191–199. [CrossRef]
41. Gonçalves, C.E.; Carvalho, H.M.; Diogo, F.L. A Multilevel Approach to the Path to Expertise in Three Different Competitive Settings. *J. Sports Sci. Med.* **2014**, *13*, 166–171.
42. Chi, M.T.H. Two Approaches to the Study of Experts' Characteristics. In *The Cambridge Handbook of Expertise and Expert Performance*; Cambridge University Press: Cambridge, UK, 2006; pp. 21–30.
43. Janse van Rensburg, D.C.; Jansen van Rensburg, A.; Fowler, P.M.; Bender, A.M.; Stevens, D.; Sullivan, K.O.; Fullagar, H.H.K.; Alonso, J.-M.; Biggins, M.; Claassen-Smithers, A.; et al. Managing Travel Fatigue and Jet Lag in Athletes: A Review and Consensus Statement. *Sport. Med.* **2021**, *51*, 2029–2050. [CrossRef]
44. Barreiros, A.N.; Fonseca, A.M. A Retrospective Analysis of Portuguese Elite Athletes' Involvement in International Competitions. *Int. J. Sport. Sci. Coach.* **2012**, *7*, 593–600. [CrossRef]
45. Mazzei, L.C.; De Bosscher, V.; Ferreira Julio, U.; Lopes Cury, R.; Silveira Böhme, M.T. High-Performance Judo: Identification of the Organisational Factors Influencing International Sporting Success. *Manag. Sport Leis.* **2021**, *26*, 541–558. [CrossRef]
46. Gonçalves, C.E.B.; Rama, L.M.L.; Figueiredo, A.B. Talent Identification and Specialization in Sport: An Overview of Some Unanswered Questions. *Int. J. Sport. Physiol. Perform.* **2012**, *7*, 390–393. [CrossRef]
47. Musch, J.; Grondin, S. Unequal Competition as an Impediment to Personal Development: A Review of the Relative Age Effect in Sport. *Dev. Rev.* **2001**, *21*, 147–167. [CrossRef]
48. Fukuda, D.H. Analysis of the Relative Age Effect in Elite Youth Judo Athletes. *Int. J. Sport. Physiol. Perform.* **2015**, *10*, 1048–1051. [CrossRef] [PubMed]
49. Kristiansen, E.; Roberts, G.C. Young Elite Athletes and Social Support: Coping with Competitive and Organizational Stress in "Olympic" Competition. *Scand. J. Med. Sci. Sport.* **2010**, *20*, 686–695. [CrossRef] [PubMed]
50. Crocker, P.R.E.; Crocker, P.R.E.; Hoar, S.D.; McDonough, M.H.; Kowalski, K.C.; Niefer, C.B. Emotional Experience in Youth Sport. In *Developmental Sport and Exercise Psychology: A Lifespan Perspective*; Weiss, M.R., Ed.; Fitness Information Technology: Morgantown, WV, USA, 2004; pp. 197–221. ISBN 1-885693-36-2.
51. Malina, R.M.; Cumming, S.P.; Rogol, A.D.; Coelho-e-Silva, M.J.; Figueiredo, A.J.; Konarski, J.M.; Kozieł, S.M. Bio-Banding in Youth Sports: Background, Concept, and Application. *Sport. Med.* **2019**, *49*, 1671–1685. [CrossRef] [PubMed]
52. Kelly, A.; Wilson, M.R.; Jackson, D.T.; Goldman, D.E.; Turnnidge, J.; Côté, J.; Williams, C.A. A Multidisciplinary Investigation into "Playing-up" in Academy Football According to Age Phase. *J. Sport. Sci.* **2021**, *39*, 854–864. [CrossRef] [PubMed]
53. Goldman, D.E.; Turnnidge, J.; Kelly, A.L.; DeVos, J.; Côté, J. Athlete Perceptions of Playing-up in Youth Soccer. *J. Appl. Sport Psychol.* **2022**, *34*, 862–885. [CrossRef]
54. Brylinsky, J. Practice Makes Perfect and Other Curricular Myths in the Sport Specialization Debate. *J. Phys. Educ. Recreat. Danc.* **2010**, *81*, 22–25. [CrossRef]
55. Giudicelli, B.B.; de Oliveira Luz, L.G.; Santos, D.H.B.; Sarmento, H.; Massart, A.G.M.; da Cunha Júnior, A.T.; Field, A.; Figueiredo, A.J.B. Age and Maturity Effects on Morphological and Physical Performance Measures of Adolescent Judo Athletes. *J. Hum. Kinet.* **2021**, *80*, 139–151. [CrossRef]
56. Giudicelli, B.B.; Luz, L.G.O.O.; Sogut, M.; Massart, A.G.; Júnior, A.C.; Figueiredo, A.J. Bio-Banding in Judo: The Mediation Role of Anthropometric Variables on the Maturation Effect. *Int. J. Environ. Res. Public Health* **2020**, *17*, 361. [CrossRef]
57. Giudicelli, B.B.; Luz, L.G.O.; Sogut, M.; Sarmento, H.; Massart, A.G.; Júnior, A.C.; Field, A.; Figueiredo, A.J. Chronological Age, Somatic Maturation and Anthropometric Measures: Association with Physical Performance of Young Male Judo Athletes. *Int. J. Environ. Res. Public Health* **2021**, *18*, 6410. [CrossRef]
58. Samardžija Pavletič, M.; Retar, I.; Samardžija Pavletič, P.; Kolar, E. Comparison of Success of Slovenian Top Level Athletes at Senior and Junior Competition Level. *Ann. Kinesiol.* **2014**, *5*, 23–40.
59. Güllich, A. *Training, Förderung, Erfolg: Steuerungsannahmen Und Empirische Befunde*; Universität des Saarlandes: Saarbrücken, Germany, 2007.
60. Slovenia, S.O. of R. of Population. Available online: https://www.stat.si/statweb (accessed on 25 October 2022).
61. Santos, L.; Fernández-Río, J.; Almansba, R.; Sterkowicz, S.; Callan, M. Perceptions of Top-Level Judo Coaches on Training and Performance. *Int. J. Sport. Sci. Coach.* **2015**, *10*, 145–158. [CrossRef]
62. Rugg, C.; Kadoor, A.; Feeley, B.T.; Pandya, N.K. The Effects of Playing Multiple High School Sports on National Basketball Association Players' Propensity for Injury and Athletic Performance. *Am. J. Sport. Med.* **2018**, *46*, 402–408. [CrossRef]
63. Baker, J.; Cote, J. Shifting Training Requirements during Athlete Development: The Relationship among Deliberate Practice, Deliberate Play and Other Sport Involvement in the Acquisition of Sport Expertise. In *Essential Processes for Attaining Peak Performance*; Meyer & Meyer Sport: Aachen, Germany, 2006; pp. 93–110. ISBN 1841261874.

children

Review

Ultrasound Imaging-Based Methods for Assessing Biological Maturity during Adolescence and Possible Application in Youth Sport: A Scoping Review

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Abstract: Bone maturity is an indicator for estimating the biological maturity of an individual. During adolescence, individuals show heterogeneous growth rates, and thus, differences in biological maturity should be considered in talent identification and development. Radiography of the left hand and wrist is considered the gold standard of biological maturity estimation. The use of ultrasound imaging (US) may be advantageous; however, its validity and reliability are under discussion. The aims of this scoping review are (1) to summarize the different methods for estimating biological maturity by US imaging in adolescents, (2) to obtain an overview of the level of validity and reliability of the methods, and (3) to point out the practicability and usefulness of ultrasound imaging in the field of youth sports. The search included articles published up to November 2022. The inclusion criteria stipulated that participants had to fall within the age range of 8 to 23 years and be free of bone disease and fractures in the region of interest. Nine body regions were investigated, while the hand and wrist were most commonly analyzed. US assessment methods were usually based on the estimation of a bone maturity stage, rather than a decimal bone age. Furthermore, 70% of the assessments were evaluated as applicable, 10% expressed restraint about implementation, and 20% were evaluated as not applicable. When tested, inter- and intra-rater reliability was high to excellent. Despite the absence of ionization, low costs, fast assessment, and accessibility, none of the US assessments could be referred to as a gold standard. If further development succeeds, its application has the potential to incorporate biological age into selection processes. This would allow for more equal opportunities in talent selection and thus make talent development fairer and more efficient.

Keywords: ultrasonography; bone age; biological maturity; youth sport; talent development

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1. Introduction

Bone maturity is an indicator that estimates the biological maturity of an individual [1,2] and may differ from chronological age, which is calculated using the current date minus the date of birth. During childhood, but more particularly during puberty, individuals may show very heterogeneous growth rates, and the physiological and psychological changes that occur during the transition from adolescence to adulthood are rapid and pronounced [3,4]. Pediatricians and researchers use bone maturity (maturity stages) or bone age (decimal bone age) estimation to evaluate the growth process for various purposes, for example, defining when treatment can take place, or to estimate age for legal purposes [2,5]. In sports, biological maturity affects physical and cognitive skills. There is evidence that talent selection processes are distorted by differences in biological age [6,7]. Especially in sports where physical components influence performance outcomes, differences in biological maturity must be considered in talent development and identification processes to ensure fairness and equality of chances [7–10]. In addition, cut-off dates based on chronological age indicate whether an athlete is eligible to compete or enter a category. In the absence of birth certificates or to avoid abuse of the system, bone age estimation can serve as an assessment tool [11,12]. Furthermore, estimates of biological maturity, e.g., age at peak height velocity and predicted adult height, can be estimated, with a certain margin of error, using an equation based on weight, as well as sitting and standing height [13–16]. Using this information, it is possible to define whether an athlete is an early, normal, or late developer, compared to the average of a specific population. This makes it possible to assess whether certain sports favor the selection and support of athletes at a particular stage of development, or to put systems in place that promote equality and fairness [17].

Doyle et al.'s [18] standards and guidelines provide a broad overview of the existing methods to estimate bone maturity. Currently, the assessment of bone age by the Greulich and Pyle or Tanner and Whitehouse methods using radiography of the left hand and wrist, i.e., the estimation of decimal bone age, are considered the gold standard of imaging techniques. However, even though the radiation dose received during an X-ray is minimal [19], researchers and physicians tend to favor other non-ionizing techniques to avoid the ethical problem posed by radiation. In addition, in many western countries (e.g., Germany and Switzerland) it is a legal requirement to select the method with the lowest radiation intensity from several available methods (Strahlenschutzgesetz (StSG, SR 814.50)). Despite being a non-ionizing technique with validated accuracy, MRI is expensive, time consuming, and less accessible [20]. Therefore, the field of auxology is currently studying sonography, focusing on two different techniques. Ultrasound imaging of bone structure relies on the production of images through high multi-frequency linear transducers that allow one to visualize the composition of growth areas, e.g., the presence of cartilage or ossification centers [21,22]. Imaging of bone anatomy allows the direct visualization of the bony epiphyses and, furthermore, the monitoring of the closing of the growth plate, a crucial diagnostic element for bone maturity estimation. Quantitative ultrasound is another technique by which the properties of bone tissue are analyzed quantitively, for example, by the speed of sound or distance attenuation factor [23,24]. These two sonographic procedures rely on gold standard methods, on existing staging systems, or have been newly developed [25,26]. From a practical, ethical, and economic point of view, ultrasonography seems to present many advantages in various fields of application. However, to date, no ultrasound method has been accepted as the gold standard yet and its clinical utility is still being discussed [20]. Some studies have developed reference values for cartilage thickness in healthy children, mainly to detect juvenile idiopathic arthritis [27–32]. However, these measurements were not directly applicable to bone maturity estimation at the publication time.

From the authors' perspective, there exist several US imaging assessment methods applied for different purposes and in different domains. The age range covered by these assessments differs from one study to the other (birth to adulthood [22]). A common method does not seem to exist, and the need for bone maturity estimation through US in youth sports is still present. As literature that summarizes methods for estimating biological maturity based on ultrasound imaging does not exist to date and there is a need for reasonable, cheap, and practicable methods, the aims of this scoping review were (1) to summarize the existing methods for estimating biological maturity through bone maturity using ultrasound imaging in adolescents, (2) to obtain an overview of the level of validity and reliability of the methods used, and (3) to point out the practicability and usefulness of ultrasound imaging in the field of youth sports.

2. Methodology

The literature search for this scoping review relied on the methodological framework of Arksey and O'Malley [33]. The established criteria and six specific steps are (i) identifying the research question, (ii) identifying relevant studies, (iii) study selection, (iv) charting the data, (v) collating, summarizing the data and reporting the results, and optionally (vi) consultation exercise.

2.1. Identifying the Research Question

The main research question was "What are ultrasound imaging methods used to estimate bone maturity of adolescents, and more specifically, what body parts are investigated and how are the results analyzed?" Leaving the quality of these studies aside, the second and third questions were: "How valid and reliable are the ultrasound imaging methods?" and "Are there any possibilities to implement these/ultrasound imaging methods in the field of sports?" A wide approach to the context, concept, and population was maintained in order to cover as many articles as possible.

2.2. Identifying Relevant Studies and Study Selection

The electronic search was conducted in the PubMed, Mendeley, and Google Scholar databases. After a preliminary search with the search terms ultrasonography, bone age, and puberty, the retrieved studies were analyzed through the Yale MeSH Analyzer to detect appropriate search terms. The following keywords combination was applied in the advanced search function of the electronic databases, using Boolean operators "OR" and "AND": ((ultraso* OR sonography) AND ((bone OR biological) AND (age OR maturity)) AND (adolesc* OR youth OR puberty)). The search included articles published up to November 2022 and was conducted by two authors (ER and MR). According to the PICOS framework, the first inclusion criterion stipulated that participants had to fall within the age range of 8 to 23 years, which represents the minimal age for the normal onset of puberty [34] and the latest age for epiphysis maturation that occurs at the clavicula [1,35]. The second inclusion criterion was that the participants had to be free of bone fractures or other diseases in the region of interest. Only studies whose objectives were to measure bone maturity using ultrasound were included. Studies involving subjects with diseases affecting skeletal growth were excluded. Quantitative ultrasound was not included. For all selected studies, the titles and abstracts were reviewed first. Secondly, full texts of the potential studies for inclusion were screened. Articles in English, German, French, and Italian were included. Once this initial search was complete, the reference lists were examined to find any new studies that met the inclusion criteria. Finally, the publications of 17 journals dedicated to ultrasonography were examined.

2.3. Data Charting

To sort and furthermore analyze the extracted material, a data-charting form was developed using Microsoft Excel. A reviewer (NH) charted the data as follows: Study, year of publication, country, intervention and aim(s), population, domain, methods, examiners, readers and duration of the assessment, and results and conclusion. The articles were separated into two groups depending on whether the ultrasound technique was compared to another accepted technique and method (labelled "validity group", VG) or whether the ultrasound method itself was tested for its reliability (labelled "reliability group", RG). Further classification was constructed on the comparison techniques and methods used and the body sites examined. The complete charting form was reexamined by a second author (ER) to ensure the correctness and completeness of the extracted data. The decision for inclusion or exclusion of the studies was then validated by a third author (MR).

3. Results

3.1. Collating, Summarizing the Data and Reporting the Results

Our first research and analysis process retrieved 53 potentially relevant articles after applying inclusion criteria to the titles and abstracts. These first selected full-text articles were then reviewed. We subsequently excluded 23 articles due to low age span or the use of quantitative ultrasound. One study was excluded as a Master's thesis containing inappropriate statistics and therefore no reliable results. Two articles were identified as identical, despite different named authors [36,37]. They were included as two independent articles in the analysis, as they were published separately. Finally, 30 articles were included (Figure 1). The data extraction tables (Tables 1 and 2) report the main content of these articles for the VG and RG, respectively. For the VG, 14 studies were included, seven of which also measured the inter- and intra-rater reliability or agreement for their measures. The RG consisted of 16 studies.

Figure 1. Article selection process.

Table 1. Articles retained for the validity group ($n = 14$).

Comparator	US Body Region(s)		Study	Year	Country	Intervention and Aim(s)	Population	Domain	Methods	Examiners, Readers and Duration	Results and Conclusion
X-ray Iliac bone and left wrist	Iliac bone and left wrist	1	Wagner et al. [38]	1995	Germany	Sonographic and radiographic examination of the iliac bone apophysis (Risser's sign) and the left distal radial epiphysis. Determination of skeletal maturity by ultrasound in order to reduce ionizing radiation to the growing skeleton.	5–19 years of age 49 girls, 15 boys Idiopathic scoliosis	Pediatrics	US of ilium: Risser Grade (0–V) US of left wrist: Radial epiphysis open or closed (yes-no) X-ray of ilium: Risser Grade (0–V) X-ray of left wrist: Greulich and Pyle (atlas)	-	Valid Applicable
X-ray Iliac bone	Iliac bone	2	Thaler et al. [39]	2008	Austria	Determination of the accuracy of ultrasound evaluation of the Risser Grade as compared to plain radiography in patients with adolescent idiopathic scoliosis.	7–17 years of age 36 females, 8 males Idiopathic scoliosis	Pediatrics	US and X-ray of ilium: Risser Grade (0–V)	US and X-ray: senior staff skeletal radiologists	Valid Applicable
X-ray Iliac bone	Iliac bone	3	Torlak et al. [40]	2012	Turkey	Assessment of the efficiency of ultrasonographic evaluation of Risser Sign compared with radiographic evaluation, and investigation of intraexaminer and interexaminer reliability of ultrasonographic evaluation.	10–17 years of age 70 females, 72 males Minor pelvic trauma or scoliosis	Pediatrics	US and X-ray of ilium: Risser Grade (0–V)	US and X-ray: two orthopedists	Valid Reliable Applicable
X-ray Iliac bone	Iliac bone	4	Chauhan et al. [41]	2019	India	Sonographic and radiographic examination of the Risser Grade. Comparison of sonographic and radiographic epiphyseal iliac crest ossification for age estimation in living.	10–22 years of age 28 females, 32 males Healthy	Pediatrics	US and X-ray of ilium: Risser Grade (0–V)	-	Valid Applicable

Table 1. *Cont.*

Comparator	US Body Region(s)		Study	Year	Country	Intervention and Aim(s)	Population	Domain	Methods	Examiners, Readers and Duration	Results and Conclusion
X-ray of left hand and wrist	Femoral head	5	Castriota-Scanderbeg et al. [42]	1998	Italy	Comparison of sonographically assessed thickness of femoral head cartilage and skeletal age determined by the GP and TW2 left hand radiograph by establishing the level of agreement between methods, the differences between the calculated skeletal age and chronological age, and the sensitivity, specificity, and predictive values of each method.	1.3–21.3 years of age 56 females, 59 males Proven or suspected growth disorder	Pediatrics	US of hip: Femoral head cartilage thickness, skeletal ages derived from normal values obtained in a healthy Italian population (distance) X-ray of left hand and wrist: Greulich and Pyle, Tanner and Whitehouse II (atlas)	US: pediatric radiologist X-ray: experienced pediatric physician	Valid Applicable
X-ray of left hand and wrist	Wrist, knee, ankle	6	Wan et al. [43]	2020	China	Clarification of the correlations between the sonographic ossification ratios of the wrist, knee, and ankle, and the radiographic bone age in patients from infants to teenagers. Development of a new parameter to evaluate bone age with ossification ratios from bones with relatively higher correlations.	0–19 years of age 139 females and 132 males No pathologic modifications of the wrist, knee and ankle	Pediatrics	US of wrist, knee and ankle: Ossification ratio X-ray of left hand and wrist: Tanner and Whitehouse III (atlas)	US examination: operators with experience for 1 and 3 years and trained with the protocol. US evaluation: radiologists 2.6 min	Valid Reliable Applicable

Table 1. *Cont.*

Comparator	US Body Region(s)		Study	Year	Country	Intervention and Aim(s)	Population	Domain	Methods	Examiners, Readers and Duration	Results and Conclusion
X-ray of left hand and wrist	Left wrist and knee	7	Wan et al. [26]	2021	China	Construction of score-for-age normal values and determination of the diagnostic performances of the method. Evaluation of ultrasonic bone age of the left hand and knee of pathologic patients with normal values of score for age. Comparison with X-ray assessment.	0–19 years of age 511 females, 578 males Normal value group: without clinical diseases potentially affecting skeletal growth Validation group: clinically suspected growth disturbance	Pediatrics	US of left wrist and knee: Ossification ratio and the skeletal maturity score X-ray of left hand and wrist: Tanner and Whitehouse III, Greulich and Pyle (atlas)	US examination and evaluation: radiologists with 20, 6, 5, 1 years of experience and trained with the protocol X-ray: radiologists with 2 and 10 years of experience in bone age radiography evaluation 2 min ± 2	Valid Reliable Applicable
X-ray of left hand and wrist	Left hand and wrist (GP + stages)	8	Ağırman et al. [36]	2018	Turkey	Assessment of the fit between the direct radiography and ultrasonography findings from the left hand–wrist and investigation of whether bone age and pubertal growth excretion are detectable with ultrasonography without ionizing radiation.	10–17 years of age 82 females, 38 males Healthy	Dentistry	US and X-ray of left hand and wrist: Greulich and Pyle (atlas) and scoring system (I–V).	X-ray: technician with at least 5 years of working experience 2–3 min	Valid Reliable Applicable

Table 1. *Cont.*

Comparator	US Body Region(s)		Study	Year	Country	Intervention and Aim(s)	Population	Domain	Methods	Examiners, Readers and Duration	Results and Conclusion
X-ray of left hand and wrist	Left hand and wrist (GP + stages)	9	Razak and Meena [37]	2018	India	Assessment of the fit between the direct radiography and ultrasonography findings from the left hand–wrist and investigation of whether bone age and pubertal growth excretion are detectable with ultrasonography without ionizing radiation.	10–17 years of age 82 females, 38 males Healthy	Dentistry	US and X-ray of left hand and wrist: Greulich and Pyle (atlas) and scoring system (I–V).	X-ray: technician with at least 5 years of working experience 2–3 min	Valid Reliable Applicable
X-ray of left hand and wrist	Left hand and wrist (SMS and OR)	10	Wan et al. [22]	2019	China	Assessment of the relationship between ultrasonic determination of ossification ratio and standard radiographic bone age from birth to near adulthood. Potential provision of a quantitative modality for estimation of bone age by conventional ultrasound.	0.1–19 years of age 94 females and 78 males No pathologic modification of the hand and wrist	Pediatrics	US of left hand and wrist: Ossification ratio and skeletal maturity score. X-ray of the left hand and wrist: Tanner and Whitehouse III (atlas)	US examination: sonographic imaging specialist US evaluation: radiologists with experience in musculoskeletal ultrasound for 1, 2, and 3 years and trained for the protocol X-ray evaluation: radiologists 4–5 min	Valid Reliable Applicable (with caution)

Table 1. *Cont.*

Comparator	US Body Region(s)		Study	Year	Country	Intervention and Aim(s)	Population	Domain	Methods	Examiners, Readers and Duration	Results and Conclusion
X-ray of left hand and wrist	Hand and wrist (stages)	11	Nessi et al. [44]	1997	Italy	Examinations of the centers of ossification of the hand and wrist in adolescent by ultrasonographic compared to radiographic evaluation. Determination of the growth phases.	7–16 years of age 26 patients Difference between physical development and chronological age	Dentistry	US and X-ray of the hand and wrist: Fishman stages (0–II)	US and X-ray: radiologists	Not valid Not applicable
X-ray of left hand and wrist	Hand and wrist (stages)	12	Giuca et al. [45]	2002	Italy	Comparison of the results of a sonographic and radiographic evaluation of the left hand and wrist.	9–18 years of age 11 females, 14 males Delayed or precocious skeletal development	Pediatrics	US and X-ray of left hand and wrist: detection of the presence of growth cartilage (yes or no)	-	Not valid Not applicable
CT	Clavicular epiphyses	13	Gonsior et al. [46]	2013	Germany	Comparison of the staging results for both clavicles of the same subjects by sonography, computed tomography, and macroscopy.	15.8–28.8 years of age 5 males Corpses without trauma of the clavicular epiphyses or cranial sternum region nor diseases affecting ossification process	Forensic medicine	US of the clavicular epiphyses: Classification following Schulz et al. (I–IV) CT of the clavicular epiphyses: Classification following Webb and Suchey (I–IV) Autopsy of the clavicular epiphyses: Classification following Webb and Suchey (I–IV)	US: one prepared and experienced examiner	Not valid Not applicable
MRI	Right knee	14	Herrmann et al. [25]	2021	Germany	Test of the feasibility of a US-based method for assessment of epiphyseal growth plate closure around the knee for forensic age estimation and comparison of the findings to MRI.	14.4–19.3 years of age 33 males Healthy	Forensic medicine	US of the knee: Classification by stages (I–III) MRI of the knee: Classification following Jopp et al. (I–III)	US examination: radiologist MRI evaluation: readers with 5 years of experience in forensic medecine 2.65 ± 2.72	Valid Reliable Applicable

Table 2. Articles retained for the reliability group (*n* = 16).

US Body Region(s)		Study	Year	Country	Intervention and Aim(s)	Population	Domain	Methods	Examinators, Readers and Duration	Results and Conclusion
Clavicle	1	Benito et al. [35]	2018	Spain	Determination of the fusion time of both sternal ends of the clavicle by ultrasonography. Evaluation of whether it may be used to estimate the legal age of adulthood in Spain. Reduction of minors' exposure to radiation.	5–30 years of age 146 females, 75 males	Forensic medicine	Sternal end of both clavicle: classification by Schulz et al. (I–IV)	-	Not reliable Applicable (with caution)
Clavicle	2	Quirmbach et al. [47]	2009	Germany	Assessment of whether the system could be used to evaluate the degree of ossification of the medial clavicular epiphyseal plate (both sides). Establish at what age full ossification could be demonstrated. See if this criterion, as proof that 21 years of age had been reached, could be demonstrated with the necessary degree of reliability required by criminal law.	18–24 years of age 77 males Healthy	Forensic medicine	Both medial clavicular epiphyseal plate: classification by Schulz et al. (I–IV)	Examiners prepared for the experiment and trained for the method	Not reliable Not applicable
Clavicle	3	Schulz et al. [48]	2008	Germany	Determination of whether the ossification stage of the right medial clavicular epiphyses can also be determined by ultrasonography.	12–30 years of age 39 females, 45 males Healthy	Forensic medicine	Right medial clavicular epiphyses: classification by Webb and Suchey (I–IV)	Physician qualified and certified	Reliable Applicable
Clavicle	4	Schulz et al. [49]	2013	Germany	Examination of the time frame of the ossification of right medial clavicular epiphysis in a large number of cases.	10–25 years old 307 females, 309 males Healthy	Forensic medicine	Right medial clavicular epiphysis: classification by Schulz et al. (I–IV)	Qualified arthrosono-graphist	Reliable Applicable
Clavicle	5	Gonsior et al. [46]	2016	Germany	Evaluation of the stage of ossification of the medial clavicular epiphysis for both sides. Assessment of whether the determination of complete union of the medial clavicular epiphysis could be used as a criterion to prove that an individual had attained the age threshold of 18 years.	14–26 years of age 215 females, 195 males Healthy	Forensic medicine	Both medial clavicular epiphysis: classification by Schulz et al. (I–IV)	Experienced or prepared examiners	Not reliable Not applicable

Table 2. *Cont.*

US Body Region(s)		Study	Year	Country	Intervention and Aim(s)	Population	Domain	Methods	Examinators, Readers and Duration	Results and Conclusion
Humerus	6	Sánchez et al. [50]	2017	Spain	Determination whether the process of ossification of the proximal humeral epiphysis can be observed using the ultrasound technique and whether studying this is of any use in estimating legal age.	5–30 years of age 146 females, 75 males	Forensic medicine	Proximal humeral epiphysis: classification in stages (0–V)	Forensic anthropologists and researcher	Reliable Applicable
Elbow	7	Schulz et al. [51]	2014	Germany	Examination of whether ultrasound examination of the ossification of the right olecranon could be used for the purposes of age estimation.	10–25 years of age 307 females, 309 males Healthy	Forensic medicine	Right olecranon: classification by Schulz et al. (I–IV)	Physician qualified and certified in the area of arthrosonography	Reliable Applicable
Distal radius	8	Ekizoglu et al. [52]	2021	Turkey	Ultrasonographic evaluation of ossification of the left distal radius epiphysis to show its utility in forensic age estimation in living individuals. Assessment of the usability of US, as a nonionizing method, for pediatric age groups. Validation of the methodology of Schmidt et al.(2013) and comparison of the result obtained by those authors to Turkish population.	9–25 years of age 366 females, 322 males Healthy	Forensic medicine	Left distal radius: classification by Schulz et al. (I–IV, modified)	Observers with 10 and 2 years of experience in forensic age estimation	Reliable Applicable
Distal radius	9	Schmidt et al. [53]	2013	Germany	Verify the potential of ultrasound techniques for use in assessing ossification of the right distal radial epiphysis and its chronological dependency as discovered in the course of the pilot study.	10–25 years of age 306 females, 309 males Healthy	Forensic medicine	Right distal radial epiphysis: classification by Schulz et al. (I–IV)	Physicians with experience in imaging procedures in forensic age estimation and certified	Reliable Applicable

Table 2. *Cont.*

US Body Region(s)		Study	Year	Country	Intervention and Aim(s)	Population	Domain	Methods	Examinators, Readers and Duration	Results and Conclusion
Distal radius	10	Karami et al. [54]	2014	Iran	Evaluation of the diagnostic accuracy (with a focus on sensitivity) of the ultrasonography in bone age determination with measuring the thickness of growth plate in the distal radius. Identification of subjects having growth plate width ≤ defined cut-off (positive test) and are actually over the determined age in each category according to the identity documents.	15–20 years of age 82 males Healthy	Sport	Width of distal radial epiphysis, cut-off point for each category (distance)	Radiographist	Reliable Applicable
Distal radius	11	Karami et al. [55]	2016	Iran	Ultrasonographic examination of the epiphysis of the left distal radius. Evaluation of the effectiveness of ultrasound-based methods in a larger and more diverse socioeconomic group of older children, where the accuracy of this method seems to be least.	14–18 years of age 100 females, 100 males Healthy	Sport	Width of left distal radial growth plate (distance)	Radiology residents	Reliable Applicable (with caution)
Iliac crest and olecranon	12	Pitlovic et al. [56]	2013	Croatia	Ultrasonographic examination of the iliac crest and the olecranon apophysis. Test of whether assessment of olecranon apophysis ossification by ultrasound has value in prediction of annal growth and peak height velocity.	10–15 years of age 134 subjects Healthy	Pediatrics	Iliac crest: Risser grade (0–V) In subjects graded as Risser 0, olecranon apophysis: additional classification (0–VI)	Orthopedic surgeon and general surgeon	Not reliable Not applicable
Iliac crest	13	Schmidt et al. [57]	2011	Germany	Pilot-analysis of the forensic applicability of a sonographic evaluation of the apophyseal ossification of the iliac crest for skeletal age assessment.	11–22 years of age 16 females, 23 males Healthy	Forensic medicine	Iliac crest: classification by Schulz et al. (I–IV)	Examiner certified in the field of skeletal sonography	Reliable Applicable

Table 2. *Cont.*

US Body Region(s)		Study	Year	Country	Intervention and Aim(s)	Population	Domain	Methods	Examinators, Readers and Duration	Results and Conclusion
Iliac crest	14	Schmidt et al. [53]	2013	Germany	Examination of the value of skeletal sonography in assessing the age-dependent process of ossification of the apophysis of the Crista iliaca in a more extensive population.	10–25 years of age 307 females, 309 males Healthy	Forensic medicine	Iliac crest: classification by Schulz et al. (I–IV)	Physicians with experience in imaging procedures used in forensic age estimation and certified	Reliable Applicable
Elbow and wrist	15	Shedge et al. [58]	2021	India	Establishment of the applicability of US, a non-invasive and safe technique, to visualize ossification centers of the left wrist and elbow joints for their appearance and fusion among boys between 14 and 17 years of age in the Ahmednagar region of India.	13.73–17.04 years of age 31 males Healthy	Pediatrics	Left wrist and elbow: classification by Schmeling et al. (I–V)	Researcher	Reliable Applicable
Wrist, second metacarpophalangeal joint, knee, ankle	16	Windschall et al. [59]	2020	International	Ultrasonographic examination of the wrist, second metacarpophalangeal joint, knee and ankle vascularization, and their ossification grade. Assessment of the intra- and interobserver reliability of identification of normal joint vascularization in healthy children in different age groups and evaluation of the intra- and interobserver agreement of a new scoring system for assessing the grade of maturation of ossification nuclei in healthy children.	2–16 years of age 5 females, 7 males Healthy	Pediatrics	Wrist, second metacarpophalangeal joint, knee and ankle: classification in stages (0–IV)	Minimum two years of expertise in pediatrics US	Reliable Applicable

3.2. Validity, Reliability, and Acceptance

The assessment methods could be classified into four main categories: (i) Assessment of the left hand-wrist compared to images of an atlas (Greulich and Pyle method), (ii) computation of a skeletal maturity score, (iii) staging the ossification process, and (iv) measurement of distance or ratio of measured distances, e.g., of the ossification center, epiphysis, or cartilage thickness. The first category provides an estimate of bone age, the second category derives bone age from a score, and the last two categories provide an estimate of bone maturity through categorization into age categories [60,61].

For the VG, a total of seven body regions were investigated for assessing bone maturity or age: The iliac bone, femoral head, wrist and hand, clavicle, knee, and ankle. The body regions most investigated by both X-ray and US were the hand and wrist. The US imaging assessment method more frequently estimated a stage of bone maturity instead of a bone age (76.7% of the assessments).

In the RG, eight body regions were investigated in different studies to test the reliability of the US measurements. These were the clavicle, wrist, elbow, iliac bone, ankle, hand, knee, and shoulder. The clavicle was the region most commonly investigated (five assessments). The assessment methods were almost all based on classifications by the bone maturity stage, with only two studies using the distance measured at the growth plate of the distal radius to classify the participants into age categories. The results obtained were therefore only estimates of bone maturity and not of bone age.

In the VG, the different US methods were statistically evaluated by the authors and were acceptable in 10 studies (71.4%), to be investigated further in 1 study (7.1%), and not valid or reliable enough in 3 studies (21.4%). The latter studies included methods assessing the femoral head cartilage thickness [42], the maturation of the clavicular epiphysis according to the stages of Schulz et al. [46], and the presence or absence of a growth plate on the distal radius and hand bones [45]. In the first two studies, agreement with the gold standard was too low or the transfer from the staging system of the comparative method could not be transferred to US imaging. In the last study, the use of US imaging was recommended as a complementary method to standard radiography. The seven studies that additionally measured the inter- and intra-rater reliability in the validity group all reached high to excellent reliability between and/or within examiners.

In the RG, the US measurements were considered reliable in 11 studies (68.8%), to be applied with caution in 2 studies (12.5%), and not sufficient in 3 studies (18.8%). Two of the insufficient studies measured the maturation stage of the medial clavicular epiphysis based on the stages of Schulz et al. [48]; however, these were in the forensic medicine domain, in which only the decision of the age threshold is critical [47,62]. The third study measured the maturation stages of the olecranon epiphysis [56]. In this study, the method was not trustworthy due to the small sample size leading to a non-significant difference between stages and growth velocity.

3.3. Usability, Practicability, and Economy

The main area in which the studies were conducted was forensic medicine, in which 13 studies (43.3%) aimed to estimate legal age, followed by pediatrics with 12 studies (40%). The main aims of these studies were to uniquely identify bone maturity or obtain information necessary to adjust the treatment of idiopathic scoliosis. Three studies were further conducted in dentistry (10%), where bone age is important for estimating the period and type of treatment. Sport was the least-represented field with only two studies (6.7%) aiming to develop a method to control chronological age reporting and avoid cheating.

Nine studies mentioned the origins of the participants or the composition of the sample. The 21 other studies did not report any information on the origin of the participants, and in this case, it was assumed that they came from the country in which the study was conducted. From this, 19 studies (63.3%) were conducted with European participants (Germany, Italy, Spain, Austria, and Croatia) and 11 studies (36.7%) with Asian (India, China, Iran, and Turkey, as it is mainly part of it) participants. The number of participants strongly differed between studies, ranging from 5 to 1089 participants. In two studies, gender was not mentioned. The average age of the subjects ranged from 9.2 (SD = 4.8) to 21.6 (SD = 4.6) years, covering the entire puberty period.

The duration of measurements, as an important variable for practicability, was mentioned in 40% of the studies in the VG and 0% in the RG mentioned. Thus, on average, the duration was 2.79 min (SD = 0.87).

4. Discussion

The first aim of this scoping review was to examine and summarize the different methods used to estimate biological maturity by ultrasound-based imaging in adolescents. In the 30 studies selected for the review, 4 main methods were listed and 9 different body parts were investigated (Table 3), highlighting the diversity in directions taken in search of a valid and reliable method to estimate bone maturity by US imaging. The second aim was to obtain an overview of the level of validity and reliability of the methods used. Despite the promising start of the results in this review (70% of methods considered as applicable), their validity and the choice of the body region investigated are still under discussion. Thus, none of the methods have yet been defined as the method of choice in the estimation of bone maturity or age. The inter- and intra-rater reliability was high in all studies, demonstrating the repeatability of measurements and estimates. The third aim of this scoping review was to discuss to point out the practicability and usefulness of US imaging in the field of youth sports. In this context, it could be shown that four different analytical procedures exist in the literature. In addition, knowledge of the biological age is a crucial component for fair selection and for the implementation of bio-banding in youth sport. Furthermore, existing methods could be found to be too inaccurate (e.g., anthropometric measurements), too expensive (e.g., MRI), or too radiation-intensive (e.g., X-ray). In contrast, ultrasound was described as practicable, cheap, and radiation-free.

Table 3. Number of assessments for each method and body region.

Technique	**US**				**RX**		**MRI**	**CT**	**Autopsy**	**N Assessments/ Body Regions**
Method / Body Region	**Stages**	**Bone Age (Atlas)**	**Maturity Score**	**Distance and Ossification Ratio**	**Stages**	**Bone Age**	**Stages**	**Stages**	**Stage**	
Ankle	1			1						2
Clavicula	6							1	1	8
Elbow	3									3
Femoral head				1						1
Hand	5	2	1		4	8				20
Iliac bone	7				4					11
Knee	2			2			1			5
Shoulder	1									1
Wrist	9	2	2	5	4	8				30
N assessments	34	4	3	9	12	16	1	1	1	81

4.1. Validity, Reliability, and Acceptance

One of the most significant advantages of using ultrasonography is the absence of ionization. According to human research and age estimation procedure legislations, the risks and intrusiveness must be reduced to a strict minimum and the technique used must prioritize a lack of radiation [63,64]. Although adult radiation exposure is minimal in an X-ray of the extremities, i.e., 0.001 mSv compared to 0.27 mSv for one year of terrestrial radiation [19,65], repeated measurements for longitudinal growth monitoring should be avoided. Thus, ultrasonography would be advantageous for biological maturity estimation, as long as the accuracy of the measurements is higher than other non-invasive methods such as anthropometric measurements. MRI is a technique that has been validated but is not generally considered a reference yet, as its usefulness has to be confirmed, and further studies with higher numbers of participants are needed [20,66]. In addition, its high costs and time consumption hinder the implementation in the field of sport, particularly in youth sport.

Of all the methods presented in the studies, 70% were considered to be acceptable, with relatively high validity and reliability. The comparison to the gold standard showed positive perspectives, although in two cases (femoral head thickness and maturation stages of clavicular epiphysis), the agreement was statistically unsatisfactory. To be accepted, the staging systems have to achieve the precision required by the goal of the assessment (e.g., the limit of age or growth monitoring). However, an estimation of decimal bone age by US imaging is lacking. For greater accuracy, the estimation of bone maturity could be combined with additional measurements of other body regions or include anthropometric parameters to prevent unprobeable deviations of results [67].

The US-based skeletal maturity score method developed by Wan et al. [22,26,43] provides interesting results. Measurements at the wrist and knee allowed them to reach values corresponding to the chronological age of healthy subjects. Furthermore, the method was also tested on subjects with growth disorders with valid results compared to the gold standard of hand radiographs and estimation by the Tanner-Whitehouse 3 and Greulich–Pyle methods. Despite the restricted classification of the maturity stages (n = 3), the study by Herrmann et al. [25] suggests the development of an atlas using the ultrasound scanning technique of the knee joint. Indeed, the creation of five images per zone (medial distal and lateral distal femoral physis, medial proximal and lateral proximal tibial physis, and lateral proximal fibular physis) provides a fairly complete overview of the zone.

Currently, the accuracy of US measurements depends heavily on the examiner's expertise and anatomical knowledge. The focus of future research in this area should therefore be the good standardization of the procedure and the objectification of the image analysis. In this sense, the aim must be to improve inter- and intra-rater reliability and simplify the procedure for researchers through good standardization.

4.2. Usability, Practicability, and Economy

Several areas of research were identified in the various studies. From a pediatric, legal, or sporting point of view, there is interest in developing a non-ionizing technique to assess biological maturity. Furthermore, orthodontic support, monitoring of idiopathic scoliosis during adolescence, and growth monitoring require repeated measurements, and as such, would profit from a non-ionizing and cheap technique. In this context, it could be shown that four different analytical procedures exist in the literature. In addition, knowledge of the biological age is a crucial component for fair selection and the implementation of bio-banding. Furthermore, existing methods could be found to be too inaccurate (e.g., anthropometric measurements), too expensive (e.g., MRI), or too radiation-intensive (e.g., X-ray). In the field of sports, the organization of systems based on biological age, such as the right to participate in competitions or bio-banding, does not represent a need for medical diagnosis per se, and therefore, it may be more difficult to allow ionizing technologies from a legal point of view. A valid method of estimating biological maturity by ultrasound would thus be a beneficial alternative.

More specifically, in the field of sport [9,12], the distribution of athletes into chronological age classes often creates imbalances between competing adolescents. Thus, the overrepresentation of early maturers and relative age effects are very common, i.e., children born at the beginning of the year are overrepresented in competitive sport compared to those born at the end of the same year [6,68,69]. This effect progressively lessens closer to the end of growth. In addition, at the onset of puberty, a disparity in performance capacity linked to the biological development of the athletes arises. For example, studies show that among soccer national team players under the age of 15, early developers are faster, more powerful, more likely to win duels, and have higher chances of being selected for talent development programs [70,71]. Conversely, late developers selected for superior teams often show superior technical abilities [71,72]. Bio-banding is a form of play in which players are divided into teams according to their biological maturity in order to mitigate differences associated with maturity status and ensure equality [72]. If the estimation of biological maturity by ultrasound proves to be more accurate than anthropometric methods, it could support such systems to ensure fairness between young athletes during competitions and selection. Monitoring growth throughout the puberty period would also help to improve and individualize training and possibly reduce the risk of injuries, especially around peak age velocity [73,74].

Depending on the field in which the method is used, the need for precision in the estimate may differ. In forensic medicine, for example, the method should be most accurate for determining a chronological age representing the majority, which is crucial for law application [63]. In the field of sport, however, growth velocity (tempo) and age at peak height velocity (timing) are the most interesting for defining the biological status of an athlete [75]. The key is to be able to categorize players showing a normal, fast, or slow growth velocity, or to define their developmental stage in order to adapt loads, restrict overloading of growth areas, and thus, possibly reduce the risk of injuries (Morbus Scheuermann, Osgood–Schlatter, Sever's disease), and organize adjusted competition categories.

According to the results of the review, many studies have developed methods that define a growth stage rather than a precise bone age (76.7% estimates for the VG and 100% in the RG). The number of growth stages ranged from a minimum of 3 to a maximum of 7. If we consider the age range of 8 to 23 years, which is the maximal range in which normal puberty and ossification processes occur, the theoretical maximum number of growth stages would divide the individuals into delimited categories of 2.1 years. In only two studies was the number of stages bigger than the age span of the participants, allowing the authors to reach a precision smaller than one year for bone age estimation [56,58]. Given that classification into biological developmental stages can be performed by anthropometrical measurements within an age range of one year [15] and that biological age can be estimated on a 0.1 year-scale, most ultrasound methods have to be refined to reach at least the same precision. In youth sport, this precision is particularly necessary because differences in performance can already be observed between athletes born 6 months apart [76].

In addition to the great diversity in methods, the aspect of different ethnicities must also be considered when incorporating anatomical variability and growth differences in the estimates [77,78]. The most promising methods should then be tested on different ethnic groups to generalize the results.

Compared to MRIs (approximately 20 min [25]), the duration of the US examination (mean = 2.79 min, SD = 0.87) is advantageous. However, the duration of the measurement and the estimation also depend on the expertise of the examiner. Of the 86.6% of studies that mentioned the level of expertise of the examiners, the measurements in only two studies were conducted by individuals who were not explicitly affiliated with a medical imaging profession or in a domain requiring expertise in estimating biological maturity [47,62]. Each of the four examiners in question had been trained by the DEGUM (German Society for Ultrasound in Medicine) introductory course to the locomotor system. However, the methods tested in these studies were assessed as invalid. The expertise of the reviewers was not questioned, as in both cases, the field of research was forensic medicine, where the definition of a legal age limit requires great precision. The expertise of the examiners therefore must be further investigated, which could, for example, be performed by examining the inter-examiner reliability of different expertise levels. Furthermore, no study reported the use of a handheld device, which would be a significant benefit in the field of sport, to facilitate field implementation and restrict the budget for purchasing such technology.

5. Perspectives

The current review demonstrates the vast number of possible methods for estimating bone maturity. This knowledge should be further explored to develop a reliable and valid method, with the aim of achieving gold standard status. For this purpose, standard planes for ultrasounds of the specific bone areas must be clearly defined. This includes the standard positioning of the limb examined during the examination. The addition of investigations on several regions of the body and the combination of different methods could help to improve the accuracy of the estimation.

Furthermore, future investigations regarding the refinement of maturity stages or a method directly measuring bone age to obtain the required precision in youth sport, as well as the inter-rater reliability of the assessment, level of expertise, and measurement accuracy of handheld devices, should be conducted. The field of application and the purpose of the measurement must be clearly defined, as the difference in existing methods can lead to very divergent results that are not applicable in all situations.

Quantitative ultrasound technology is a promising approach to be considered, and a device has been developed to perform measurements on the wrist. This technology has been validated [23,24]; however, the accuracy of the measurement has yet to be improved, as it is no more accurate than anthropometric methods [67]. As the growth plate is a three-dimensional structure and its bone surface is irregular, methods based on sound speed are prone to errors. However, it would be interesting to compare this technology to ultrasound imaging and possibly combine the advantages of both technologies.

6. Limitations

Since the aim of scoping reviews is different from that of systematic reviews, an analysis of the quality of the methodology or risk of bias was not conducted [79].

7. Conclusions

This is the first review of ultrasound imaging for assessing maturity. While ultrasound imaging of the wrist and the knee show promising results, none of the ultrasound assessments investigated can be referred to as a gold standard yet, as further validation studies are required. The diversity of the methods, body parts investigated, and the goals sought in the various domains of application do not allow the determination of which method could be developed into the gold standard.

Future studies should carefully analyze the sources of bias that may emerge and aim to develop standardized study designs, considering the diversity between ethnicities, gender, the expertise level of the examiners, the measurements of different body regions, and the combination of several methods and/or ultrasound technologies. The development of such a method would be interesting for the field of sport, due to the absence of ionization, its accessibility, its lower costs, and the rapidity of assessment. Its application has the potential to incorporate biological age into selection processes. This would allow for more equal opportunities in talent selection and thus make talent development fairer and more efficient.

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References

1. Mughal, A.M.; Hassan, N.; Ahmed, A. Bone Age Assessment Methods: A Critical Review. *Pak. J. Med. Sci.* **2014**, *30*, 211. [CrossRef] [PubMed]
2. Satoh, M. Bone Age: Assessment Methods and Clinical Applications. *Clin. Pediatr. Endocrinol.* **2015**, *24*, 143–152. [CrossRef] [PubMed]

3. Engebretsen, L.; Steffen, K.; Bahr, R.; Broderick, C.; Dvorak, J.; Janarv, P.-M.; Johnson, A.; Leglise, M.; Mamisch, T.C.; McKay, D.; et al. The International Olympic Committee Consensus Statement on Age Determination in High-Level Young Athletes. *Br. J. Sport. Med.* **2010**, *44*, 476–484. [CrossRef] [PubMed]
4. Tanner, J.M. Issues and Advances in Adolescent Growth and Development. *J. Adolesc. Health Care Off. Publ. Soc. Adolesc. Med.* **1987**, *8*, 470–478. [CrossRef] [PubMed]
5. Subramanian, S.; Viswanathan, V.K. Bone Age. In *StatPearls*; StatPearls Publishing: Treasure Island, FL, USA, 2022.
6. Smith, K.L.; Weir, P.L.; Till, K.; Romann, M.; Cobley, S. Correction to: Relative Age Effects Across and Within Female Sport Contexts: A Systematic Review and Meta-Analysis. *Sport. Med.* **2018**, *48*, 1989–1990. [CrossRef] [PubMed]
7. Vaeyens, R.; Lenoir, M.; Williams, A.M.; Philippaerts, R.M. Talent Identification and Development Programmes in Sport: Current Models and Future Directions. *Sport. Med.* **2008**, *38*, 703–714. [CrossRef] [PubMed]
8. Fransen, J.; Skorski, S.; Baxter-Jones, A.D.G. Estimating Is Not Measuring: The Use of Non-Invasive Estimations of Somatic Maturity in Youth Football. *Sci. Med. Footb.* **2021**, *5*, 261–262. [CrossRef] [PubMed]
9. Malina, R.M.; Rogol, A.D.; Cumming, S.P.; Coelho e Silva, M.J.; Figueiredo, A.J. Biological Maturation of Youth Athletes: Assessment and Implications. *Br. J. Sport. Med.* **2015**, *49*, 852–859. [CrossRef]
10. Pаśko, W.; Śliż, M.; Paszkowski, M.; Zieliński, J.; Polak, K.; Huzarski, M.; Przednowek, K. Characteristics of Cognitive Abilities among Youths Practicing Football. *Int. J. Environ. Res. Public Health* **2021**, *18*, 1371. [CrossRef]
11. Dvorak, J.; George, J.; Junge, A.; Hodler, J. Age Determination by Magnetic Resonance Imaging of the Wrist in Adolescent Male Football Players. *Br. J. Sport. Med.* **2006**, *41*, 45–52. [CrossRef]
12. Malina, R.M. Skeletal Age and Age Verification in Youth Sport. *Sports Med.* **2011**, *41*, 925–947. [CrossRef] [PubMed]
13. Fransen, J.; Bush, S.; Woodcock, S.; Novak, A.; Deprez, D.; Baxter-Jones, A.D.G.; Vaeyens, R.; Lenoir, M. Improving the Prediction of Maturity From Anthropometric Variables Using a Maturity Ratio. *Pediatr. Exerc. Sci.* **2018**, *30*, 296–307. [CrossRef] [PubMed]
14. Khamis, H.J.; Roche, A.F. Predicting Adult Stature without Using Skeletal Age: The Khamis-Roche Method. *Pediatrics* **1994**, *94 (4 Pt 1)*, 504–507. [PubMed]
15. Mirwald, R.L.; Baxter-Jones, A.D.G.; Bailey, D.A.; Beunen, G.P. An Assessment of Maturity from Anthropometric Measurements. *Med. Sci. Sport. Exerc.* **2002**, *34*, 689–694. [CrossRef] [PubMed]
16. Moore, S.A.; Mckay, H.A.; Macdonald, H.; Nettlefold, L.; Baxter-Jones, A.D.G.; Cameron, N.; Brasher, P.M.A. Enhancing a Somatic Maturity Prediction Model. *Med. Sci. Sport. Exerc.* **2015**, *47*, 1755–1764. [CrossRef]
17. Malina, R.M.; Cumming, S.P.; Rogol, A.D.; Coelho-e-Silva, M.J.; Figueiredo, A.J.; Konarski, J.M.; Kozieł, S.M. Bio-Banding in Youth Sports: Background, Concept, and Application. *Sport. Med.* **2019**, *49*, 1671–1685. [CrossRef]
18. Doyle, E.; Márquez-Grant, N.; Field, L.; Holmes, T.; Arthurs, O.J.; van Rijn, R.R.; Hackman, L.; Kasper, K.; Lewis, J.; Loomis, P.; et al. Guidelines for Best Practice: Imaging for Age Estimation in the Living. *J. Forensic Radiol. Imaging* **2019**, *16*, 38–49. [CrossRef]
19. Mettler, F.A.; Huda, W.; Yoshizumi, T.T.; Mahesh, M. Effective Doses in Radiology and Diagnostic Nuclear Medicine: A Catalog. *Radiology* **2008**, *248*, 254–263. [CrossRef]
20. Prokop-Piotrkowska, M.; Marszałek-Dziuba, K.; Moszczyńska, E.; Szalecki, M.; Jurkiewicz, E. Traditional and New Methods of Bone Age Assessment-An Overview. *J. Clin. Res. Pediatr. Endocrinol.* **2021**, *13*, 251–262. [CrossRef]
21. Spârchez, M.; Fodor, D. What's New in Musculoskeletal Ultrasound in Pediatric Rheumatology? *Med. Ultrason.* **2018**, *20*, 371. [CrossRef]
22. Wan, J.; Zhao, Y.; Feng, Q.; Sun, Z.; Zhang, C. Potential Value of Conventional Ultrasound in Estimation of Bone Age in Patients from Birth to Near Adulthood. *Ultrasound Med. Biol.* **2019**, *45*, 2878–2886. [CrossRef] [PubMed]
23. Rachmiel, M.; Naugolni, L.; Mazor-Aronovitch, K.; Koren-Morag, N.; Bistritzer, T. Bone Age Assessments by Quantitative Ultrasound (SonicBone) and Hand X-Ray Based Methods Are Comparable. *Isr. Med. Assoc. J.* **2017**, *19*, 5. [PubMed]
24. Shimura, N.; Koyama, S.; Arisaka, O.; Imataka, M.; Sato, K.; Matsuura, M. Assessment of Measurement of Children's Bone Age Ultrasonically with Sunlight BonAge. *Clin. Pediatr. Endocrinol.* **2005**, *14* (Suppl. S24), S24_17–S24_20. [CrossRef]
25. Herrmann, J.; Säring, D.; Auf der Mauer, M.; Groth, M.; Jopp-van Well, E. Forensic Age Assessment of the Knee: Proposal of a New Classification System Using Two-Dimensional Ultrasound Volumes and Comparison to MRI. *Eur. Radiol.* **2021**, *31*, 3237–3247. [CrossRef]
26. Wan, J.; Zhao, Y.; Feng, Q.; Lv, P.; Hong, K.; Zhang, C. Statistical Confirmation of a Method of US Determination of Bone Age. *Radiology* **2021**, *300*, 176–183. [CrossRef]
27. Castriota-Scanderbeg, A.; De Micheli, V. Ultrasound of Femoral Head Cartilage: A New Method of Assessing Bone Age. *Skelet. Radiol.* **1995**, *24*, 197–200. [CrossRef]
28. Spannow, A.; Stenboeg, E.; Pfeiffer-Jensen, M.; Fiirgaard, B.; Haislund, M.; Ostergaard, M.; Andersen, N.; Herlin, T. Ultrasound and MRI Measurements of Joint Cartilage in Healthy Children: A Validation Study. *Ultraschall Med. Eur. J. Ultrasound* **2010**, *32* (Suppl. S1), 110–116. [CrossRef]
29. Trauzeddel, R.; Windschall, D.; Trauzeddel, R.; Nirschl, C.; Ganser, G.; Palm-Beden, K.; Berendes, R.; Haller, M.; Krumrey-Langkammerer, M.; Nimtz-Talaska, A.; et al. Arthrosonographic Reference Values of the Shoulder Joint in Healthy Children and Adolescents: A Cross-Sectional Multicentre Ultrasound Study. *Klin. Pädiatr.* **2017**, *229*, 293–301. [CrossRef]
30. Trauzeddel, R.; Lehman, H.; Trauzeddel, R.F.; Haller, M.; Palm-Beden, K.; Ganser, G.; Berendes, R.; Nirschl, C.; Nimtz-Talaska, A.; Krumrey-Langkammerer, M.; et al. Age Dependent Ultrasound B-Mode Findings of the Elbow Joint in Healthy Children and Adolescents. *Rheumatol. Int.* **2019**, *39*, 1007–1018. [CrossRef]

31. Windschall, D.; Trauzeddel, R.; Haller, M.; Krumrey-Langkammerer, M.; Nimtz-Talaska, A.; Berendes, R.; Ganser, G.; Nirschl, C.; Schoof, P.; Trauzeddel, R.F.; et al. Pediatric Musculoskeletal Ultrasound: Age- and Sex-Related Normal B-Mode Findings of the Knee. *Rheumatol. Int.* **2016**, *36*, 1569–1577. [CrossRef]
32. Żuber, Z.; Owczarek, A.; Sobczyk, M.; Migas-Majoch, A.; Turowska-Heydel, D.; Sternal, A.; Michalczak, J.; Chudek, J. Establishing Percentile Charts for Hip Joint Capsule and Synovial Cavity Thickness in Apparently Healthy Children. *Pediatr. Rheumatol.* **2017**, *15*, 8. [CrossRef] [PubMed]
33. Arksey, H.; O'Malley, L. Scoping Studies: Towards a Methodological Framework. *Int. J. Soc. Res. Methodol.* **2005**, *8*, 19–32. [CrossRef]
34. Muir, A. Precocious Puberty. *Pediatr. Rev.* **2006**, *27*, 373–381. [CrossRef] [PubMed]
35. Benito, M.; Muñoz, A.; Beltrán, I.; Labajo, E.; Perea, B.; Sánchez, J.A. Assessment of Adulthood in the Living Spanish Population Based on Ossification of the Medial Clavicle Epiphysis Using Ultrasound Methods. *Forensic Sci. Int.* **2018**, *284*, 161–166. [CrossRef] [PubMed]
36. Ağırman, K.T.; Bilge, O.M.; Miloğlu, O. Ultrasonography in Determining Pubertal Growth and Bone Age. *Dentomaxillofacial Radiol.* **2018**, *47*, 20170398. [CrossRef]
37. Meena, G. The Importance of Conventional Radiography and Ultrasound in Determining Bone Age. *Orthop. Res. Online J.* **2018**, *4*, 1–7. [CrossRef]
38. Wagner, U.A.; Diedrich, V.; Schmitt, O. Determination of Skeletal Maturity by Ultrasound: A Preliminary Report. *Skelet. Radiol.* **1995**, *24*, 417–420. [CrossRef]
39. Thaler, M.; Kaufmann, G.; Steingruber, I.; Mayr, E.; Liebensteiner, M.; Bach, C. Radiographic versus Ultrasound Evaluation of the Risser Grade in Adolescent Idiopathic Scoliosis: A Prospective Study of 46 Patients. *Eur. Spine J.* **2008**, *17*, 1251–1255. [CrossRef]
40. Torlak, G.; Kiter, E.; Oto, M.; Akman, A. Ultrasonographic Evaluation of the Risser Sign. *Spine* **2012**, *37*, 316–320. [CrossRef]
41. Chauhan, M.; Agrawal, A.; Dikshit, P.C.; Pradhan, G.S. Sonography Touchstone Testing Gold Standard Radiography for Medico-Legal Age Estimation in Living: A Prospective Triple Blind Study. *J. Forensic Med. Toxicol.* **2019**, *36*, 64. [CrossRef]
42. Castriota-Scanderbeg, A.; Sacco, M.C.; Emberti-Gialloreti, L.; Fraracci, L. Skeletal Age Assessment in Children and Young Adults: Comparison between a Newly Developed Sonographic Method and Conventional Methods. *Skelet. Radiol.* **1998**, *27*, 271–277. [CrossRef] [PubMed]
43. Wan, J.; Zhao, Y.; Feng, Q.; Zhang, C. Summation of Ossification Ratios of Radius, Ulna and Femur: A New Parameter to Evaluate Bone Age by Ultrasound. *Ultrasound Med. Biol.* **2020**, *46*, 1761–1768. [CrossRef] [PubMed]
44. Nessi, R.; Garattini, G.; Bazzini, E.; Zaffaroni, R.; Lazzerini, F. Ultrasonography assessment of ossification foci of the wrist and pubertal growth spurt. *Radiol. Med.* **1997**, *94*, 43–46.
45. Giuca, M.R.; Mazza, P.; Marrapese, E.; Cesaretti, G.; Calderazzi, A.; Carafoli, D.; Saggese, G. A Comparison between Radiographic and Sonographic Assessment of Hand and Wrist Bones for the Estimation of Skeletal Age in the Child Patient. *Eur. J. Paediatr. Dent.* **2002**, *3*, 6.
46. Gonsior, M.; Ramsthaler, F.; Gehl, A.; Verhoff, M.A. Morphology as a Cause for Different Classification of the Ossification Stage of the Medial Clavicular Epiphysis by Ultrasound, Computed Tomography, and Macroscopy. *Int. J. Leg. Med.* **2013**, *127*, 1013–1021. [CrossRef]
47. Quirmbach, F.; Ramsthaler, F.; Verhoff, M.A. Evaluation of the Ossification of the Medial Clavicular Epiphysis with a Digital Ultrasonic System to Determine the Age Threshold of 21 Years. *Int. J. Leg. Med.* **2009**, *123*, 241–245. [CrossRef] [PubMed]
48. Schulz, R.; Zwiesigk, P.; Schiborr, M.; Schmidt, S.; Schmeling, A. Ultrasound Studies on the Time Course of Clavicular Ossification. *Int. J. Leg. Med.* **2008**, *122*, 163–167. [CrossRef] [PubMed]
49. Schulz, R.; Schiborr, M.; Pfeiffer, H.; Schmidt, S.; Schmeling, A. Sonographic Assessment of the Ossification of the Medial Clavicular Epiphysis in 616 Individuals. *Forensic Sci. Med. Pathol.* **2013**, *9*, 351–357. [CrossRef]
50. Sánchez, M.B.; Codinha, S.; García, A.M.; Sánchez, J.A.S. Estimating Legal Age Based on Fusion of The Proximal Humeral Epiphysis. *Int. J. Leg. Med.* **2017**, *131*, 1133–1140. [CrossRef]
51. Schulz, R.; Schiborr, M.; Pfeiffer, H.; Schmidt, S.; Schmeling, A. Forensic Age Estimation in Living Subjects Based on Ultrasound Examination of the Ossification of the Olecranon. *J. Forensic Leg. Med.* **2014**, *22*, 68–72. [CrossRef]
52. Ekizoglu, O.; Er, A.; Buyuktoka, A.D.; Bozdag, M.; Karaman, G.; Moghaddam, N.; Grabherr, S. Ultrasonographic Assessment of Ossification of the Distal Radial Epiphysis for Estimating Forensic Age. *Int. J. Leg. Med.* **2021**, *135*, 1573–1580. [CrossRef] [PubMed]
53. Schmidt, S.; Schiborr, M.; Pfeiffer, H.; Schmeling, A.; Schulz, R. Sonographic Examination of the Apophysis of the Iliac Crest for Forensic Age Estimation in Living Persons. *Sci. Justice* **2013**, *53*, 395–401. [CrossRef] [PubMed]
54. Karami, M.; Moshirfatemi, A.; Daneshvar, P. Age Determination Using Ultrasonography in Young Football Players. *Adv. Biomed. Res.* **2014**, *3*, 174. [CrossRef] [PubMed]
55. Karami, M.; Moradi, M.; Khazaei, M.; Modaresi, M.-R.; Asadi, K.; Soleimani, M. Detection of Secondary Ossification Centers by Sonography. *Adv. Biomed. Res.* **2016**, *5*, 12. [PubMed]
56. Pitlovi, V. A Correlation of Peak Height Velocity and Olecranon Apophysis Ossification Assessed by Ultrasound. *Coll. Antropol.* **2013**, *37*, 1285–1289.
57. Schmidt, S.; Schmeling, A.; Zwiesigk, P.; Pfeiffer, H.; Schulz, R. Sonographic Evaluation of Apophyseal Ossification of the Iliac Crest in Forensic Age Diagnostics in Living Individuals. *Int. J. Leg. Med.* **2011**, *125*, 271–276. [CrossRef]

58. Shedge, R.; Kanchan, T.; Kushwaha, K.P.S.; Krishan, K. Ultrasonographic Evaluation of the Wrist and Elbow Joints: A Pilot Study to Explore a Non-Invasive Technique for Age Estimation. *Med. Sci. Law* **2021**, *61*, 14–22. [CrossRef]
59. Windschall, D.; Collado, P.; Vojinovic, J.; Magni-Manzoni, S.; Balint, P.; Bruyn, G.A.W.; Hernandez-Diaz, C.; Nieto, J.C.; Ravagnani, V.; Tzaribachev, N.; et al. Age-Related Vascularization and Ossification of Joints in Children: An International Pilot Study to Test Multiobserver Ultrasound Reliability. *Arthritis Care Res.* **2020**, *72*, 498–506. [CrossRef]
60. Martin, D.D.; Calder, A.D.; Ranke, M.B.; Binder, G.; Thodberg, H.H. Accuracy and Self-Validation of Automated Bone Age Determination. *Sci. Rep.* **2022**, *12*, 6388. [CrossRef]
61. Pyle, S.I.; Waterhouse, A.M.; Greulich, W.W. Attributes of the Radiographic Standard of Reference for the National Health Examination Survey. *Am. J. Phys. Anthropol.* **1971**, *35*, 331–337. [CrossRef]
62. Gonsior, M.; Ramsthaler, F.; Birngruber, C.; Obert, M.; Verhoff, M.A. The Completely Fused Medial Clavicular Epiphysis in High-Frequency Ultrasound Scans as a Diagnostic Criterion for Forensic Age Estimations in the Living. *Int. J. Leg. Med.* **2016**, *130*, 1603–1613. [CrossRef] [PubMed]
63. European Asylum Support Office. *EASO Practical Guide on Age Assessment*, 2nd ed.; European Asylum Support Office: Valletta, Malta, 2018; p. 116.
64. The Federal Assembly of the Swiss Confederation. *Federal Act on Research Involving Human Beings (Human Research Act, HRA) 810.30*; The Federal Assembly of the Swiss Confederation: Bern, Switzerland, 2011.
65. Shahbazi-Gahrouei, D.; Setayandeh, S.; Gholami, M. A Review on Natural Background Radiation. *Adv. Biomed. Res.* **2013**, *2*, 65. [CrossRef] [PubMed]
66. Hojreh, A.; Gamper, J.; Schmook, M.T.; Weber, M.; Prayer, D.; Herold, C.J.; Noebauer-Huhmann, I.-M. Hand MRI and the Greulich-Pyle Atlas in Skeletal Age Estimation in Adolescents. *Skelet. Radiol.* **2018**, *47*, 963–971. [CrossRef] [PubMed]
67. Leyhr, D.; Murr, D.; Basten, L.; Eichler, K.; Hauser, T.; Lüdin, D.; Romann, M.; Sardo, G.; Höner, O. Biological Maturity Status in Elite Youth Soccer Players: A Comparison of Pragmatic Diagnostics With Magnetic Resonance Imaging. *Front. Sport. Act. Living* **2020**, *2*, 587861. [CrossRef]
68. Baxter-Jones, A.D.G.; Barbour-Tuck, E.N.; Dale, D.; Sherar, L.B.; Knight, C.J.; Cumming, S.P.; Ferguson, L.J.; Kowalski, K.C.; Humbert, M.L. The Role of Growth and Maturation during Adolescence on Team-Selection and Short-Term Sports Participation. *Ann. Hum. Biol.* **2020**, *47*, 316–323. [CrossRef]
69. Cobley, S.; Baker, J.; Wattie, N.; McKenna, J. Annual Age-Grouping and Athlete Development: A Meta-Analytical Review of Relative Age Effects in Sport. *Sport. Med.* **2009**, *39*, 235–256. [CrossRef]
70. Dimundo, F.; Cole, M.; Blagrove, R.C.; McAuley, A.B.T.; Till, K.; Kelly, A.L. Talent Identification in an English Premiership Rugby Union Academy: Multidisciplinary Characteristics of Selected and Non-Selected Male Under-15 Players. *Front. Sport. Act. Living* **2021**, *3*, 688143. [CrossRef]
71. Lüdin, D.; Donath, L.; Cobley, S.; Romann, M. Effect of Bio-Banding on Physiological and Technical-Tactical Key Performance Indicators in Youth Elite Soccer. *Eur. J. Sport Sci.* **2021**, *22*, 1–9. [CrossRef]
72. Cumming, S.P.; Searle, C.; Hemsley, J.K.; Haswell, F.; Edwards, H.; Scott, S.; Gross, A.; Ryan, D.; Lewis, J.; White, P.; et al. Biological Maturation, Relative Age and Self-Regulation in Male Professional Academy Soccer Players: A Test of the Underdog Hypothesis. *Psychol. Sport Exerc.* **2018**, *39*, 147–153. [CrossRef]
73. Greydanus, D.E.; Omar, H.; Pratt, H.D. The Adolescent Female Athlete: Current Concepts and Conundrums. *Pediatr. Clin. North Am.* **2010**, *57*, 697–718. [CrossRef]
74. Monasterio, X.; Bidaurrazaga-Letona, I.; Larruskain, J.; Lekue, J.A.; Diaz-Beitia, G.; Santisteban, J.M.; Martin-Garetxana, I.; Gil, S.M. Relative Skeletal Maturity Status Affects Injury Burden in U14 Elite Academy Football Players. *Scand. J. Med. Sci. Sport.* **2022**, *32*, 1400–1409. [CrossRef] [PubMed]
75. Malina, R.M. Secular Trends in Growth, Maturation and Physical Performance: A Review. *Anthropol. Rev.* **2004**, *67*, 29.
76. Toselli, S.; Mauro, M.; Grigoletto, A.; Cataldi, S.; Benedetti, L.; Nanni, G.; Di Miceli, R.; Aiello, P.; Gallamini, D.; Fischetti, F.; et al. Maturation Selection Biases and Relative Age Effect in Italian Soccer Players of Different Levels. *Biology* **2022**, *11*, 1559. [CrossRef] [PubMed]
77. Grgic, O.; Shevroja, E.; Dhamo, B.; Uitterlinden, A.G.; Wolvius, E.B.; Rivadeneira, F.; Medina-Gomez, C. Skeletal Maturation in Relation to Ethnic Background in Children of School Age: The Generation R Study. *Bone* **2020**, *132*, 115180. [CrossRef] [PubMed]
78. Ontell, F.K.; Ivanovic, M.; Ablin, D.S.; Barlow, T.W. Bone Age in Children of Diverse Ethnicity. *Am. J. Roentgenol.* **1996**, *167*, 1395–1398. [CrossRef]
79. Tricco, A. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Ann. Intern. Med.* **2018**, *169*, 467–473. [CrossRef]

children

Article

Design and Reliability of an Observational Framework to Evaluate the Individual Offensive Behavior in Youth Soccer—The INDISOC Tool

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Abstract: Despite the great development of match analysis in professional soccer during the last decade, very few studies have assessed the individual technical and tactical behaviors of youth soccer players. The purpose of this paper was to design and assess the reliability of an observational instrument to evaluate the INDIvidual offensive behavior in competitive 7 and 11-a-side SOCcer (INDISOC). A total of eight experts in soccer training and analysis were included in the design of the tool by means of meetings and exploratory observations. This process involved design and re-design steps of the INDISOC tool to its final format which includes twelve dimensions related to the spatial, technical, and tactical constraints of individual behavior in soccer. The unit of analysis was the individual ball possession (IBP), described as the time that starts when a player can perform an action with the ball, and which ends when the IBP for another player begins. In the INDISOC tool, the IBP is analyzed taking into account three temporal moments: (1) receiving the ball, (2) processing the ball, and (3) culminating the individual action. Inter-observer and intra-observer analyses were performed and the kappa (K) coefficients were calculated to test the instrument reliability. The K values showed optimal inter (7-a-side: 0.73–0.95; 11-a-side: 0.76–0.98) and intra-observer (7-a-side: 0.84–1;11-a-side: 0.79–1) reliability levels. These results support the notion that the INDISOC observational tool could be a suitable instrument for analyzing the individual offensive behavior in competitive youth (7-a-side), junior and senior (11-a-side) soccer.

Keywords: observational methodology; match analysis; football; youth development; technical demands

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1. Introduction

The complex nature of the game of soccer (association football), considered as a dynamic and interactive phenomenon, makes it complicated to objectify its evaluation [1]. The recent technological innovations in the field of match analysis are leading to an increasing volume of data in professional soccer [2,3]. This fact is also contributing to the publication of a higher number of research papers about teams' performance during elite soccer competitions [4,5]. However, despite the great development of match analysis in the last years, there is limited research on the individual dimensions of performance in players, and especially in children [6,7]. Particularly, very few studies have assessed the individual technical and tactical performance of youth soccer players both in training and competition [8,9].

From a pedagogical perspective, evaluating the individual tactical performance may be crucial to design an appropriate learning process in youth ages. In this sense, Barreira, Casal, Losada, and Maneiro [10] suggested that the assessment of technical skills needs to be further developed in the natural context of soccer (i.e., small-sided games), by creating observational tools that allow to capture data during matches or other contextualized games. In this sense, one of the most important performance factors that discriminate between high-skilled and less-skilled soccer players is the ability to make optimal decisions during diverse match situations [11]. This ability allows players to solve different tactical situations with effectiveness under spatial and time constraints. For this reason, a key question for researchers in soccer is how to design observational tools to assess the tactical ability and talent of youth soccer players.

In this regard, systematic observation is considered a suitable methodology for analyzing tactical behavior [12] because it permits the inclusion of categorical data from the qualitative evaluation of different dimensions of match performance and may improve the ability to describe soccer match play actions [13,14]. From this methodology, a variety of observational tools have been created in the last decades to assess the players behaviors in soccer [15], such as the "Performance Assessment in Team Sports" (TSAP) [16], "Game Performance Assessment Instrument (GPAI) [17], "Procedural Tactical Knowledge Test (KORA) [18], "System of Tactical Assessment in soccer (FUT-SAT) [19], "Game performance evaluation tool" (GPET) [20], the "Instrument for Measurement of Learning and Performance in Football" (IMLPFoot) [21], the "observational tool for technical and tactical actions in the offensive phase in soccer [22], and the "Football Competence Observation System (FOCOS) [23].

These tools have provided interesting frameworks to analyze individual tactical behavior in soccer in different contexts. For instance, the GPAI, GPET, and KORA, designed for invasion sports, focus on evaluating the decision-making process of youth/beginner players (6–14 years old), based on the implementation of general principles of play related to the ball possession/progression and the numerical superiority or spatial advantage during small sided games. The IMLPFoot is a soccer-specific tool that focuses on the evaluation of the decision-making, technical execution, and results of the main offensive and defensive actions made by players during small sided games. Otherwise, The FUT-SAT instrument focuses on the tactical behavior, tactical performance, and decision making of players during the actual match play based on ten core tactical principles. However, this tool does not analyze the specific technical or tactical actions that the players display. The FOCOS tool analyzes the roles, the own actions of acquired subroles, and the principles adopted by the players in a small-sided game format (Gk + 4v4+ Gk), offering a complete analysis of the behaviors that the player can develop during their performance. Finally, the observational tool created by Ortega-Toro et al. [22] provides a technical–tactical analysis of the players during the start, development, and end of the individual ball possession. This interesting tool included the evaluation of dimensions related to the type of technical action, numerical situation in relation to the opposing team, and the offensive support of the player with the ball.

In general, the creation of these tools has helped researchers and coaches to perform studies about the technical and tactical skills in youth soccer players, as well as to explore the effect of different training tasks on the player's actions. For instance, Castelao et al. [24] used the FUTSAT tool and observed that smaller training formats such as 3v3 are more likely to emphasize tactical principles such as delay and penetration, whereas larger formats (e.g., 5v5) can increase the utilization of principles such as defensive unity and balance. Another example is the study of Praxedes et al. [25], which used the GPET to evaluate the positive improvements in passing and dribbling of youth soccer players after a training intervention based on modified soccer games in youth players.

However, despite the variety and quality of the existing observational tools, it is relevant to mention that their design is primarily oriented to the analysis of tactical skills occurring in modified versions of soccer, such as small sided games, what may limit their application to analyze players in the real competition. This fact has certain advantages such as increasing player participation, reducing the complexity of the game, and controlling the tactical environment where the player is evaluated. Nevertheless, this aspect also has limitations such as not considering the effects of the contextual variables, as well as not analyzing the player under the real physical, spatial, and time constraints.

On the other hand, it is crucial to highlight that due to the complex and interdependent nature of game actions in soccer, the individual performance of soccer players depends on their interaction with teammates, opponents, and spatial–temporal constraints. Nevertheless, the mentioned tools are not designed to analyze the interaction of the observed players with their teammates to capture the connection between the individual player and the team. In addition, the majority of these instruments do not consider the effect of the interaction between the player's actions and the opposing team's behavior.

Therefore, the aim of this study was to design an observational tool to analyze the INDIvidual offensive behavior in SOCcer (INDISOC) in 7-a-side and 11-a-side competition, considering the interaction of the player with the collective offensive behavior and the opposing team spatial and organizational constraints. The main objective of this tool is to help coaches and researchers to evaluate the tactical ability especially of young and junior players, but it is also applicable to senior players.

2. Methods

2.1. Participants

A total of eight experts participated throughout the process of designing the INDISOC observational tool, who met at least three of the following four inclusion criteria: (1) graduate in Sport Sciences, (2) hold a Soccer Coach UEFA Pro License, (3) have more than 5 years of soccer coaching experience at the academy or senior level, (4) have a PhD in observational methodology in team sports.

2.2. Procedure

The research design followed four steps based on the methodology used in previous studies that validated observational tools in team sports [22,26–28]. In the first step, a review of the literature was conducted to establish an exhaustive list of previously published observational tools and technical behaviors analyzed in research studies (the major databases explored were SportDiscus®, PubMed, Web of Science, Google Scholar, and Dialnet). As for previous observational tools, it is important to highlight the most recent instruments for the individual analysis in soccer such as the FUT-SAT [19], GPET [20], S-SBMT [29], IMLPFoot [21], and FOCOS [23]. It is crucial to mention that other studies such as the one of Ortega-Toro et al. [22] developed the idea of considering three different moments within the IBP, which offered another perspective in the analysis of technical and tactical actions in soccer. In this manner, the player´s behavior could be evaluated according to several dimensions at the start, development, and the end of IBPs. Regarding the technical actions, previous studies usually analyzed ball technical actions such as "passes, touches per possession, passes towards the opponent goal, successful passes, shots, crosses, dribbles, clearances, aerial challenges, interceptions, losses of control, tackles, corners, free kicks, throw-ins, and rules breached" [30,31].

The second step consisted of designing a proposal for elaborating an observational tool for the analysis of individual tactical behavior in soccer. For this purpose, a group of four internal experts was created and group meetings were conducted to develop the tool construction. The group of experts set the objective to create a tool that was able not only to analyze the technical actions but also to evaluate the tactical context where the actions take place according to the collective behavior and opponent interaction. With this idea, the tool must include the analysis of individual, environmental, and task constraints, such as previous studies claimed [32,33]. Additionally, the group of experts decided to focus on the analysis of the attacker with the ball, discarding the analysis of defensive actions or offensive actions off the ball. The attacker with the ball includes the behavior of goalkeepers, although no specific dimensions are created for this field position as in the study of Jara et al. [28]. This decision, despite the limitations it entails, was made to design a very specific tool based on offensive actions with the ball.

In this way, practices of exploratory observation to identify potential dimensions and categories were carried out by the experts. Initially, the unit of analysis was exclusively the technical–tactical action developed by the player, including one only temporal moment. In this stage, a total of 22 possible dimensions were identified and explored. However, the re-design carried out throughout the exploratory observations reduced the dimensions to 16, discarding those dimensions less relevant and those who provided redundant information. Additionally, due to the complexity and temporal variability of the players' tactical behaviors, different temporal moments were identified within the individual sequences. In this manner, the unit of analysis changed from the technical–tactical action to the "individual ball possession" [34], differentiating three temporal moments during the IBP (receiving the ball, processing the ball, culminating the action), which is similar to the observational tool created by Ortega-Toro et al. [22]. Once the main variables and categories were developed and no more appearance of new behaviors was detected during exploratory observation, a theoretical document including operational definitions and graphic representations was made.

In the third step, content validity was established through the consultation of other four external experts and Aikens´s V coefficient was calculated [35]. In this regard, group meetings with these experts were set to analyze the content of the theoretical framework of the INDISOC tool. During these meetings, the experts were asked about (a) the level of comprehension of the operational definitions of the dimensions from the observational tool; (b) the level of pertinence of these dimensions; (c) the need to include other dimensions in the observational tool; and (d) the overall evaluation of the observational tool. In this process, the dimensions of the INDISOC tool were reduced from 16 to 12, focusing on those dimensions more relevant and easier to analyze and interpret, according to the suggestions made by the external experts.

In the fourth step, the inter-observer and intra-observer reliability was tested for both 7-a-side and 11-a-side soccer. For this purpose, two observers were trained in the use of the INDISOC tool for four weeks. This training included theoretical and practical lessons, exploratory observations, and discussion between the observers and the internal experts. For 7-a-side soccer, the observer and the main researcher analyzed 163 IBPs corresponding to two matches of the U12 tournament LaLiga *Promises* 2021. For 11-a-side soccer, the other observer and the main researcher analyzed 103 IBPs performed by the Spanish player Pedri during the match Spain versus Sweden in the 2020 Eurocup. For the analysis of interpretative stability, the main researcher re-observed the IBPs four weeks later to check the intra-observer reliability.

Ethical approval was not required for this study because the tactical analyses of players were performed in matches that were recorded from TV broadcasters and the videos were public. In this regard, confidentiality was not an issue and authorization was not required from the observed players, so that the research consisted solely of naturalistic observation in a public TV broadcast of a routinary competition of soccer players in their teams [36,37] where no invasive, individual, or identifiable measures were performed.

2.3. Observational Instrument

The INDISOC instrument is a combination of field format and category systems [38]. The observation design is punctual, because the data collection takes place in one single session, idiographic, because it is focused on a study unit (the player), and multidimensional, because the player´s performance is based on various criteria [39].

The unit of analysis is the IBP, described by Link and Hoernig [34] as the time that starts when a player can perform an action with the ball (following an IBP of another player or a game interruption) and it ends when an IBP for another player begins. As is shown in Figure 1, the IBP is evaluated in three different moments: (1) receiving the ball: this period involves just the moment when the observed player comes into contact with the ball; (2) processing the ball: this period covers the time since the player comes into contact with the ball until he/she stops being in contact with it; and (3) culminating the action: this period covers the time since the player makes the last contact with the ball until a tactical outcome is achieved.

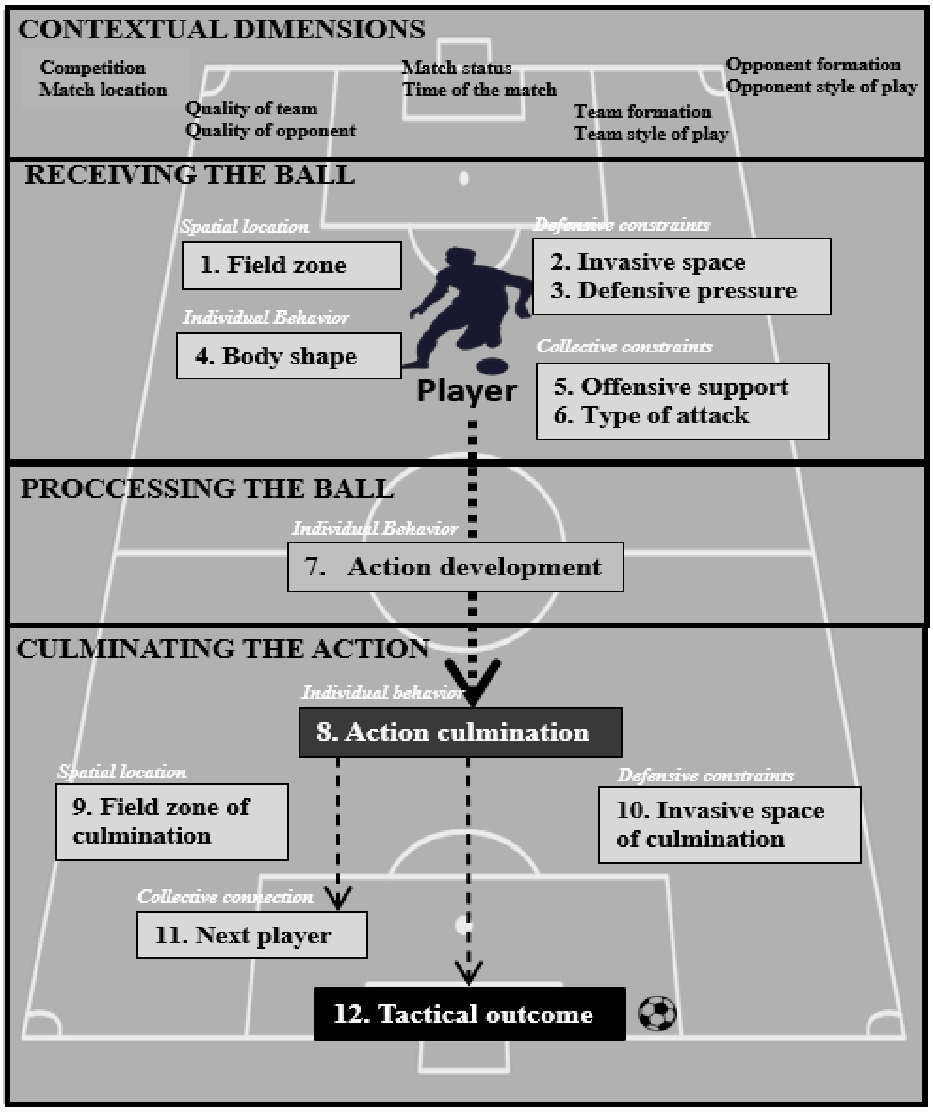


Figure 1. Scheme of the macro-criteria, temporal moments, and dimensions of the INDISOC tool.

2.4. Receiving the Ball

When the player receives the ball, six different dimensions are analyzed to capture the spatial and tactical context where the player starts the IBP (Table 1). To capture the location of the players, two key dimensions were created. First, the field space was divided into four sectors and four channels, forming sixteen different zones that evaluate the specific location of the players in relation to the official soccer field (Figure 2). It is important to highlight that in the offensive sector, specific zones were created based on the scoring pentagon, which a determined space where there is less than 20 m from the goal and exists high shooting angle, aspects that are crucial to score goals [40–42]. According to this pentagon, different areas are subdivided into zones in order to perform a more specific analysis of the individual possessions that achieve goals or scoring chances [42].

Secondly, this tool evaluates the location of the player in relation to the position of the defensive team. This fact aims to evaluate the players' actions in a representative spatial and tactical context. For this purpose, the opponent interaction is captured using the space of defensive occupation (SDO) [43] that in our tool is called "invasive space" because the location of the player within this space shows the level of invasion over the opposing defensive organization. The SDO was defined by Grehaigne [44] as the space that is formed by the positions of the players located, at a specific moment, in the periphery of a team in play, except the goalkeeper. This defensive shape creates different subspaces that are dynamic and change every second depending on the movement of the players. In this way, the location of the ball carrier in relation to the SDO of the opponent is evaluated based on ten subspaces that have been created considering previous studies [42,43,45]. It is crucial to mention that the different subspaces of the SDO must be adapted depending on the competition format (7-a-side vs. 11-a-side) and tactical formation. Figure 3 shows the different subspaces according to the most used defensive tactical formations both in 7-a-side and 11-a-side [46–48]. In addition to the invasive space, the "defensive pressure" is the other dimension related to opponent interaction that reflects the closeness and behavior of defensive players in relation to the attacker with the ball when receiving the ball possession.

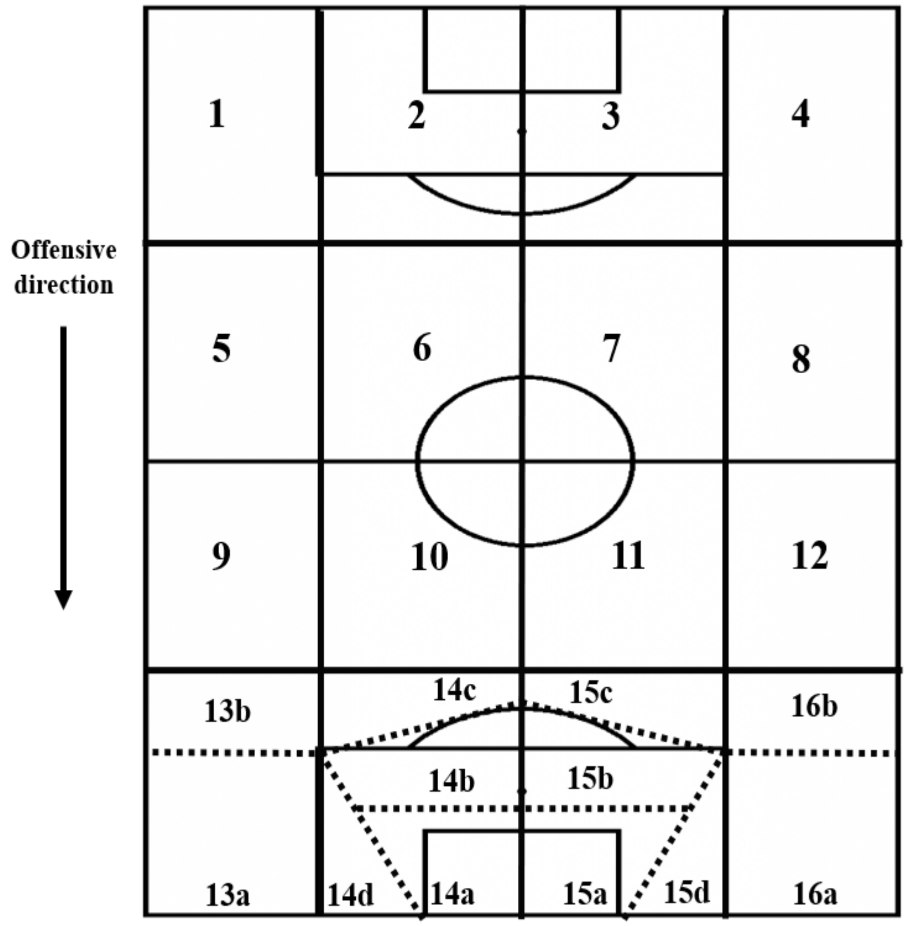


Figure 2. Zones of the field and "score pentagon". The "score pentagon" is subdivided into several areas to perform a more detailed evaluation of goals and goal scoring opportunities.

Furthermore, the INDISOC considers the offensive tactical scenario where the player receives the ball (Table 1). For that purpose, the dimension "offensive support" and "type of attack" are analyzed. The first dimension shows the number of possible passing options that the observed player has in the moment of receiving the ball. This dimension reflects the influence of the team positioning and available passing lanes on individual performance. Moreover, evaluating the type of attack contributes to contextualize the collective organization and the moment of play when the IBP takes place [49].

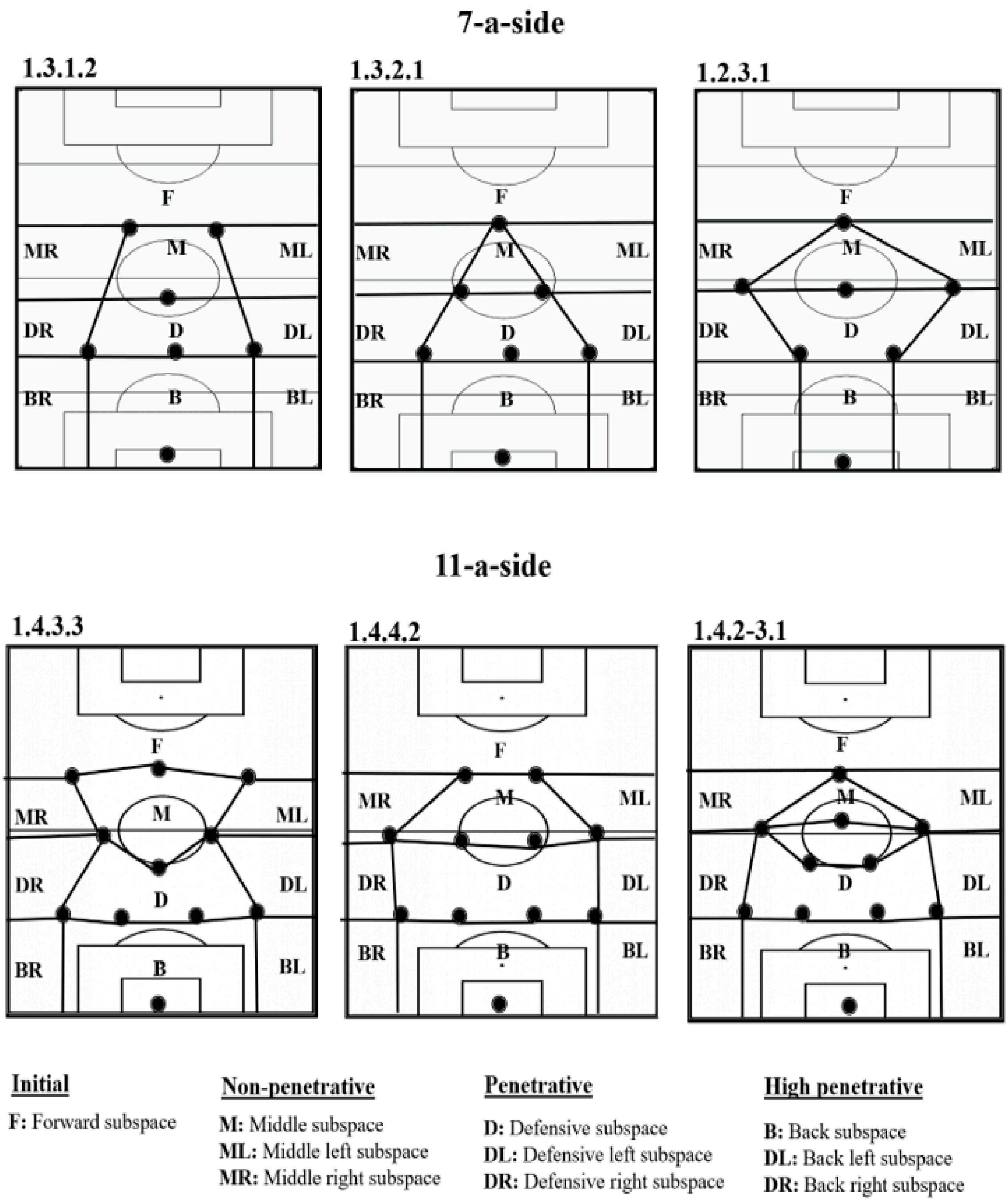


Figure 3. Different subspaces of the space of defensive occupation according to the tactical formation both in 7- and 11-a-side soccer.

Table 1. Operational definitions for the dimensions included in the moment of receiving the ball.

Dimension	Categories	Subcategories
1. Field zone Zone of the field where the player receives or recovers the ball (Figure 2)	**Defensive sector**	1; 2; 3; and 4.
	Pre-defensive sector	5; 6; 7; and 8
	Pre-offensive sector	9; 10; 11; and 12.
	Offensive sector	13a, 13b, 14a, 14b, 14c, 14d. 15a, 15b, 15c, 15d, 16a, 16b.
2. Invasive space Area within the SDO of the opponent where the player receives the ball (Figure 3)	**Initial subspace**	Forward zone **(F)**
	Non-penetrative subspace	Middle Right zone **(MR)**, Middle Left Zone **(ML)**, Middle zone **(M)**
	Penetrative subspace	Defensive right zone **(DR)**, defensive left zone **(DL)**, defensive zone **(D)**
	High-penetrative subspace	Back right zone **(BR)**, back left zone **(BL)**, back zone **(B)**.
3. Defensive pressure Distance between the player with the ball and the immediate pressuring of opponent player(s) during the first three seconds of ball possession	**Initial pressure:** one or several opponent players pressure the attacker within the first 3 s of the possession (the defender(s) are located within 1.5 m of the player) **Non-initial pressure:** any player pressures the attacker during the first 3 s of the possession.	
4. Body shape Body orientation with respect to the opponent goal at the moment of receiving the ball	**Facing the goal:** Player's chest is facing the opposing goal **Facing right:** Player's chest is facing the right line in relation to the opposing goal **Facing left:** Player's chest is facing the left side in relation to the opposing goal **Back to goal:** Player's back is facing the opposite side of the opposing goal.	
5. Offensive support Number of passing options that the on-the-ball attacker possesses at the moment of receiving the ball possession.	**Offensive support**	**Many options:** The player has open passing lanes with three or more teammates **Few options:** The player has open lanes with one or two teammates
	No offensive support	**No options:** The player has no open passing lanes with his/her teammates.
6. Type of attack Degree of offensive directness in the offensive process [14,50].	**Positional attack:** (a) The team possession begins by winning the ball in play or restarting the game, (b) the opposing team is prepared defensively, and (c) the circulation of the ball takes place more in width than in depth [50] and the intention of the team is to disorder the opponent using either fast, direct, or combinative play. **Counterattack:** (a) The team possession begins by winning the ball in play, (b) the progression towards the goal attempts to utilize a degree of imbalance from start to the end with high tempo [14], (c) the intention of the team is to exploit the space left by the opposing team when they were attacking, and (d) the opposing team does not have the opportunity to reorganize their system and be prepared defensively.	

2.5. Processing the Ball

Immediately after receiving the ball, the INDISOC analyzes the type of ball processing actions that players decide to perform by differentiating between quick actions based on receiving/passing and actions based on carrying the ball and dribbling (Table 2).

2.6. Culminating the Action

After processing the ball and depending on the tactical scenario, players can decide between multiple options to culminate their action and contribute to the success of the team's offensive sequence (Table 3). This moment is evaluated by the INDISOC tool by analyzing five dimensions. The first dimension is the type of "action culmination", which evaluates the degree of penetration over the opponent that players try to achieve with their actions based on the offensive principles of play. In addition to evaluate the tactical intention, this dimension includes subcategories that specify the technical–tactical actions executed by the players. For example, this dimension not only register if the player tries to shoot at goal, but also what type of shot performs, differentiating between volleys, headers, and one-touch shots, etc. Thus, this dimension offers a complete analysis of players' tactical and technical performance when culminating their individual actions. To tactically contextualize this action, the field zone, and the invasive space of the opponent where it takes place, are also registered within this moment.

Table 2. Operational definitions for the dimensions included in the moment of processing the ball.

Dimension	Categories	Subcategories
7. Type of action. Behavior of the ball carrier since he/she receives the ball until the culmination of his/her action.	**Receiving and passing**	**One-touch action:** The ball carrier only needs one contact with the ball to culminate his/her action. **Quick action (2–4 ball touches):** the ball carrier needs few contacts with the ball to culminate his/her action
	Running with the ball	**Carrying the ball:** the ball carrier runs with the ball performing multiple touches or directional changes. **Dribbling:** The ball carrier attempts to beat an opponent in possession of the ball

Table 3. Operational definitions for the dimensions included in the moment of culminating the action.

Dimension	Categories	Subcategories
8. Action culmination: Final action of the player that intends to pass to a teammate or to shoot at the goal	**Possess**	**Non-penetrative pass:** the ball carrier performs a pass that does not past opponent player(s)
	Progress	**Penetrative pass:** the ball carrier performs a pass towards the opponent's goal past opponent player(s) Key pass: the ball carrier performs a pass from central channels of the field that breaks the opposing defensive line.
	Assist	**Key pass with assist:** the ball carrier performs a pass from central channels of the field that breaks the opposing defensive line and allows the receiver to have an immediate scoring opportunity **Cross:** the ball carrier performs a pass from the exterior channels of the field in the opposing half (Figure 2) towards the penalty box **Goal pass:** the ball carrier performs a pass from the penalty box that allows the receiver to have an immediate scoring opportunity
	Finish	**Shot-feet:** the ball carrier shoots at the goal while the ball is on the ground using two or more contacts to the ball. **Shot-feet (one-touch):** the ball carrier shoots at the goal while the ball is on the ground using one single contact to the ball **Header:** the ball carrier shoots at the goal while the ball is in the air by heading the ball. **Volley:** the ball carrier shoots at goal while the ball is in the air by using one single contact to the ball
	Other	**No culmination:** The ball carrier does not achieve ball possession. **Long ball:** The ball carrier performs a long distance (+40 m) and high pass without a clear receiver. **Clearance:** The ball carrier clears the ball away without a defined offensive purpose.

Table 3. *Cont.*

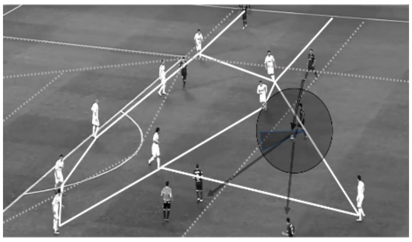
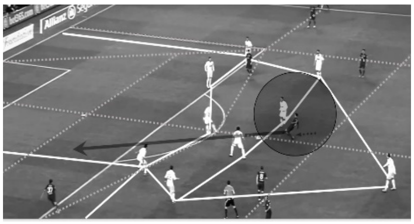
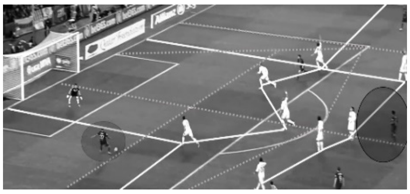
Dimension	Categories	Subcategories
9. Field zone of culmination Zone of the field where the player performs the final action of the IBP (Figure 2)	**Defensive sector**	1; 2; 3; and 4.
	Pre-defensive sector	5; 6; 7; and 8
	Pre-offensive sector	9; 10; 11; and 12.
	Offensive sector	13a; 13b; 14a; 14b; 14c; and 14d. 15a; 15b; 15c; 15d; 16a; and 16b.
10. Invasive space of culmination Area within the Space of Defensive Occupation (SDO) of the opponent where the observed player performs the final action of the IBP (Figure 3)	**Initial subspace**	Forward zone **(F)**:
	Non-penetrative subspace	Middle Right zone **(MR)**, Middle Left Zone **(ML)**, Middle zone **(M)**
	Penetrative subspace	Defensive right zone **(DR)**, defensive left zone **(DL)**, defensive zone **(D)**
	High penetrative subspace	Back right zone **(BR)**, back left zone **(BL)**, back zone **(B)**.
11. Individual tactical outcome: Final performance of the action, considering the success when passing/shooting.	**Successful (1)**	Pass completed/Goal/Foul received, corner or throw-in achieved.
	No Successful (0)	Pass intercepted/missed/Shot off target./Ball out of play/Ball lost by tackle/Turnover/Foul committed/No control of the ball:.
12. Next teammate *: Receiving player when the observed player performs a pass.	**Goalkeeper**	Goalkeeper
	Full back	Left full back; Right full back
	Central back	Right Central Back; Left Central Back
	Midfielders	Defensive midfielder; Offensive midfielder
	Wingers	Right winger; Left winger
	Forwards	Forward
	No connection	The observed player does not perform a pass

* The categories and sub-categories of this dimension may be adjusted depending on the team formation used by the observed team.

Finally, the tactical outcome of the IBP was evaluated by analyzing two dimensions. On one hand, the dimension “next player” registers the connection between the observed player and the next receiving player, when the culminating action is a pass. This evaluation allows evaluating the passing interaction between players and quantifying the most frequent passing networks of the observer player. On the other hand, the last dimension called “tactical outcome” is key to quantify the success of the action depending on the achieved performance. In this sense, the player will achieve a successful action if the pass connects to a receiving player, or the shot achieves goal. Additionally, an IBP is considered successful if the observed player receives a foul when processing the ball or achieves a corner-kick or throw-in for the attacking team. This last dimension can be used as a dependent variable in research studies to check the interactive effect of the previous independent dimensions on the tactical success of individual ball possessions.

In Table 4, a practical example of the analysis of a specific IBP in 11-a-side soccer can be observed. In this example, the three moments of the IBP are shown graphically, where the key task and individual constraints under analysis are highlighted, such as the invasive space, the field zone of intervention, the offensive support, body shape, and the action culmination. Additionally, in this specific example, the tool shows the requirement of completeness, so that any behavior under analysis could be assigned to one of the categories and subcategories. Additionally, the tool meets the criterion of mutual exclusivity, since there is not overlap of the categories and each analyzed behavior was assigned to a single category [38].

Table 4. Example of analysis of the IBP using the dimensions of the INDISOC tool.

Moment	Dimension	Category	Subcategory
Receiving the ball 	**1. Field zone** **2. Invasive space** **3. Defensive pressure** **4. Body shape** **5. Offensive support** **6. Type of attack**	Pre-offensive Non-penetrative No pressure Facing forward Offensive support Organized attack	10 Middle zone - - Many options -
Processing the ball 	**7. Type of action**	Controlling and passing	Quick action
Culminating the action 	**8. Action culmination** **9. Field zone of culmination** **10. Invasive space of culmination** **11. Next player** **12. Tactical outcome**	Assist Offensive Non-penetrative Wingers Positive	Key pass with assist 14c Middle zone Left winger Pass completed

2.7. Statistical Analysis

To evaluate the inter- and intra-observer concordance of the INDISOC dimensions, Cohen's kappa index [51] was calculated using the LINCE-PLUS software [52].

3. Results

Table 5 shows the values of content validity in form of Aiken's V coefficients for each of the dimensions that form the INDISOC tool. It can be observed that all dimensions presented values higher than 0.85 both for pertinence and comprehension. Additionally, a lower average value was obtained in comprehension (0.93) than in pertinence (0.97).

Table 6 shows the Kappa (K) values for each of the dimensions of the INDISOC observational tool. In general, all K values were higher than 0.73 for the sub-categories section and 0.81 for the categories section.

The K values of the inter-observer analysis were lower (0.73–0.98) than the values of the intra-observer analysis (0.79–1). Furthermore, the K values for the categories were higher than when these categories were divided into sub-categories both for inter-observer (0.85–0.97 vs. 0.73 vs. 0.93) and intra-observer (0.89–1 vs. 0.79–0.98), respectively.

The lowest K values were obtained in dimensions related to the invasive space both for the moment of receiving the ball (0.73–0.89) and culminating the action (0.76–0.87). On the other hand, the highest K values were observed for dimensions related to the field zones (0.90–1), type of attack (0.95–1), and tactical outcome (0.85–0.98).

Table 5. Values of content validity (Aikens's V) of the dimensions that form the INDISOC observational tool.

Moment	Dimension	Aikens's V	
		Pertinence	Comprehension
Receiving the ball	1. Field zone	1	0.92
	2. Invasive space	0.95	0.91
	3. Defensive pressure	1	0.87
	4. Body shape	1	0.97
	5. Offensive support	1	0.95
	6. Type of attack	0.95	0.88
Processing the ball	7. Type of action	1	0.92
Culminating the action	8. Action culmination	0.95	0.95
	9. Field zone of culmination	1	0.92
	10. Invasive space of culmination	0.95	0.91
	11. Next teammate	0.85	0.87
	12. Tactical outcome	1	0.87
Average score		0.97	0.93

Table 6. Kappa values obtained for the dimensions of the INDISOC observational tool in 7-a-side and 11-a-side soccer.

7-a-Side Soccer					
Moment	Dimension	*K* Inter-Observer		*K* Intra-Observer	
		Categories	Subcategories	Categories	Subcategories
Receiving the ball	1. Field zone	0.93	0.90	0.98	0.93
	2. Invasive space	0.83	0.73	0.93	0.86
	3. Defensive pressure	0.82	-	0.95	
	4. Body shape	0.95	-	0.98	
	5. Offensive support	0.90	0.84	0.91	0.88
	6. Type of attack	0.95	-	0.98	
Processing the ball	7. Type of action	0.91	0.82	0.97	0.95
Culminating the action	8. Action culmination	0.89	0.82	0.99	0.93
	9. Field zone of culmination	0.94	0.90	1	0.98
	10. Invasive space of culmination	0.81	0.74	0.88	0.84
	11. Next teammate	0.95	-	1	
	12. Tactical outcome	0.92	0.85	0.96	0.91

Table 6. *Cont.*

11-a-Side Soccer					
Moment	**Dimension**	***K* Inter-Observer**		***K* Intra-Observer**	
		Categories	**Subcategories**	**Categories**	**Subcategories**
Receiving the ball	1. Field zone	0.97	0.92	1	0.96
	2. Invasive space	0.86	0.78	0.89	0.81
	3. Defensive pressure	0.88	-	0.94	
	4. Body shape	0.93	-	0.98	
	5. Offensive support	0.93	0.85	0.97	0.92
	6. Type of attack	0.97	-	1	
Processing the ball	7. Type of action	0.98	0.87	1	0.97
Culminating the action	8. Action culmination	0.91	0.81	0.95	0.89
	9. Field zone of culmination	0.98	0.93	1	0.98
	10. Invasive space of culmination	0.85	0.76	0.87	0.79
	11. Next teammate	0.97	-	1	
	12. Tactical outcome	0.94	0.91	0.98	0.96

4. Discussion

The aim of this study was to design and check the reliability of an observational tool to analyze the individual offensive behavior in competitive 7- and 11-a-side soccer.

Firstly, this paper presented the design process of the INDISOC tool, which provides an observational framework to analyze individual offensive behavior in competitive soccer, and especially in youth players. In comparison with previous instruments, this tool not only evaluates the individual behavior, but also considers the influence of environmental and task constraints such as contextual variables, spatial location, defending positioning, and pressure, as well as the team's collective organization and passing support. In fact, some of the dimensions included in this instrument such as the invasive space, defensive pressure and type of attack have been adapted from the REOFUT tool [42], which is designed to analyze the collective performance in soccer. The inclusion of real game constraints provides greater contextualization of the players' behavior, as previous studies claimed [32,33,53], and gives researchers the possibility to analyze the interactive effects of multiple dimensions on individual behavior and performance.

Additionally, this observational tool is different from previous instruments such as the GPET [20], IMLPFoot [21], or FOCOS [23] because of its exclusive focus on analyzing the real 7- and 11-a-side competition, which can complement the information provided by the mentioned tools in training formats. In fact, the INDISOC shares with tools such as the GPAI [17], GPET [20], or FUT-SAT [19] the evaluation of individual behaviors considering their relationship with offensive principles of play [54]. However, one of the most crucial aspects of the INDISOC is to describe in detail the type of technical–tactical actions that can be performed both for processing the ball and culminating the actions, focusing on its tactical functionality rather than solely its execution, as some authors suggested [55]. In this sense, the INDISOC tool presents some similar features in relation to the observational framework created by Ortega-Toro et al. [22]. Specifically, both tools organize the observation in the same three temporal moments of the IBP (start, development, and end) and evaluate some common dimensions such as the player's offensive support and type of technical actions performed. However, the INDISOC tool focuses its analysis on the implementation of the offensive principles of play, as well as evaluates the technical–tactical performance with different categories. In fact, the format of this tool that includes categories and subcategories allows researchers to have two levels of analysis to modulate the specificity of the tactical evaluation. Considering the subcategories, the INDISOC permits not only to evaluating the tactical principle implemented by the player (i.e., possess, progress, finish), but also analyzing in detail the type of action executed (i.e., penetrative pass, key pass, cross, header, volley, etc.).

Secondly, this paper checked the reliability of INDISOC through the analysis of agreement according to the proposal of the Kappa index, considered as a suitable method to measure the agreement for categorical data in sport performance [56]. In this sense, the INDISOC dimensions showed an excellent level of reliability according to the criteria of previous studies [57,58]. Specifically, the inter-observer analysis registered lower levels of reliability than the intra-observer one. This fact may be possible due to the nature of some dimensions, where the interpretation by the observers has a greater importance and, therefore, some observations may naturally be more complex to perform more accurately than others [59].

For instance, the dimensions "field zone", "body shape", "type of attack", "next teammate", and "field zone of culmination" registered K values higher than 0.90 both for categories and subcategories. This high level of reliability is probably due to a lower degree of interpretation by the observers when analyzing the game actions. However, the two dimensions related to the invasive space obtained the lowest levels of agreement, especially considering the analysis of subcategories (inter-observer = 0.73–0.86; intra-observers: 0.79–0.89). This fact could be related to the dynamic nature of the subspaces within the SDO that change every second during the IBP and require a higher degree of interpretation by the observers. Nevertheless, our analysis agrees with previous studies in demonstrating that the evaluation of the SDO can be a reliable measure for the analysis of the game space in soccer [42,43,45].

The presented tool has several limitations. On one hand, the tactical evaluation is only focused on the offensive moment and, particularly, on the attacker with the ball. Thus, this tool does not analyze the offensive behaviors off the ball and the defensive moment. This fact, despite being reductionist considering the globality of the game, makes this tool more specific and focuses exclusively on the actions with the ball, which have a key weight in the offensive individual and collective performance. On the other hand, this tool is based on notational analysis and therefore on the observation, interpretation, and recording of events that occur during the game. This method may not entirely capture the complex and interactive nature of individual tactical actions during the game, as some authors have claimed [60–62]. Finally, the next limitation can also be considered an opportunity for development in the future. INDISOC has been designed and validated only for the analysis of 7- and 11-a-side competitive soccer. Thus, the next step for this research group should be to explore its adaptation to analyze small-sided games, which would expand its use in multiple contexts.

Nevertheless, the INDISOC provides relevant applications both for the academic and professional fields. Academically, this tool can be used for researchers to perform case-studies of players, playing positions, specific teams, or competitions in both 7-a-side and 11-a-side soccer. In this vein, the design of this tool allows researchers to carry out descriptive, comparative, and predictive analyses, where the combined and interactive effects of environmental, task, and individual constraints on tactical performance can be evaluated. Additionally, this tool can be used in conjunction with other types of data (positional data) in order to create mixed-method (quantitative and qualitative) analyses. From a professional perspective, this tool can be useful for coaches and performance analysts especially in youth soccer to evaluate the individual performance of specific players and design appropriate learning processes in children and adolescent players.

In conclusion, the results of the present study indicated optimal inter- and intra-reliability levels, suggesting that the INDISOC observational tool could be a suitable tool for analyzing individual offensive behavior in competitive 7- and 11-a-side soccer.

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References

1. Sarmento, H.; Anguera, M.; Campaniço, J.; Leitão, J. Development and Validation of a Notational System to Study the Offensive Process in Football. *Medicina* **2010**, *46*, 401–408. [CrossRef] [PubMed]
2. Goes, F.R.; Meerhoff, L.A.; Bueno, M.J.O.; Rodrigues, D.M.; Moura, F.A.; Brink, M.S.; Elferink-Gemser, M.T.; Knobbe, A.J.; Cunha, S.A.; Torres, R.S.; et al. Unlocking the Potential of Big Data to Support Tactical Performance Analysis in Professional Soccer: A Systematic Review. *Eur. J. Sport Sci.* **2020**, *21*, 481–496. [CrossRef] [PubMed]
3. Link, D.; Lang, S.; Seidenschwarz, P. Real Time Quantification of Dangerousity in Football Using Spatiotemporal Tracking Data. *PLoS ONE* **2016**, *11*, e0168768. [CrossRef]
4. Low, B.; Coutinho, D.; Gonçalves, B.; Rein, R.; Memmert, D.; Sampaio, J. A Systematic Review of Collective Tactical Behaviours in Football Using Positional Data. *Sport. Med.* **2020**, *50*, 343–385. [CrossRef] [PubMed]
5. Forcher, L.; Altmann, S.; Forcher, L.; Jekauc, D.; Kempe, M. The Use of Player Tracking Data to Analyze Defensive Play in Professional Soccer-A Scoping Review. *Int. J. Sport. Sci. Coach.* **2022**, 17479541221075734. [CrossRef]
6. Sarmento, H.; Anguera, M.T.; Pereira, A.; Araújo, D. Talent Identification and Development in Male Football: A Systematic Review. *Sport. Med.* **2018**, *48*, 907–931. [CrossRef]
7. Sarmento, H.; Marcelino, R.; Anguera, M.T.; Campaniço, J.; Matos, N.; Leitão, J.C. Match Analysis in Football: A Systematic Review. *J. Sport. Sci.* **2014**, *32*, 1831–1843. [CrossRef]
8. Práxedes, A.; Del Villar Álvarez, F.; Moreno, A.; Gil-Arias, A.; Davids, K. Effects of a nonlinear pedagogy intervention programme on the emergent tactical behaviours of youth footballers. *Phys. Educ. Sport Pedagog.* **2019**, *24*, 332–343. [CrossRef]
9. de Assis, V.J.; González-Víllora, S.; Clemente, F.M.; Cardoso, F.; Teoldo, I. Do Youth Soccer Players with Different Tactical Behaviour Also Perform Differently in Decision-Making and Visual Search Strategies? *Int. J. Perform. Anal. Sport* **2020**, *20*, 1143–1156. [CrossRef]
10. Barreira, D.; Casal, C.A.; Losada, J.L.; Maneiro, R. Editorial: Observational Methodology in Sport: Performance Key Elements. *Front. Psychol.* **2020**, *11*, 59556. [CrossRef]
11. Roca, A.; Ford, P.; McRobert, A.; Williams, A. Perceptual-Cognitive Skills and Their Interaction as a Function of Task Constraints in Soccer. *J. Sport Exerc.* **2013**, *35*, 144–155. [CrossRef]
12. Anguera, M.; Mendo, A. La Metodología Observacional En El Ámbito Del Deporte. *E-balonmano.com Rev. Cienc. Deporte* **2013**, *9*, 135–160.
13. Hughes, M.; Bartlett, R. The Use of Performance Indicators in Performance Analysis. *J. Sport. Sci.* **2002**, *20*, 739–754. [CrossRef]
14. Tenga, A.; Kanstad, D.; Ronglan, L.; Bahr, R. Developing a New Method for Team Match Performance Analysis in Professional Soccer and Testing Its Reliability. *Int. J. Perform. Anal. Sport* **2009**, *9*, 8–25. [CrossRef]
15. González-Víllora, S.; Serra-Olivares, J.; Pastor-Vicedo, J.C.; da Costa, I.T. Review of the Tactical Evaluation Tools for Youth Players, Assessing the Tactics in Team Sports: Football. *Springerplus* **2015**, *4*, 663. [CrossRef] [PubMed]
16. Grehaigne, J.; Godbout, P.; Bouthier, D. Performance Assessment in Team Sports. *J. Teach. Phys. Educ.* **1997**, *16*, 500–516. [CrossRef]
17. Oslin, J.; Mitchell, S.; Griffin, L. The Game Performance Assessment Instrument (GPAI): Development and Preliminary Validation. *J. Teach. Phys. Educ.* **1998**, *17*, 231–243. [CrossRef]
18. Roth, K.; Kroger, C. *Escola da Bola-Um ABC para Iniciantes nos Jogos Esportivos*; Phorte Editora: Sao Paulo, Brazil, 2002.
19. Teoldo, I.; Garganta, J.; Greco, P.; Mesquita, I.; Maia, J. System of Tactical Assessment in Soccer (FUT-SAT): Development and Preliminary Validation. *Motricidade* **2011**, *7*, 69–83.
20. Garcia-López, L.; González-Villora, S.; Gutierrez, D.; Serra-Olivares, J. Development and Validation of the Game Performance Evaluation Tool (GPET) in Soccer. *Sport TK* **2013**, *2*, 89–99.

21. García-Ceberino, J.; Antúnez, A.; Ibañez, S.; Feu, S. Design and Validation of the Instrument for the Measurement of Learning and Performance in Football. *Int. J. Environ. Res. Public Health* **2020**, *17*, 4629. [CrossRef]
22. Ortega-Toro, E.; García-Angulo, A.; Giménez-Egido, J.M.; García-Angulo, F.J.; Palao, J.M. Design, Validation, and Reliability of an Observation Instrument for Technical and Tactical Actions of the Offense Phase in Soccer. *Front. Psychol.* **2019**, *10*, 22. [CrossRef] [PubMed]
23. Sánchez-López, R.; Echeazarra, I.; Castellano, J. Validation of a Football Competence Observation System (FOCOS), Linked to Procedural Tactical Knowledge. *Sustainability* **2021**, *13*, 6780. [CrossRef]
24. Castelão, D.; Garganta, J.; Santos, R.; Teoldo, I. Comparison of Tactical Behaviour and Performance of Youth Soccer Players in 3v3 and 5v5 Small-Sided Games. *Int. J. Perform. Anal. Sport* **2014**, *14*, 801–813. [CrossRef]
25. Práxedes, A.; del Villar, F.; Pizarro, D.; Moreno, A. The Impact of Nonlinear Pedagogy on Decision-Making and Execution in Youth Soccer Players According to Game Actions. *J. Hum. Kinet.* **2018**, *62*, 185–198. [CrossRef]
26. Ibáñez, S.J.; Martinez-Fernández, S.; Gonzalez-Espinosa, S.; García-Rubio, J.; Feu, S. Designing and Validating a Basketball Learning and Performance Assessment Instrument (BALPAI). *Front. Psychol.* **2019**, *10*, 1595. [CrossRef]
27. Villarejo, D.; Ortega, E.; Gómez, M.Á.; Palao, J.M. Design, Validation, and Reliability of an Observational Instrument for Ball Possessions in Rugby Union. *Int. J. Perform. Anal. Sport* **2014**, *14*, 955–967. [CrossRef]
28. Jara, D.; Gómez, M.; Ortega, E.; Saiz de Baranda, P. Design, Validation, and Reliability of an Observational Instrument for the Defensive and Offensive Technical-Tactical Actions of the Goalkeeper. *Kinesiology* **2020**, *52*, 257. [CrossRef]
29. Cobb, N.; Unnithan, V.; McRobert, A. The Validity, Objectivity, and Reliability of a Soccer-Specific Behaviour Measurement Tool. *Sci. Med. Football* **2018**, *2*, 196–202. [CrossRef]
30. Bergmann, F.; Braksiek, M.; Meier, C. The Influence of Different Game Formats on Technical Actions and Playing Time Parameters—A Study with under-7 and under-9 Soccer Players in a Competitive Context. *Int. J. Sport. Sci. Coach.* **2022**, 17479541211051654. [CrossRef]
31. Gai, Y.; Volossovitch, A.; Leicht, A.; Gómez, M. Technical and Physical Performances of Chinese Super League Soccer Players Differ According to Their Playing Status and Position. *Int. J. Perform. Anal. Sport* **2019**, *19*, 878–892. [CrossRef]
32. Mackenzie, R.; Cushion, C. Performance Analysis in Football: A Critical Review and Implications for Future Research. *J. Sport Sci.* **2013**, *31*, 639–676. [CrossRef] [PubMed]
33. Travassos, B.; Davids, K.; Araújo, D.; Esteves, T.P.; Esteves, P.T. Performance Analysis in Team Sports: Advances from an Ecological Dynamics Approach. *Int. J. Perform. Anal. Sport* **2013**, *13*, 83–95. [CrossRef]
34. Link, D.; Hoernig, M. Individual Ball Possession in Soccer. *PLoS ONE.* **2017**, *12*, e0179953. [CrossRef]
35. Aiken, L.R. Three Coefficients for Analyzing the Reliability and Validity of Ratings. *Educ. Psychol. Meas.* **1985**, *45*, 131–142. [CrossRef]
36. American Psychological Association. *Ethical Principles of Psychologists and Code of Conduct*; American Psychological Association: Washington, DC, USA, 2010.
37. Winter, E.M.; Maughan, R.J. Requirements for Ethics Approvals. *J. Sport. Sci.* **2009**, *27*, 985. [CrossRef]
38. Anguera, M.; Magnusson, M.; Jonsson, G. Instrumentos No Estandar: Planteamiento, Desarrollo y Posibilidades. *Avan. Medicion* **2007**, *5*, 63–82.
39. Anguera, M.T.; Blanco Villaseñor, A.; Mendo, A.H.; Luis, J.; López, L. Diseños Observacionales: Ajuste y Aplicación En Psicología Del Deporte. *Rev. Psicol. Deporte* **2011**, *11*, 63–76.
40. Pollard, R.; Reep, C. Measuring the Effectiveness of Playing Strategies at Soccer. *J. R. Stat. Soc. Ser. D Stat.* **1997**, *46*, 541–550. [CrossRef]
41. Gonzalez-Rodenas, J.; Mitrotasios, M.; Aranda, R.; Armatas, V. Combined Effects of Tactical, Technical and Contextual Factors on Shooting Effectiveness in European Professional Soccer. *Int. J. Perform. Anal. Sport* **2020**, *20*, 280–293. [CrossRef]
42. Aranda, R.; González-Ródenas, J.; López-Bondia, I.; Aranda-Malavés, R.; Tudela-Desantes, A.; Anguera, M.T. "REOFUT" as an Observation Tool for Tactical Analysis on Offensive Performance in Soccer: Mixed Method Perspective. *Front. Psychol.* **2019**, *10*, 1476. [CrossRef]
43. Seabra, F.; Dantas, S. Space Definition for Match Analysis in Soccer. *Int. J. Perform. Anal. Sport* **2006**, *6*, 97–113. [CrossRef]
44. Grehaigne, J. *La Organización del Juego en el Fútbol*; INDE: Barcelona, Spain, 2001.
45. Castellano, J.; Mendo, A.H.; Gómez De Segura, P.; Fontetxa, E.; Bueno, I. Sistema de Codificación y Análisis de La Calidad Del Dato En El Fútbol de Rendimiento. *Psicothema* **2000**, *12*, 635–641.
46. Mesoudi, A. Cultural Evolution of Football Tactics: Strategic Social Learning in Managers' Choice of Formation. *Evol. Hum. Sci.* **2020**, *2*, E25. [CrossRef]
47. Delgado, J.; Longoria, R.; Enríquez, O.; Luján, R.; Gastélum, G. Sistemas Tácticos y Resultados de Competición Del Mundial de Fútbol Asociación de Rusia 2018. *Retos* **2019**, *36*, 503–509.
48. Pascual-Verdú, N.; Antonio Carbonell-Martínez, J.; Jiménez-Olmedo, J.M. Influence of Games System on the Physical and Physiological Demands in Young Soccer 7 (U12). *J. Phys. Educ. Sport* **2019**, *19*, 2411–2417. [CrossRef]
49. Hewitt, A.; Greenham, G.; Norton, K. Game Style in Soccer: What Is It and Can We Quantify It? *Int. J. Perform. Anal. Sport* **2016**, *16*, 355–372. [CrossRef]
50. Sarmento, H.; Figueiredo, A.; Lago-Peñas, C.; Milanovic, Z.; Barbosa, A.; Tadeu, P.; Bradley, P. Influence of Tactical and Situational Variables on Offensive Sequences during Elite Football Matches. *J. Strength Cond. Res.* **2018**, *32*, 2331–2339. [CrossRef]
51. Cohen, J. A Coefficient of Agreement for Nominal Scales. *Educ. Psychol. Meas.* **1960**, *20*, 37–46. [CrossRef]
52. Soto-Fernández, A.; Camerino, O.; Iglesias, X.; Anguera, M.T.; Castañer, M. LINCE PLUS Software for Systematic Observational Studies in Sports and Health. *Behav. Res. Methods* **2022**, *54*, 1263–1271. [CrossRef]

53. Sarmento, H.; Clemente, F.M.; Araújo, D.; Davids, K.; McRobert, A.; Figueiredo, A. What Performance Analysts Need to Know About Research Trends in Association Football (2012–2016): A Systematic Review. *Sport. Med.* **2018**, *48*, 799–836. [CrossRef]
54. Bayer, C. *La Enseñanza de Los Juegos Deportivos [The Teaching of Collective Sports Games]*; Hispano Europea: Barcelona, Brazil, 1992.
55. McLean, S.; Salmon, P.M.; Gorman, A.D.; Read, G.J.M.; Solomon, C. What's in a Game? A Systems Approach to Enhancing Performance Analysis in Football. *PLoS ONE.* **2017**, *12*, e0172565. [CrossRef] [PubMed]
56. Robinson, G.; O'Donoghue, P. A Weighted Kappa Statistic for Reliability Testing in Performance Analysis of Sport. *Int. J. Perform. Anal. Sport* **2007**, *7*, 12–19. [CrossRef]
57. Altman, D. Some Common Problems in Medical Research. In *Practical Statistics for Medical Research*; Altman, D., Ed.; Chapman & Hall: London, UK, 1991; pp. 403–409.
58. Fleiss, J.; Levin, B.; Paik, M. *Statistical Methods for Rates and Proportions*; John Wiley & Sons: Hoboken, NJ, USA, 2013.
59. James, N. Notational Analysis in Soccer: Past, Present and Future. *Int. J. Perform. Anal. Sport* **2006**, *6*, 67–81. [CrossRef]
60. Glazier, P.S. Game, Set and Match? Substantive Issues and Future Directions in Performance Analysis. *Sport. Med.* **2010**, *40*, 625–634. [CrossRef]
61. Vilar, L.; Araújo, D.; Davids, K.; Button, C. The Role of Ecological Dynamics in Analysing Performance in Team Sports. *Sport. Med.* **2012**, *42*, 1–10. [CrossRef] [PubMed]
62. Duarte, R.; Araújo, D.; Correia, V.; Davids, K. Sports Teams as Superorganisms. *Sport. Med.* **2012**, *42*, 633–642. [CrossRef]

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Article

A Proof-of-Concept Evaluation of the 1616 Story-Based Positive Youth Development Program

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Abstract: The 1616 Program is a newly developed and evidence-informed story-based positive youth development (PYD) program for young ice hockey players (10–12 years of age) in North America. The program uses elite ice hockey players as role models—through story-telling—to serve as inspirational figures to engage youth athletes and important social agents (i.e., parents, coaches) with evidence-informed PYD concepts. The objective of this study was to use a Proof-of-Concept evaluation to assess whether the 1616 Program 'worked' in enhancing PYD outcomes and to determine if the concepts were engaging and enjoyable for youth, their parents, and coaches. The 5 week Proof-of-Concept evaluation was conducted with 11 ice hockey teams (n = 160 youths, 93 parents, and 11 coaches), encompassing both qualitative (e.g., focus groups) and quantitative (e.g., retrospective pretest-posttest questionnaires) processes and outcome assessments. Results showed that the program was well received by participants and positively impacted the intended outcomes. Overall, the data presented in this Proof-of-Concept evaluation was deemed to support the development and implementation of the full-scale 1616 Program for a more comprehensive evaluation.

Keywords: knowledge to action; pilot test; character development; partnership research

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1. Introduction

Extensive evidence supports the positive outcomes of sport participation for youth [1]. Unfortunately, despite the potential for physical, social, and emotional development, researchers caution that simply participating in sport is not enough [2]. Indeed, sport should not be assumed to automatically contribute to healthy developmental opportunities, especially with the growing emphasis on performance and achievement at younger and younger ages [3–5]. As such, ensuring that sport programs are age appropriate, include challenging and enjoyable activities, and involve quality social relations is paramount for promoting sport as a vehicle for positive youth development (PYD) [6]. Given calls to develop evidence-informed and practically relevant PYD programs that maximize the benefits associated with sport participation [7,8], within the following paper we describe the initial evaluation process of a novel PYD program meant to intentionally improve the sport experiences for youth, their parents/caregivers, and their coaches.

Given that youth sport programs serve as a viable avenue to promote PYD, sporting organizations have sought to develop programming that can assist in ensuring that involvement-related benefits are realized [9]. The Ladd Foundation is one such charitable organization that is set on promoting developmentally rich sport opportunities for youth involved in ice hockey across North America. Brandy and Andrew Ladd, the founders of the Ladd Foundation, assembled a team of experts to develop the 1616 Program. The program derives its name from Andrew's National Hockey League (NHL) playing number, 16, the duration of the program, 16 weeks, and the year 1616, when the term "buffalo" was first used to describe the American Bison. The program's main message centers around developing a 'Buffalo Mindset,' which focuses on banding together and moving through a challenge with the support of a herd, akin to a buffalo's behavior.

A team of researchers was asked to assist with developing the program to ensure that the program content was evidence-informed and aligned with the sporting context. Since the primary delivery mechanism was storytelling, various other organizations specializing in educational material and digital and video content creation were engaged in the partnership (e.g., Impact Society, Banner TV, The Post Game, and Anthem). For a more detailed description of partnership development, please see Martin et al. [10]. The content of the 1616 Program provides a PYD-facilitative experience to young athletes, integrated as scaffolding for their typical ice hockey participation. It also provides parents and coaches with actionable knowledge and strategies closely related to and supportive of the activities that the athletes are engaging in. As numerous invested partners were involved throughout development, the intervention was designed following the guidelines of an integrated Knowledge Translation approach (iKT) [10,11]. A major strength of iKT projects is that they leverage an organization's resources and unique experiences in a particular context, combined with specific topic expert knowledge, to result in more relevant and impactful policy and practice [11].

Through the 1616 Program, the Ladd Foundation sought to promote healthy sport experiences by capitalizing on inspirational stories from elite athletes without over-structuring or detracting from physical practice and playing time for youth. Their initial objective was to ensure that an intervention with youth ice hockey players did not impose additional requirements (e.g., training workshops) on already busy parents and coaches and, perhaps most importantly, was free for any interested teams/organizations. They grounded the 1616 Program in PYD and coaching literature, specifically the sport-based Personal Assets Framework (PAF) [6]. This body of literature suggests that youth thrive as a result of the dynamic interactions of developmental systems and the adaptive regulations of person-context relations [12,13]. Specifically, the PAF suggests that through the interactions of three dynamic elements (i.e., appropriate settings, quality social dynamics, and personal engagement in activities), participation can foster both short-term (i.e., across a sport season; 4Cs: competence, confidence, connection, and character) and long-term (i.e., the cumulation of multiple seasons; 3 Ps: participation, performance, and personal development) outcomes for young athletes. The main messaging throughout the program emphasizes the 4Cs, which our partnership used to represent PYD generally.

It is important to recognize that developing and evaluating novel sport interventions should not be seen as separate processes. For instance, recent systematic reviews and meta-analyses emphasize that, although there is some evidence for the effectiveness of sport-based PYD interventions, the quality of evaluations and transparency of the research process are lacking [14,15]. In recent years, researchers have seen an increase in the use of both outcome and process evaluations in youth sport programming, with evidence linking program features (i.e., delivery and functionality) as central to achieving expected outcomes [16,17]. Researchers have noted the need to avoid viewing outcomes as either attained or not attained [18,19]. Instead, they suggested focusing on substantial individual variation in conditions, capabilities, and resources linked to program settings and implementation. Thus, an essential aspect of determining the quality of sport-based PYD programs and how they can be improved and sustained over time is to understand what components make them effective, how they affect the participants, and under what circumstances [14,16].

Given the extensive personnel, time, and financial resources dedicated to the development of the 1616 Program [10], it was necessary first to evaluate how the PYD concepts were experienced and perceived by youth, parents, and coaches before continuing to conduct full-scale implementation and evaluation. Therefore, before making a final decision on the content and processes of finalizing a full 16 week 1616 program, we conducted a Proof-of-Concept (PoC) evaluation to assess the impact and effectiveness of the program on a shorter time scale and with an accessible sample [20]. Importantly, PoC trials are a resource-effective way to demonstrate (a) preliminary efficacy on target behavioral mechanisms (i.e., outcome evaluation) and (b) implementation effectiveness (i.e., process evaluation) to inform the development of more comprehensive iterations and rigorous evaluations of a program [21,22]. The purpose of our PoC, then, was to collect feedback to improve program content and delivery as well as gain certainty that the concepts and story-based intervention approach were valuable to the participants. As such, the PoC involved a 5 week evaluation of a sample of the weekly story-based content and activity structures.

2. PoC Purpose

Two primary research objectives were determined through several PoC collaborative planning meetings with the Ladd Foundation, Impact Society, and the research group. Objective 1 (OB1) was to evaluate whether the 1616 Program 'worked' in enhancing PYD-related outcomes in youth. Objective 2 (OB2) was to determine if the concepts were engaging and enjoyable for youth, their parents, and coaches. More specifically, we were interested in knowing if representative weeks from the proposed program could positively impact youth competence, confidence, connection, and character (i.e., outcome evaluation; OB1) and whether the program's PYD concepts and story-based structure were feasible and acceptable—that is, appropriate, delivered effectively and engagingly, and whether participants were satisfied with the quality (i.e., process evaluation; OB2). Ultimately, this study's objective was to gather information from the participants that would help inform further decisions about full-scale program development and implementation.

3. Methods

3.1. PoC Program Overview

For each week during the 5 week PoC evaluation, new material was introduced to youth, parents, and coaches on a selected topic from existing sport and PYD literature (i.e., spanning confidence, connection, or character). The primary (and unique) content delivery mechanism involved a ~5 min edited video of a professional (e.g., NHL, Professional Women's Hockey Players' Association) or international (e.g., Olympic) ice hockey player telling their personal story concerning a particular PYD concept. As an overview of the PoC content, week 1 involved a program introduction focused on the concept of commitment/engagement. Weeks 2–4 involved the concepts of morality/integrity, psychological safety, and self-efficacy, followed by a consolidation and program conclusion in week 5. Throughout the program, participants were given access to online videos/stories in addition to reflection and action-based activities (e.g., 'Live It Outs') each week. The videos/stories, and additional activities were narrated and introduced by an animated buffalo named 'Buffalou'. The program's content was tailored for relevance to young ice hockey players aged 10–12 years.

In addition to the content provided to youth, parents were sent resources each week to support their child through the sport experience (e.g., 'the Car Ride Home', 'Conversation Starters'). Importantly, these resources were informed by current youth sports literature about parent education, communication, and reflective practice [23–25]. Similarly, coaches were sent coaching-specific tips and ice hockey-specific drills to include within their practices—all aimed at improving their professional, interpersonal, and intrapersonal knowledge and behaviors [26,27].

3.2. Participants

The PoC was conducted with a convenience sample comparable to previously completed mixed-methods PoC studies exploring novel behavioral interventions [28]. Samples for PoC testing can be small and accessible rather than large and representative, given the purpose of determining whether continued development and more rigorous testing are merited [21]. Participants were recruited through word-of-mouth and snowball techniques led by the partner organization. In total, 11 youth ice hockey teams from

U9 to U14 age groups, including their parents and coaches, from across North America were involved. Although the program was designed for the 10–12 year-old range, the age range was expanded to explore receptiveness with younger (9 year-olds) and older (14 year-olds) populations. Five teams were from Canadian provinces (British Columbia, Alberta, Manitoba, and Ontario), and the remaining six were located across the United States (Illinois, Maryland, and North Carolina). Whereas the overall participant pool consisted of 11 teams with parents and coaches, not all invested partners from each team provided data (e.g., questionnaire/interview responses) for the PoC. Below, we provide specific sample demographics pertaining to responses for the different evaluation components.

3.3. Evaluation Design and Analysis

Given the aim of quality assurance and program improvement from the PoC for the Ladd Foundation, this project received approval from the first author's institutional research ethics board. Specific quantitative and qualitative methods were selected to balance the need to satisfy our research objectives while remaining practical and user-friendly for participants—a priority outlined by the Ladd Foundation and the iKT approach in general. First, the research team used questionnaires (e.g., retrospective pretest-posttest [RPP] and one-group pretest-posttest questionnaires) to assess changes in youth, parents, and coaches' desired outcomes (OB1). It is important to highlight that, unlike traditional pretest-posttest questionnaires, RPP has respondents, at *one* posttest time point, rate items based on their recall of two specific instances: 'now' and 'before' [29]. This decision was made in consultation with the partners, who emphasized the need to limit the time demands imposed on participants. In partnership research, it is critical to consider the requests of all partners when attempting to achieve common objectives [30]. It is also worth noting that an RPP approach allows participants to more accurately gauge the degree of change between time points through greater self-awareness [29]. All quantitative measures were collected remotely via SurveyMonkey. Second, focus group interviews were conducted at the end of the 5 week program to explore engagement and enjoyment for youth, their parents, and coaches (OB2). The interviews were conducted via Zoom, recorded, and transcribed with participant permission, then thematically analyzed [31]. Recurring themes, suggestions, and feedback were summarized concerning each invested partner group.

The following sections outline the methods used to assess each objective, separated for each partner. As such, the first section introduces and describes the methods used to evaluate selected outcomes (OB1) for youth, parents, and coaches. The subsequent section addresses methods used to assess process-related factors (OB2) for youth, parents, and coaches.

3.4. Outcome Evaluations (OB1)

3.4.1. Youth

Retrospective Pretest-Posttest (RPP) Weekly Questionnaires. In RPP format, youth from the 11 teams provided weekly information on learning and the impact of the weekly program content. The weekly questionnaires targeted perceptions of the story topic that week and were completed based on a Likert scale from 1 (*not at all*) to 5 (*very much*) for two time points: 'now' and 'before this week'. Week 1 included items from the commitment (4 items, e.g., 'How dedicated are you to playing hockey on this team?') and enjoyment (4 items, e.g., 'Do you enjoy playing hockey this season?') subscales from the sport commitment model [32]. Week 2 included items from the Youth Sport Values Questionnaire (YSVQ-2) for the moral (3 items, e.g., 'I try to be fair'), competence (3 items, e.g., 'I set my own targets'), and status (3 items, e.g., 'I am a leader in the group') subscales [33]. Week 3 included items meant to assess perceptions of a psychologically safe climate pertaining to coach support (4 items, e.g., 'My coach is flexible about how I play my position'), role clarity (3 items; 'The amount expected of me is clearly defined'), and self-expression (3 items; 'It is okay to express my true feelings') previously used in sport [34,35]. Week 4 had five items assessing sport self-confidence (e.g., 'I am confident about performing well in hockey') from the Competitive State Anxiety Inventory-2 [36]. Finally, week 5 included four items, representing a composite measure of the Cs (e.g., connection: 'I feel connected to teammates'). From the 11 hockey teams, an average of 63.40 (*SD* = 13.8) youth (M_{age} = 10.90 years, *SD* = 0.19) completed the questionnaire every week.

Pretest-Posttest Questionnaires. A pretest-posttest questionnaire was created and administered before week 1 and at the end of week 5. Importantly, this decision represented the first stage of an iterative process whereby the results were deemed secondary. We recognized that not all topics would be covered in five weeks; however, given that the eventual complete program would include a pre-post assessment, we were interested in exploring the practicality, feasibility, and receptiveness of questionnaire completion. In collaboration with the partners, item decisions were made to provide a comprehensive evaluation within a manageable time for completion (~20–30 min). Following guidelines advanced by Vierimaa et al. [37] for creating a PYD Cs 'Tool Kit,' 70 items expected to represent connection [32,38,39], confidence [36], and character [40,41] were selected, and responses were provided on a Likert scale from 1 (*not at all/none/nothing*) to 5 (*very much/a lot*). Across the 11 hockey teams, 160 youth (44% female; M_{age} = 11.17 years; *SD* = 4.30 years) responded to the pretest questionnaire, and 83 (M_{age} = 10.8 years; *SD* = 1.20 years) responded to the posttest questionnaire. Across the sample, 82% identified as white, 9% as Eastern Asian, 6% preferred not to answer, 1% as black or African American, 1% as Middle Eastern, and 1% as race/ethnicity not listed.

Follow-up Focus Group Interviews. Using interviews alongside small sample pre-experimental studies can assist in determining whether to move forward with program development and rigorous testing [21]. Following the 5 week PoC, focus groups (*n* = 4) were conducted with 14 youth aged 9 years (*SD* = 1.25 years) to explore engagement and learning through the 1616 Program (e.g., 'What did you learn from the story that the player told?').

3.4.2. Parents

RPP Questionnaires. Parents (*n* = 93; 46% female) participated in a post-program questionnaire presented in RPP format meant to compare perceptions about (a) their child, (b) themselves, and (c) the sport environment before and after the program. Four items about their children were specific to each 'C' (e.g., connection: 'I believe that my child feels connected to their teammates'). Twenty items about themselves were based on the COM-B behavior change theory [42,43] to explore their perceived *Capability* (e.g., 'I have the necessary knowledge and skills to support my child's confidence'), *Opportunity* (e.g., 'I am aware of opportunities where I can support my child's confidence'), and *Motivation* (e.g., 'I am motivated to support my child's confidence') to engage in *Behaviors* that supported their child and about their sport parent self-efficacy (e.g., 'How confident are you in your ability to promote good sportspersonship') on a Likert scale ranging from 1 (*not at all*) to 5 (*very much*) [44]. Finally, we were also interested in knowing whether parents felt that the program improved the quality of the sport environment by adapting 41 of the 51 items from the Program Quality Assessment in Youth Sport (PQAYS) to a self-report format for psychological safety, appropriate structure, supportive relationships, opportunities to belong, positive social norms, support for efficacy and mattering, opportunities for skill-building (sport/physical and life skills), and integration of family [45]. On average, parents were 42.5 years old (*SD* = 6.67), and 81% identified as white, 13% as Eastern Asian, 3% preferred not to answer, 2% had no race/ethnicity listed, and 1% were black or African American.

Follow-up Focus Group Interviews. At the end of the 5 weeks, a sample of willing parents (*n* = 13; 23% female) took part in remote (i.e., Zoom) focus groups (*n* = 5) about their experiences, perceptions, and engagement with the program. To understand parent-related outcomes, parents were asked questions such as, 'Did you learn anything from the program?' and 'What aspects of the program had the greatest impact on you?'.

3.4.3. Coaches

RPP Questionnaires. One coach (head or assistant) from each of the 11 teams completed an RPP post-program questionnaire meant to explore changes in perceptions before and after the program about (a) their athletes and (b) themselves. Similar to parents, coaches rated their athletes' improvement for the Cs based on an item for each (e.g., connection: 'I believe that my athletes feel connected to their teammates'). They also completed items about their perceived *Capability*, *Opportunity*, and *Motivation* to engage in *Behaviors* that supported their athletes [42,43] and about their coach-specific efficacy [44] with items adapted to coaching roles (e.g., 'How confident are you in your ability to build team cohesion') on a Likert scale ranging from 1 (*not at all*) to 5 (*very much*). All coaches (n = 11) were identified as male and were, on average, 44.82 years old (SD = 7.39) and predominantly white (9% race not identified).

Follow-up Focus Group Interviews. A sample of coaches (n = 8) took part in follow-up interviews to explore their experiences, perceptions of, and engagement with the program. To explore coach-related outcomes, coaches were asked questions such as, 'What plans do you have to change anything or do anything differently as a result of this program?' and 'What aspects of the program had the greatest impact on you?'.

3.5. Process Evaluations (OB2)

3.5.1. Youth

Weekly Process Questionnaires. At the end of each week, youths were asked ten process-related questions that were responded to with 'yes' or 'no' or on a Likert scale from 1 (*not at all*) to 5 (*very much*). Four items were experiential in nature (e.g., 'Did you have fun this week?') and six were engagement-related (e.g., 'Did you watch the video this week?'). Overall, these items were meant to determine how enjoyable the weekly video was, the degree to which the reflection items helped them understand the topic, and if the 'Live It Out' action item was useful.

Posttest Process Questionnaires. At the end of the program, the youth responded to seven items addressing program-specific feedback about the quality and amount of content shared (e.g., 'Did Buffalou add value to the videos?'; 'What did you think of the amount of stuff we shared?'; 'How was the length of the weekly player videos?'). These were responded to by selecting a provided option or were rated on a scale from 1 (*not at all*) to 5 (*very much*).

Follow-up Focus Group Interviews. During the focus groups discussed previously for OB1, youth were also asked more process-related questions. These were meant to target overall program implementation and experience (e.g., 'Did you like receiving the different stories online through videos?'; 'Which video did you like/dislike the most and why?').

3.5.2. Parents

Post-Program Process Questionnaires. Fifteen items were provided to parents addressing the quality of the content and delivery and descriptions of intentions for future use (e.g., 'The 1616 Program was well structured and organized'; 'I would recommend the 1616 Program to others') that were answered on a 7-point Likert scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*).

Follow-up Focus Group Interviews. During the OB1 interviews discussed previously, parents were also asked about their perceptions of how the program was delivered, what they thought about its quality, and if they found it enjoyable (e.g., 'What did you think about the way the content was delivered?').

3.5.3. Coaches

Post-Program Process Questionnaires. Fifteen items were given to coaches that sought feedback about the quality of delivery and intentions for future use (e.g., 'The 1616 Program was well structured and organized'; 'I would recommend the 1616 Program to others') on a 7-point Likert scale from 1 (*strongly disagree*) to 7 (*strongly agree*).

Follow-up Focus Group Interviews. In addition to the questions discussed previously for OB1, more in-depth feedback about the delivery, quality, and enjoyment (e.g., 'What did you think about the way the content was delivered?') was obtained in the post-program follow-up interviews with coaches.

4. Results

4.1. Outcome Evaluations (OB1)

4.1.1. Youth

RPP Weekly Questionnaires. Table 1 provides the means (*SD*), mean difference, *t*-statistic, *p*-value, and confidence interval (CI) for the weekly topics assessed. Athletes reported a significant difference in perceptions for both commitment (M*diff*: 0.12, $p < 0.001$, CI: [0.05, 0.18]) and enjoyment (M*diff*: 0.06, $p < 0.001$, CI: [0.02, 0.11]) during week 1. Moral values (M*diff*: 0.17, $p < 0.001$, CI: [0.09, 0.24]) and competence values (M*diff*: 0.21, $p < 0.001$, CI: [0.11, 0.30]) demonstrated a significant difference for week 2, while role clarity (M*diff*: 0.09, $p = 0.002$, CI: [0.04, 0.15]) demonstrated a significant difference for week 3. Perceptions of confidence (M*diff*: 0.29, $p < 0.001$, CI: [0.18, 0.41]) increased significantly during week 4, as did the PYD Cs (M*diff*: 0.33, $p < 0.001$, CI: [0.22, 0.45]) during week 5.

Table 1. Youth means, standard deviations, mean difference, *t*-statistic, *p*-value, and confidence interval for RPP responses.

Variable Name	Mean T1 (*SD*)	Mean T2 (*SD*)	Mean Difference	*t*-Statistic	*p*-Value	95% CI
Commitment	4.71 (0.24)	4.83 (0.31)	0.12	3.70	<0.001	[0.05, 0.18]
Enjoyment	4.79 (0.36)	4.85 (0.32)	0.06	2.64	<0.001	[0.02, 0.11]
Confidence	4.04 (0.68)	4.33 (0.62)	0.29	5.20	<0.001	[0.18, 0.41]
Moral values	4.69 (0.38)	4.86 (0.22)	0.17	4.47	<0.001	[0.09, 0.24]
Competence values	4.6 (0.52)	4.81 (0.35)	0.21	4.40	<0.001	[0.11, 0.30]
Status values	3.57 (0.88)	3.65 (0.90)	0.07	1.81	0.075	[−0.01, 0.15]
Psych safety—Coach support	4.06 (0.70)	4.1 (0.68)	0.04	1.66	0.101	[−0.01, 0.09]
Psych safety—Role clarity	4.36 (0.59)	4.45 (0.54)	0.09	3.28	0.002	[0.04, 0.15]
Psych safety—Self expression	4.35 (0.66)	4.41 (0.65)	0.05	1.75	0.085	[−0.01, 0.11]
PYD Cs	4.17 (0.61)	4.5 (0.48)	0.33	5.95	<0.001	[0.22, 0.45]

Pretest-Posttest Questionnaires. Table 2 provides the means (*SD*), mean difference, *t*-statistic, *p*-value, and CI for the pre- and post-topics assessed. Overall, measures remained unchanged or improved marginally. Increases in youth cognitive centrality (M*diff*: 0.20, $p = 0.059$, CI: [−0.01, 0.40]) and confidence (M*diff*: 0.12, $p = 0.061$, CI: [−0.01, 0.25]) were observed. Only mental toughness (M*diff*: 0.21, $p = 0.002$, CI: [0.08, 0.33]) demonstrated a significant difference.

Follow-up Focus Group Interviews. Youth engagement and learning were evident from follow-up focus groups. As an example, athletes described learning to take responsibility for their development in hockey and showed an understanding of how their work ethic would benefit their competence and confidence: 'I learned to try my hardest, even when the coaches or your parents aren't looking and, to be honest, always' (Player 12, U9). There was also some indication that the messages learned could translate beyond the hockey setting: 'It was fun, I actually learned about how to be more confident in myself" (Player 13, U9), and 'Being confident in yourself in school like if you have a test, and at hockey' (Player 5, U9).

Table 2. Youth means, standard deviations, mean difference, *t*-statistic, *p*-value, and confidence interval for pre- and post-responses.

Variable Name	Mean T1 (*SD*)	Mean T2 (*SD*)	Mean Difference	*t*-Statistic	*p*-Value	95% CI
Commitment	4.79 (0.36)	4.82 (0.41)	0.06	1.02	0.312	[−0.05, 0.16]
Enjoyment	4.85 (0.34)	4.83 (0.41)	0.02	0.30	0.762	[−0.09, 0.11]
Confidence	4.28 (0.60)	4.9 (0.48)	0.12	1.91	0.061	[−0.01, 0.25]
Task-orientation	4.63 (0.40)	4.65 (0.39)	0.02	0.42	0.678	[−0.09, 0.14]
Ego-orientation	3.44 (1.00)	3.29 (1.15)	0.02	0.21	0.837	[−0.21, 0.26]
Ingroup ties	4.45 (0.71)	4.44 (0.79)	0.13	1.57	0.122	[−0.03, 0.28]
Cognitive centrality	4.07 (0.84)	4.12 (0.98)	0.20	1.93	0.059	[−0.01, 0.40]
Ingroup affect	4.80 (0.47)	4.68 (0.58)	−0.08	−1.65	0.104	[−0.17, 0.02]
Coach closeness	4.81 (0.37)	4.80 (0.45)	0.00	0.00	1.00	[−0.10, 0.10]
Positive parental involvement	4.64 (0.46)	4.63 (0.57)	0.04	0.46	0.650	[−0.13, 0.21]
Mental toughness	4.14 (0.50)	4.29 (0.51)	0.21	3.32	0.002	[0.08, 0.33]

4.1.2. Parents

RPP Questionnaires. Table 3 provides the means (*SD*), mean difference, *t*-statistic, *p*-value, and CI for the RPP responses. A significant difference was observed in parents' perceptions of improvement in their children's 4Cs (*Mdiff:* 0.54, $p < 0.001$, CI: [0.43, 0.65]). There were also significant differences in perceptions of their own capability (M*diff*: 0.57, $p < 0.001$, CI: [0.42, 0.71]), opportunity (M*diff*: 0.61, $p < 0.001$, CI: [0.47, 0.75]), and motivation (M*diff*: 0.42, $p < 0.001$, CI: [0.29, 0.56]) to support their child. Parents also demonstrated significant differences in their perceptions of their efficacy toward motivating their children (M*diff*: 0.55, $p < 0.001$, CI: [0.42, 0.68]) and character building with their children (M*diff*: 0.29, $p < 0.001$, CI: [0.19, 0.40]). Importantly, significant differences for all the features of a quality sport environment were observed (see Table 3).

Table 3. Parent means, standard deviations, mean difference, *t*-statistic, *p*-value, and confidence interval for RPP responses.

Variable Name	Mean T1	Mean T2	Mean Difference	*t*-Statistic	*p*-Value	95% CI
4Cs	3.88 (0.62)	4.42 (0.40)	0.54	9.94	<0.001	[0.43, 0.65]
Capability to support a child	3.78 (0.78)	4.35 (0.56)	0.57	7.91	<0.001	[0.42, 0.71]
Opportunities to support a child	3.66 (0.79)	4.27 (0.59)	0.61	8.54	<0.001	[0.47, 0.75]
Motivation to support a child	4.33 (0.74)	4.75 (0.41)	0.42	6.26	<0.001	[0.29, 0.56]
Sport parent efficacy—motivation	3.83 (0.76)	4.38 (0.57)	0.55	8.31	<0.001	[0.42, 0.68]
Sport parent efficacy—character building	4.50 (0.63)	4.80 (0.32)	0.29	5.49	<0.001	[0.19, 0.40]
Psychological safety created by coaches	4.23 (0.66)	4.43 (0.61)	0.20	5.44	<0.001	[0.13, 0.28]
Appropriate structure	4.59 (0.40)	4.72 (0.35)	0.13	5.08	<0.001	[0.08, 0.18]
Supportive relationships	4.31 (0.56)	4.53 (0.51)	0.22	5.76	<0.001	[0.15, 0.30]
Opportunities to belong	4.05 (0.71)	4.49 (0.62)	0.43	7.67	<0.001	[0.32, 0.55]
Positive social norms	4.59 (0.48)	4.72 (0.39)	0.13	3.75	<0.001	[0.06, 0.20]
Support for efficacy and mattering	4.08 (0.63)	4.29 (0.61)	0.21	5.70	<0.001	[0.14, 0.29]
Opportunities for skill-building: sports and physical skills	4.49 (0.48)	4.66 (0.39)	0.17	4.96	<0.001	[0.10, 0.24]
Opportunities for skill-building: life skills	3.69 (0.86)	3.93 (0.85)	0.24	5.04	<0.001	[0.14, 0.33]
Integration of families	4.59 (0.47)	4.69 (0.44)	0.10	3.09	0.002	[0.03, 0.16]

Follow-up Focus Group Interviews. These results were further supported and contextualized by interview responses whereby parents discussed how the program influenced their general ability to support their children. For instance, one participant stated in relation to their capability and opportunity: 'We gravitated towards the conversation starters ... we're always trying to get something started with our son because he's all over the place ... it was nice to get him started on a path to have a discussion' (Parent 1, U10). Parents also commented on how the program shaped their team's sporting environment:

'Our team hasn't won a game yet, so there's been lots of things that haven't gone well ... this has been a very good program for our team. We've all faced adversity, so we talk about going into the storm and about being a herd. It's been very timely for our group. I think it's helped, pardon the pun, 'weather the storm". (Parent 4, U13).

4.1.3. Coaches

RPP Questionnaires. Significant improvements were observed in all but one of the topics assessed with coaches (see Table 4). They felt that their athletes improved for the 4Cs (M*diff*: 0.91, $p < 0.001$, CI: [0.57, 1.25]) and they felt they themselves improved in their capability (M*diff*: 0.59, $p = 0.003$, CI: [0.24, 0.94]), awareness of opportunities (M*diff*: 0.68, $p = 0.006$, CI: [0.24, 1.12]), and motivation (M*diff*: 0.86, $p < 0.001$, CI: [0.48, 1.25]) to support their athletes. They also improved in their beliefs for character building (M*diff*: 0.39, $p = 0.002$, CI: [0.17, 0.62]), but not for their ability to improve hockey technique.

Table 4. Coach means, standard deviations, mean difference, *t*-statistic, *p*-value, and confidence interval for RPP responses.

Variable Name	Mean T1	Mean T2	Mean Difference	*t*-Statistic	*p*-Value	95% CI
4Cs	3.20 (0.60)	4.11 (0.39)	0.91	5.99	<0.001	[0.57, 1.25]
Capability to support	3.84 (0.66)	4.43 (0.39)	0.59	3.80	0.003	[0.24, 0.94]
Opportunities to support	3.75 (0.64)	4.43 (0.67)	0.68	3.46	0.006	[0.24, 1.12]
Motivation to support	3.86 (0.61)	4.73 (0.42)	0.86	5.04	<0.001	[0.48, 1.25]
Coach efficacy—motivate athletes	4.11 (0.50)	4.50 (0.48)	0.39	3.89	0.002	[0.17, 0.62]
Coach efficacy—technique development	4.62 (0.44)	4.67 (0.43)	0.05	0.54	0.602	[−0.14, 0.23]

Follow-up Focus Group Interviews. Coach responses supported the previous results during interviews. For example, a coach discussed how the program allowed them to support athletes' development of the Cs: 'It gave us coaches an idea every week of different things to try with your group; whether it's character building or on ice—actual skill-specific stuff. It's an [in-depth] resource . . . overall just such a positive experience for everyone' (Coach 4, U10). Coaches also commented on how the program enhanced their motivation to support their athletes: 'The videos really spoke a lot to me as a coach. I want to make that difference now. I don't want a player to have success in spite of me' (Coach 2, U14).

4.2. Process Evaluations (OB2)

4.2.1. Youth

Weekly Youth Process Questionnaires. As shown in Table 5, process features about perceptions of enjoyment, learning, improvement, and excitement were highly rated. From a fidelity perspective, it is also clear that almost all participants reported watching the videos, completing the reflection questions, and engaging with the 'Live it Out' activities. Interestingly, differences in engagement could be seen when broken down based on age group (i.e., U10, U12, and U14). Specifically, 89% of U10 youth and 86% of U12 youth rated their level of fun engaging in the program as a four or higher. However, as youth age increased, the description of fun decreased. For instance, only 64% of U14 youth rated their level of fun as a four or higher. A similar finding was observed for the level of excitement to engage with the full 1616 Program. Whereas 86% of U10 youth rated excitement as a four or higher, 73% of U14 youth rated their level as a four or higher. In relation to the quality of the weekly video, 95% of U10 and U12 youth selected four or above, compared to 60% of U14 youth. Comparable ratings were observed when youths were asked to rate their engagement with the reflections and LIOs.

Table 5. Question, mean (SD), and % responses above four for Weekly Youth Process Questionnaires.

Question Type	Question	Week 1 Commitment	Week 2 Morality/Integrity	Week 3 Psych Safety	Week 4 Self-Efficacy	Week 5 Cs Summary
General Experience Questions	1. Did you have fun?	4.6 (0.6)	4.6 (0.7)	4.7 (0.6)	4.5 (0.8)	4.8 (0.4)
	2. Did you learn something about yourself?	3.9 (1.2)	4.2 (0.9)	4.1 (0.8)	3.9 (1.0)	4.4 (0.8)
	3. Did you improve at hockey?	4.3 (0.8)	4.2 (0.8)	4.3 (0.9)	4.2 (0.9)	4.4 (0.8)
	4. Are you excited about next week?	4.4 (0.8)	4.3 (0.7)	4.4 (0.7)	4.3 (0.8)	-
Process/Engagement Questions	1. Did you watch the video?	99% yes	100% yes	100% yes	100% yes	98% yes
	2. How enjoyable was it?	4.1 (0.6)	4.1 (0.7)	4.2 (0.6)	4.2 (0.8)	4.4 (0.7)
	3. Did you read the reflection item?	96% yes	96% yes	97% yes	95% yes	93% yes
	4. Did it help you understand?	4.3 (0.8)	4.2 (0.9)	4.5 (0.6)	4.2 (1.0)	4.3 (1.0)
	5. Did you complete the live it out?	86% yes	91% yes	96% yes	92% yes	97% yes
	6. Was it worth it?	4.1 (0.9)	4 (1.0)	4.3 (0.7)	4.2 (0.9)	4.4 (0.7)

Note. These items were determined in consultation with the partners.

Post-Program Process Questionnaires. Table 6 demonstrates that generally, the youth felt strongly about the quality and content of the resources and identified their favorite videos from the program.

Table 6. Youth post-program process evaluation items and responses.

Feedback Item	Total Youth (*n* = 69)
1. Did you like Buffalou? (1 = Not at all/5 = Very much)	4.2 (1.1)
2. Did Buffalou add value to the videos? (1 = Not at all/5 = Very much)	4.1 (1.1)
3. Did you think the stuff with Buffalou was funny? (1 = Not at all/5 = Very much)	3.7 (1.3)
4. Did you think the stuff in the 1616 Program was cool? (1 = Not at all/5 = Very much)	4.3 (0.8)
5. What did you think about the amount of stuff we shared? (1 = Too much/2 = Not enough/3 = Just right)	7.1% (Too much) 11.4% (Not enough) 81.4% (Just right)
6. How was the length of the weekly player videos? (1 = Too much/2 = Not enough/3 = Just right)	10.1% (Too much) 7.2% (Not enough) 82.6% (Just right)
7. Which was your favorite video?	29%—Week 5 25%—Week 1 23%—Week 4 13%—Week 3 10%—Week 2

Note. These items were determined in consultation with the partners.

Follow-up Focus Group Interviews. Overall, there was a sense of engagement with the stories being told, and athletes could relate to the messages delivered by the players. For instance, they described their excitement with the way the reports were delivered: 'It was fun to see different players and the stories that they've been through' (Player 1, U9) and ' . . . it felt like you actually knew them personally' (Player 5, U9). However, focus groups also highlighted the need for content to be age appropriate. Similar to the results presented above, older athletes were not as engaged with certain aspects, such as the buffalo mascot for the program, 'I didn't like the buffalo in the first two videos. He was a little much' (Player 14, U14). Conversely, younger athletes found the pace and some of the content difficult to follow. For instance, although athletes described enjoying the stories and self-reflection questions, one athlete discussed needing more clarity on the weekly messages, 'Just the way it's said could be a little better . . . I guess [the message] just has to be a little clearer' (Player 1, U9). Additionally, another player discussed the fast pace of the weekly content, 'Maybe give us more time to talk about [the content of] each week' (Player 6, U9).

4.2.2. Parents

Post-Program Process Questionnaires. Table 7 shows that on a Likert scale from 1 (*strongly disagree*) to 7 (*strongly agree*), 100% of parents selected a response of five or higher when describing the program as aligning with their beliefs and values, as useful, credible, and a positive experience, as well-structured and organized, and as effective. Areas of improvement marked by parents for the Ladd Foundation to consider were observed in relation to effectiveness over other resources (82%), the available evidence of the impact of the program (91%), and time requirements (91%).

Table 7. Parent post-program content feedback.

Feedback Item	# of Responses	Mean/7 (*SD*)	% Response > 5
1. The content of the 1616 Program is compatible with my personal beliefs and values in relation to sport.	82	6.6 (0.7)	100%
2. The 1616 Program is useful.	82	6.2 (1.0)	100%
3. The 1616 Program is credible.	82	6.3 (0.9)	100%
4. The benefits of the 1616 Program are obvious.	82	6.1 (1.2)	100%
5. The 1616 Program is more effective than other youth sports improvement resources.	82	5.3 (1.2)	82%
6. The evidence regarding the impact of being involved with the 1616 Program is available.	82	5.5 (1.2)	91%
7. The 1616 Program was a positive experience.	82	6.4 (0.8)	100%
8. The 1616 Program was well structured and organized.	82	6.2 (0.9)	100%
9. The time requirements for the 1616 Program were appropriate.	82	5.7 (1.3)	91%
10. The delivery of the 1616 Program online was effective.	82	5.9 (1.2)	100%
11. The stories/videos were an effective way to introduce the topics.	82	6.3 (0.8)	100%
12. The reflection items were an effective way to have children think about the topics.	82	6.1 (1.0)	100%
13. The 'live it outs' were an effective way to have children engage in behaviors.	82	6.1 (0.9)	100%
14. The 1616 Program helped with positive development for children.	82	6.3 (0.9)	100%
15. I would recommend the 1616 Program to others.	82	6.2 (0.9)	100%

Note. These items were determined in consultation with the partners.

Follow-up Focus Group Interviews. During interviews, parents expanded their appreciation for the resources shared through the program. One parent elaborated: 'The 'Chats with Brandy' videos where you can see them talking to their kids and how they're relaying the same weekly messages to them in their own day-to-day life . . . that gave us more to talk about than just the normal 'How was your day?' The way that it tied a lot of things together was really beneficial.' (U10 Parent).

Parents also highlighted several challenges/barriers they experienced with the program, including the frequency of messaging they were receiving and the speed at which new content was being presented: 'I feel like it was a lot of texts and emails. I would say ask people what they prefer and then just get that one [form of communication] rather than both' (U10 Parent). Another parent recommended spacing out the delivery of the content to allow for more time to digest the messaging: 'We were talking about spreading the [content] out . . . then they really get to dive a little bit deeper into each one of them' (U10 Parent).

4.2.3. Coaches

Post-Program Process Questionnaires. Table 8 shows that on a Likert scale from 1 (*strongly disagree*) to 7 (*strongly agree*), 100% of coaches selected a response of five or higher to describe the program as aligning with their beliefs and values, as useful, credible, and a positive experience, as well-structured and organized, and as effective. Whereas all items were rated highly, areas to consider for improvement could be demonstrating effectiveness over other resources (82% five or higher), available evidence of the impact of the program (91% five or higher), and time requirements (91% five or higher).

Follow-up Focus Group Interviews. Coaches provided contextualizing feedback during the follow-up interviews: 'The 4 Cs . . . that's the stuff that carries on and off the ice, and if hockey becomes a teaching tool for that, great. That's where the strength of the program is, the culture. The 4 Cs did resonate with the [athletes]' (Coach 3, U12). Coaches also discussed witnessing the program's positive impact on their athletes: 'It's a positive experience for the kids. They really start to learn about overcoming adversity, struggling, and character building, and it's presented in a great way' (Coach 4, U10).

Table 8. Coach post-program content feedback.

Feedback Item	# of Responses	Mean/7 (*SD*)	% Response > 5
1. The content of the 1616 Program is compatible with my personal beliefs and values in relation to sport.	11	6.9 (0.3)	100%
2. The 1616 Program is useful.	11	6.8 (0.4)	100%
3. The 1616 Program is credible.	11	6.8 (0.4)	100%
4. The benefits of the 1616 Program are obvious.	11	6.6 (0.5)	100%
5. The 1616 Program is more effective than other youth sports improvement resources.	11	5.8 (1.1)	82%
6. The evidence regarding the impact of being involved with the 1616 Program is available.	11	6.1 (0.9)	91%
7. The 1616 Program was a positive experience.	11	7 (0.0)	100%
8. The 1616 Program was well structured and organized.	11	6.5 (0.5)	100%
9. The time requirements for the 1616 Program were appropriate.	11	6.3 (0.9)	91%
10. The delivery of the 1616 Program online was effective.	11	6.5 (0.5)	100%
11. The stories/videos were an effective way to introduce the topics.	11	6.5 (0.5)	100%
12. The reflection items were an effective way to have children think about the topics.	11	6.3 (0.8)	100%
13. The 'live it outs' were an effective way to have children engage in behaviors.	11	6.5 (0.5)	100%
14. The 1616 Program helped with positive development for children.	11	6.7 (0.5)	100%
15. I would recommend the 1616 Program to others.	11	6.9 (0.3)	100%

Note. These items were determined in consultation with the partners.

5. Discussion

The purpose of this article was to describe the evaluation of a PoC trial involving the 1616 Program. The two overarching objectives for the 5 week PoC were to evaluate whether the 1616 Program 'worked' in enhancing PYD-related outcomes, validate the story-based intervention approach (i.e., OB1), and explore participant process-related experiences (i.e., OB2). In doing so, we would determine whether full-scale development was warranted and what changes needed to be made before rolling out the complete program. Within the following sections, we summarize the findings, discuss implications as they pertain to the literature, and conclude by describing the next steps for continued development and refinement of the program.

5.1. Outcome Evaluation (OB1)

There are relevant outcome-related findings for youth, parents, and coaches. Concerning youth, the RPP evaluations demonstrated that every week, the youth felt that they improved in relation to the topic introduced. Given that the eventual 1616 Program will aim to include a weekly message over 16 weeks, this is a promising finding. In other words, an introductory video/story, accompanied by a reflection question and 'Live It Out' activity, represents a format whereby youth feel like they learn and improve with a particular PYD topic. Although the theoretical and conceptual foundation and rationale for the program structure are described elsewhere [10], we expected that introducing significant role models and reflection questions could leverage social learning and behavior modeling theories for youth [46]. Similarly, we also considered goal setting and action planning research [47,48] in relation to how the 'Live It Out' activities would enable youth to engage in relevant behaviors that aligned with the topic and were meaningful to them. From a measurement perspective, it is also worth noting the benefits of using RPP formats for variables that traditionally have high baseline measures [49], which was found with the current sample.

Interestingly, the only significant finding concerning the pretest-posttest questionnaires involved mental toughness [40]. Although a representative dimension of social identity and confidence was nearing significance, this finding warrants discussion. While many reasons could be advanced, two in particular should be noted. First, as seen in Table 2, it is possible that a ceiling effect was present, with participants leaving little room for improvement at Time 2. This finding supports our decision to include pretest-posttest and RPP evaluations [50]. Second, the 5 week PoC structure did not represent the theoretically informed planning for the full 16 week program [10]. For instance, concepts for connection were not directly included due to timing and athlete availability decisions, so it is perhaps not surprising that those specific variables did not improve. As the eventual program is finalized, it will be imperative to ensure that the variables and measurements selected align with our conceptualization of the topics covered and that these are clearly articulated [14]. Similarly, whereas the eventual program will involve a 1 week introductory/engagement phase, a 13 week 'Cs' promotion phase, and a 2 week consolidation/maintenance phase grounded in team building intervention literature [51], this was not possible in the PoC, and so the weekly content represented more of a silo structure. Therefore, despite the lack of significance from the pretest-posttest evaluations, we believe that for the reasons stated here, in conjunction with the findings from the RPP and the follow-up interviews, youth generally benefited from the program.

Regarding parents, results suggested favorable outcomes. For instance, in comparison to before the program, they believed their children improved across the 4Cs. Further, the quality of the sport environment is critical for healthy development [6], and parents reported significant increases across all dimensions proposed by Bean et al. [45]. They also reported improvements in beliefs about their capability, awareness of opportunities, and motivation to support their children, which are important indicators for eventual engagement in behaviors [43]. Finally, the importance of self-efficacy is widely accepted [46], so it is noteworthy that the content provided to parents improved their confidence in their own parenting/ability to support their children. Through the interviews, parents noted how the resources helped them engage in conversations with their children that they might not have otherwise had. They also discussed how their conversations extended beyond ice hockey, whereby they implemented the tips with their child(ren) in various contexts, such as school.

Our results suggested that the program was also effective from the coach's perspective. For instance, they felt that their athletes improved for the 4Cs. Similarly, they felt that their capability and motivation to support their athletes improved, in addition to their awareness of opportunities to do so [43]. It is worth noting that although they also had stronger beliefs in their ability to promote character building amongst their athletes, the program was not felt to have improved their ability to teach hockey techniques. Although the main aim of the program is to emphasize PYD generally, one of the Cs is competence, so helping coaches improve hockey skills specifically is important. As we continue with program development and plan a more comprehensive evaluation of the full program, we will need to explore how the skill videos provided to coaches can more effectively influence their efficacy beliefs. Finally, in addition to these findings, coaches discussed how the resources helped them avoid 'tunnel vision' towards performance-related outcomes and instead promoted intentional behaviors and helped them understand the impact of their actions on their athletes.

5.2. Process Evaluation (OB2)

The second aim of the PoC evaluation was to explore participant experiences with the program. Our findings suggest that the overarching idea and messaging of the 1616 Program were well received by all participants. For example, focus group discussions with each of the stakeholders revealed that the 'Buffalo Mindset' and 4Cs resonated and aligned with participants' sport values. For the youth specifically, almost all reported engaging with the content, and the mean responses were all above four on a 5-point Likert scale when asked if they were enjoyable, if they improved understanding, and if they were worthwhile (see Table 5). Similarly, and based on the planning process for the PoC, the feedback was requested by and noted as particularly impactful for the creative committee from the iKT partnership [10] in relation to the amount of content provided and the length of the videos, as two examples.

The coaches and parents appreciated the common language that the program provided and how it was applicable to other contexts, providing them with a language/vocabulary to communicate with their athletes and children. Suggestions for improvement from these participants mainly focused on program delivery rather than the content itself. For instance, they indicated that the content and messaging were being sent too frequently. As such, in subsequent conversations with the program partners, the quality and intentionality of content delivery will be prioritized for the proposed 16 week program. This will allow time for content to be absorbed by participants and provide opportunities for greater engagement in activities. Notably, the lowest responses from coach and parent feedback were their perceptions that (a) the 1616 Program was more effective than other programs, (b) evidence of its potential impact was available, and (c) time requirements were appropriate (see Tables 7 and 8). This finding aligns with research on parent education programs in sport, where parents noted that "knowledge is power . . . " [52] (p. 441). In this regard, the onus will be on future iterations of the program to ensure that parent resources are informative and practical and that the evidence from which the suggestions are taken is readily available to parents. Similarly, the time requirements will be a critical consideration, as time is a consistent barrier to coach and parent programs [49]. This has been an a priori objective for the Ladd Foundation since program development's inception.

6. Conclusions

This article described the initial evaluation of a 5 week PoC test of the 1616 Program. This was an important first step in program development and represented a novel attempt to evaluate an initial program originating from an iKT approach in sport. Indeed, recent reviews highlight the limitations of PYD interventions in sports [14]. Thus, the descriptive account of our evaluation highlights the benefits of engaging in PoC testing of both outcome and process evaluations [16] and could serve as a useful template for others interested in such undertakings. Notably, although the findings from both the process and outcome evaluations justify continued program development and implementation of the full 16 week program, this PoC evaluation highlights important considerations and justifies changes to ensure that the program is most impactful for youth.

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References

1. Eime, R.M.; Young, J.A.; Harvey, J.T.; Charity, M.J.; Payne, W.R. A systematic review of the psychological and social benefits of participation in sport for children and adolescents: Informing development of a conceptual model of health through sport. *Int. J. Behav. Nutr. Phys. Act.* **2013**, *10*, 98. [CrossRef]
2. Côté, J.; Fraser-Thomas, J. Youth involvement and positive development in sport. In *Sport Psychology: A Canadian Perspective*; Crocker, P., Ed.; Pearson: Toronto, ON, Canada, 2016; pp. 256–287.
3. Buckley, P.S.; Bishop, M.; Kane, P.; Ciccotti, M.C.; Selverian, S.; Exume, D.; Emper, W.; Freedman, K.B.; Hammoud, S.; Cohen, S.B.; et al. Early single-sport specialization: A survey of 3090 high school, collegiate, and professional athletes. *Orthop. J. Sports Med.* **2017**, *5*, 2325967117703944. [CrossRef] [PubMed]
4. Coakley, J. Youth sports: What counts as 'positive development?'. *J. Sport Soc. Issues* **2011**, *35*, 306–324. [CrossRef]

5. Smith, M.M. Early sport specialization: A historical perspective. *Kinesiol. Rev.* **2015**, *4*, 220–229. [CrossRef]
6. Côté, J.; Turnnidge, J.; Murata, A.; McGuire, C.; Martin, L. Youth sport research: Describing the integrated dynamic elements of the personal assets framework. *Int. J. Sport Psychol.* **2020**, *51*, 562–578. [CrossRef]
7. Bean, C.; Forneris, T. Examining the importance of intentionally structuring the youth sport context to facilitate positive youth development. *J. Appl. Sport Psychol.* **2016**, *28*, 410–425. [CrossRef]
8. Holt, N.L.; Deal, C.J.; Smyth, C.L. Future directions for positive youth development through sport. In *Positive Youth Development through Sport*, 2nd ed.; Holt, N., Ed.; Routledge: London, UK, 2016; pp. 229–240.
9. Fraser-Thomas, J.; Côté, J.; Deakin, J. Youth sport programs: An avenue to foster positive youth development. *Phys. Educ. Sport Pedagog.* **2005**, *10*, 49–70. [CrossRef]
10. Martin, L.J.; Erickson, K.; Coletti, J.; Saizew, K.; McGuire, C.S.; Primeau, C.; Wolff, M.; Ladd, B.; Côté, J. An integrated knowledge translation approach to developing a story-based positive youth development program in sport: The 1616 Program. under review.
11. Kothari, A.; McCutcheon, C.; Graham, I.D. Defining integrated knowledge translation and moving forward: A response to recent commentaries. *Int. J. Health Policy Manag.* **2017**, *6*, 299–300. [CrossRef]
12. Agans, J.P.; Säfvenbom, R.; Davis, J.L.; Bowers, E.P.; Lerner, R.M. Positive movement experiences: Approaching the study of athletic participation, exercise, and leisure activity through relational developmental systems theory and the concept of embodiment. *Adv. Child. Dev. Behav.* **2013**, *45*, 261–286. [CrossRef]
13. Lerner, R.M.; Dowling, E.; Anderson, P.M. Positive youth development: Thriving as the basis of personhood and civil society. *Appl. Dev. Sci.* **2003**, *7*, 172–180. [CrossRef]
14. Bruner, M.W.; McLaren, C.D.; Sutcliffe, J.T.; Gardner, L.A.; Lubans, D.R.; Smith, J.J.; Vella, S.A. The effect of sport-based interventions on positive youth development: A systematic review and meta-analysis. *Int. Rev. Sport Exerc. Psychol.* **2021**, 1–28. [CrossRef]
15. Whitley, M.A.; Massey, W.V.; Camiré, M.; Boutet, M.; Borbee, A. Sport-based youth development interventions in the United States: A systematic review. *BMC Public Health* **2019**, *19*, 89. [CrossRef] [PubMed]
16. Arnold, M.E.; Cater, M. From then to now: Emerging directions for youth program evaluation. *J. Youth Dev.* **2011**, *6*, 80–92. [CrossRef]
17. Tolan, P. Positive youth development interventions: Advancing evaluation theory and practice. *Appl. Dev. Sci.* **2016**, *20*, 147–149. [CrossRef]
18. Lerner, R.M.; Lerner, J.V.; Urban, J.B.; Zaff, J. Evaluating programs aimed at promoting positive youth development: A relational development systems-based view. *Appl. Dev. Sci.* **2016**, *20*, 175–187. [CrossRef]
19. Scales, P.C.; Benson, P.L.; Oesterle, S.; Hill, K.G.; Hawkins, J.D.; Pashak, T.J. The dimensions of successful young adult development: A conceptual and measurement framework. *Appl. Dev. Sci.* **2016**, *20*, 150–174. [CrossRef]
20. Thabane, L.; Ma, J.; Chu, R.; Cheng, J.; Ismaila, A.; Rios, L.P.; Robson, R.; Thabane, M.; Giangregorio, L.; Goldsmith, C.H. A Tutorial on Pilot Studies: The What, Why and How. *BMC Med. Res. Methodol.* **2010**, *10*, 1. Available online: http://www.biomedcentral.com/1471-2288/10/1 (accessed on 1 January 2023). [CrossRef]
21. Czajkowski, S.M.; Powell, L.H.; Adler, N.; Naar-King, S.; Reynolds, K.D.; Hunter, C.M.; Laraia, B.; Olster, D.H.; Perna, F.M.; Peterson, J.C.; et al. From ideas to efficacy: The ORBIT model for developing behavioral treatments for chronic diseases. *Health Psychol.* **2015**, *34*, 971–982. [CrossRef]
22. Harrison, V.; Proudfoot, J.; Wee, P.P.; Parker, G.; Pavlovic, D.H.; Manicavasagar, V. Mobile mental health: Review of the emerging field and proof of concept study. *J. Ment. Health* **2011**, *20*, 509–524. [CrossRef]
23. Azimi, S.; Tamminen, K.A. Parental communication and reflective practice among youth sport parents. *J. Appl. Sport Psychol.* **2020**, *34*, 109–132. [CrossRef]
24. Dorsch, T.E.; Smith, A.L.; Dotterer, A.M. Individual, relationship, and context factors associated with parent support and pressure in organized youth sport. *Psychol. Sport Exerc.* **2016**, *23*, 132–141. [CrossRef]
25. Thrower, S.N.; Harwood, C.G.; Spray, C.M. Educating and supporting tennis parents: An action research study. *Qual. Res. Sport Exerc. Health* **2017**, *9*, 600–618. [CrossRef]
26. Côté, J.; Gilbert, W. An integrative definition of coaching effectiveness and expertise. *Int. J. Sports Sci. Coach.* **2009**, *4*, 307–323. [CrossRef]
27. Turnnidge, J.; Côté, J. Transformational coaching workshop: Applying a person-centered approach to coach development programs. *Int. Sport Coach. J.* **2017**, *4*, 314–325. [CrossRef]
28. Coventry, P.A.; Neale, C.; Dyke, A.; Pateman, R.; Cinderby, S. The mental health benefits of purposeful activities in public green spaces in urban and semi-urban neighbourhoods: A mixed-methods pilot and proof of concept study. *Int. J. Environ. Res. Public Health* **2019**, *16*, 2712. [CrossRef]
29. Little, T.D.; Chang, R.; Gorrall, B.K.; Waggenspack, L.; Fukuda, E.; Allen, P.J.; Noam, G.G. The retrospective pretest-posttest design redux: On its validity as an alternative to traditional pretest-posttest measurement. *Int. J. Behav. Dev.* **2020**, *44*, 175–183. [CrossRef]
30. Melton, T.N.; Agans, J.P.; Lawhon, B.; Mateer, T.J.; Freeman, S.; Taff, B.D. "Pick your team wisely": A case study of a long-standing research-practice partnership. *Eval. Program. Plann.* **2022**, *95*, 102169. [CrossRef]
31. Braun, V.; Clarke, V. Can I use TA? Should I use TA? Should I not use TA? Comparing reflexive thematic analysis and other pattern-based qualitative analytic approaches. *Couns. Psychother. Res.* **2021**, *21*, 37–47. [CrossRef]

32. Scanlan, T.K.; Carpenter, P.J.; Schmidt, G.W.; Simons, J.P.; Schmidt, G.W.; Keeler, B. An introduction to the Sport Commitment Model. *J. Sport Exerc. Psychol.* **1993**, *15*, 1–15. [CrossRef]
33. Lee, J.M.; Whitehead, J.; Ntoumanis, N.; Hatzigeorgiadis, A. Relationships among values, achievement orientations, and attitudes in youth sport. *J. Sport Exerc. Psychol.* **2008**, *30*, 588–610. [CrossRef]
34. McLaren, C.D.; Spink, K.S. Testing boundary conditions in the communication cohesion relationship in team sport: The case for psychological safety. *Group Dyn.* **2022**, *26*, 12–23. [CrossRef]
35. Spink, K.S.; Wilson, K.S.; Brawley, L.R.; Odnokon, P. The perception of team environment: The relationship between the psychological climate and members' perceived effort in high-performance groups. *Group Dyn.* **2013**, *17*, 150–161. [CrossRef]
36. Cox, R.H.; Martens, M.P.; Russell, W.D. Measuring anxiety in athletics: The revised competitive state anxiety inventory–2. *J. Sport Exerc. Psychol.* **2003**, *25*, 519–533. [CrossRef]
37. Vierimaa, M.; Erickson, K.; Côté, J.; Gilbert, W. Positive youth development: A measurement framework for sport. *Int. J. Sports Sci. Coach.* **2012**, *7*, 601–614. [CrossRef]
38. Bruner, M.W.; Benson, A.J. Evaluating the psychometric properties of the Social Identity Questionnaire for Sport (SIQS). *Psychol. Sport Exerc.* **2018**, *35*, 181–188. [CrossRef]
39. Jowett, S.; Ntoumanis, N. The coach-athlete relationship questionnaire (CART-Q): Development and initial validation. *Scand. J. Med. Sci. Sports* **2004**, *14*, 245–257. [CrossRef]
40. Gucciardi, D.F.; Hanton, S.; Gordon, S.; Mallett, C.J.; Temby, P. The concept of mental toughness: Tests of dimensionality, nomological network, and traitness. *J. Personal.* **2015**, *83*, 26–44. [CrossRef]
41. Kavussanu, M.; Boardley, I.D. The prosocial and antisocial behavior in sport scale. *J. Sport Exerc. Psychol.* **2009**, *31*, 97–117. [CrossRef]
42. Huijg, J.M.; Gebhardt, W.A.; Crone, M.R.; Dusseldorp, E.; Presseau, J. Discriminant content validity of a theoretical domains framework questionnaire for use in implementation research. *Implement. Sci.* **2014**, *9*, 11. [CrossRef]
43. Michie, S. Implementation science: Understanding behaviour change and maintenance. *BMC Health Serv. Res.* **2014**, *14*, 9. [CrossRef]
44. Feltz, D.L.; Chase, M.A.; Moritz, S.E.; Sullivan, P.J. A conceptual model of coaching efficacy: Preliminary investigation and instrument development. *J. Educ. Psychol.* **1999**, *91*, 765–776. [CrossRef]
45. Bean, C.; Kramers, S.; Camiré, M.; Fraser-Thomas, J.; Forneris, T. Development of an observational measure assessing program quality processes in youth sport. *Cogent Soc. Sci.* **2018**, *4*, 1467304. [CrossRef]
46. Bandura, A. The explanatory and predictive scope of self-efficacy theory. *J. Soc. Clin. Psychol.* **1986**, *4*, 359–373. [CrossRef]
47. Gollwitzer, P.M. Implementation intentions: Strong effects of simple plans. *Am. Psychol.* **1999**, *54*, 493–503. [CrossRef]
48. Locke, E.A.; Latham, G.P. *A Theory of Goal Setting & Task. Performance*; Prentice-Hall, Inc.: Englewood Cliffs, NJ, USA, 1990.
49. Skeff, K.M.; Stratos, G.A.; Bergen, M.R. Evaluation of a medical faculty development program: A comparison of traditional pre/post and retrospective pre/post self-assessment ratings. *Eval. Health Prof.* **1992**, *15*, 350–366. [CrossRef]
50. Geldhof, G.J.; Warner, D.A.; Finders, J.K.; Thogmartin, A.A.; Clark, A.; Longway, K.A. Revisiting the utility of retrospective pre-post designs: The need for mixed-method pilot data. *Eval. Program. Plann.* **2018**, *70*, 83–89. [CrossRef]
51. Carron, A.V.; Spink, K.S. Team building in an exercise setting. *Sport Psychol.* **1993**, *7*, 8–18. [CrossRef]
52. Dorsch, T.E.; King, M.Q.; Tulane, S.; Osai, K.V.; Dunn, C.R.; Carlsen, C.P. Parent education in youth sport: A community case study of parents, coaches, and administrators. *J. Appl. Sport Psychol.* **2019**, *31*, 427–450. [CrossRef]

children

MDPI

Article

The Influence of Contextual Factors on the Relative Age Effect in Male International Rugby Union: The Impact of Sociocultural Influences and Playing Position

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Abstract: The purpose of this study is not only to establish whether the relative age effect (RAE) exists in male international rugby union players, but also to investigate the impact of sociocultural influences (i.e., northern and southern hemispheres) and playing position (i.e., backs, forwards, and scrum-halves). The birth date and the playing position of 7144 senior male professional rugby players included in the rosters of the season 2020–2021 were collected from the top 10 nations of the World Rugby rankings (i.e., Argentina, Australia, England, France, Ireland, Japan, New Zealand, Scotland, South Africa, and Wales). Data were analyzed using a chi-square goodness-of-fit test to compare the observed and expected birth quarter (Q) distributions. Results showed that relatively older players were overrepresented in all the sample ($p < 0.001$; Q1 = 28.8% vs. Q4 = 20.3%). In players competing in both hemispheres, the RAE was weak despite a more pronounced RAE emerging for southern players. In addition, the RAE was present in backs and forwards, but inconsistent for scrum-halves. In general, the data suggest that relatively older players may be more likely to reach expertise at senior levels than their later-born peers, and that the effect was consistent in different sociocultural contexts as well as in backs and forwards.

Keywords: RAE; rugby football union; talent development; athlete development; cultural context; talent identification

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1. Introduction

Talent identification and development programs are current topics throughout the majority of sports governing bodies/federations. These organizations aim to create pathways from the initial enrolment into sports at 'grassroots' level (i.e., entry) to the adult professional level (i.e., expertise) [1]. However, the decision-making process to identify and develop talented athletes with the prerequisites and potentialities to become future high-level athletes is complex, not straightforward, and highly challenging [1,2]. Indeed, a complex interplay between the performer (e.g., physiological factors; psychosocial characteristics; technical and tactical skills), environment (e.g., impact of parents, coaches, and peers; sociocultural influences; organizational structures), and task (e.g., participation history; opportunities and access to facilities and resources; playing position) influence the pathway towards senior success and long-term athletic development (for a review see [1–3]).

One selection bias that can arise during these processes is the relative age effect (RAE). The RAE reflects the (dis)advantages and outcomes resulting from an interaction between the selected dates and birthdate [4,5]. During childhood, young athletes are banded according to (bi)annual-age groups to facilitate equitable learning opportunities and competitive experiences by limiting intragroup physical and cognitive differences [6]. However, an interval of one or two years within the same age cohort can create developmental differences and participation and attainment among peers, which benefits relatively older athletes while disadvantaging relatively younger athletes. One of the underlying causes of the RAE has been explained through physiological biases (i.e., the maturation-selection hypothesis) [4,7]. Accordingly, players born in the early months near the selection date are likely at a physical advantage due to normative growth and/or physical characteristics [7]. Relatively older athletes also possess more playing experiences in the early stages of participation, which can aid their short-term performance [8]. Furthermore, the social agents model introduced by Hancock and colleagues [9] explains the RAE as a social phenomenon. The model outlines that different social agents, including parents, coaches, and athletes themselves may positively or negatively impact the RAE (i.e., the selection of some players at the expense of others). For example, coaches can impact relatively older athletes' self-esteem by giving them, for instance, more attention during practice or more playing time. Indeed, when relatively older athletes receive positive feedback regarding their performances, the same are more likely to have high self-perception and self-expectations and, thus, motivated to continue participating in sports activities [10]. These aspects, related to the self-fulfilling prophecy, may lead athletes to perform at levels consistent with expectations. In addition, Kelly and colleagues [11] used the personal assets framework to explain the immediate, short-, and long-term developmental outcomes of the RAE, which highlights the need to better understand how relative age must be examined across different timescales and sociocultural contexts to better understand the aforementioned mechanisms. Overall, despite the true mechanisms of the RAE remaining inconclusive, what is known is that it can limit the possibility of selecting relatively younger talents with long-term potential, which has significant implications on performance, participation, and personal development [11].

It is plausible to suggest that rugby union's contact and invasive nature combined with the high physical demand required during competition may exacerbate the RAE [12]. A player being chronologically older than peers may lead to performance requirement advantages [13], including rucking, running with the ball, scrummaging, and tackling. Consequently, coaches and practitioners may be more prone (consciously or unconsciously) to select relatively older athletes due to their greater physical performance capacities at the youth level [13].

In this regard, several national studies in the rugby union context, especially considering European countries [12,14–21], who identified an over- and under-representation of the relatively older and younger players, respectively, highlighted the influence of contextual factors such as gender, age group, competition level, sociocultural factors, and playing position. In male rugby, a birthdate inequality was observed in UK rugby league during initial enrolment at grassroots level that starts from the Under-7 stage until the senior age group [21]. Similarly, in Welsh rugby, the RAE was presented from the Under-7 stage to Under-19, where the percentage of players born in the first three months from the selection date (i.e., Q1 = 29%) was higher than the percentage of players born in the last three months from the selection date (i.e., Q4 = 21%) [19]. Additionally, the RAE increased when selection steps and performance levels increased, indicating that when fewer places on the squad occurred, the RAE increased [21]. Indeed, the odds ratios (ORs) identified a significant risk of the RAE increasing between players born in Q1 and Q4 when the performance levels increased (e.g., in Under-16 categories: district OR = 2.64; regional OR = 4.67; national OR = 11.96) [19].

Interestingly, when the RAE was explored during the transition from academy to the professional level in rugby, a possible reversal effect of relative age [22] occurred [23,24]. Specifically, while the proportion of relatively older players was higher at the academy level (i.e., Q1 = 41.5% vs. Q4 = 8.47%), the proportion of relatively younger players who reached success at professional levels was higher compared to the relatively older players (i.e., Q1 = 20% vs. Q4 = 50%) [23]. This finding was confirmed by Kelly and colleagues [18], where relatively younger players were about four times more likely to achieve professional or international status during their senior career once they entered the talent pathway. This phenomenon, commonly explained by the underdog hypothesis [22,25], may lead the relatively younger peers to have greater potentiality for later success in comparison with their relatively older peers [26].

Despite the RAE seeming conclusive at the youth level, findings remain mixed at the senior level depending on sociocultural context. For example, in the UK, no significant difference was highlighted in the quartile distributions within senior cohorts (e.g., Q1 and Q4; ~25%) [18]. On the contrary, rugby union players born near the selection date in Italy were about 1.5 times more likely to reach the first and second elite division even if the index decreases as age increases [20]. Contrastingly, from a French perspective, the RAE had a weak or no magnitude effect [14,16]. Although, another study on the French senior league showed that the RAE existed for forwards (especially for back row forwards) but not for backs [16]. When analyzing the top 10 internationally ranked teams over 20 years, Jones and colleagues [27] revealed the traditional skewed distribution for backs (favoring Q1) and reversal RAE for forwards (favoring Q4). In addition, during a cross-cultural comparison, the RAE was observed in Australian, English, New Zealand, and South African professional players [15], whilst South Africa was the only country with a pronounced RAE according to all playing position (i.e., forwards and backs). Moreover, differences in the playing philosophy (i.e., technical, and tactical model of performance) were reported to exist between northern and southern hemispheres (e.g., more offloads, more tries in southern hemisphere), as well as in the strength and conditioning practice (e.g., emphasis on strength and power training or on objectively determining training loads) [28,29]. Together, these findings suggested that the possible differences in national culture and playing position are important considerations to examine while exploring who is at risk of the RAE [12].

To date, only one study, to the authors' knowledge, investigated the RAE by adopting a cross-cultural approach and analyzing senior male professional rugby, including Australian, English, New Zealand, and South African male players [15]. Therefore, investigating this issue may be important to better understand rugby players' birth distribution, and the consequent national federation policy associated to the talent identification system. As a consequence, and in consideration of the possible differences in the national cultural context and playing position, this study aimed to: (a) evaluate the potential differences between the countries of the northern and southern hemispheres, and (b) examine possible differences between playing positions based on backs, forwards, and scrum-halves. Due to the heterogeneity in RAE results at the senior level in rugby union, no a priori hypothesis was formulated. Nevertheless, we expected to find possible differences due to the divergent technical and tactical model of performance between northern and southern hemispheres. Additionally, we expected to find RAE magnitude difference when considering players' position according to Kearney [15].

2. Materials and Methods

Data were downloaded from the open web https://www.ultimaterugby.com/ on 1 December 2021. The database contains information about male teams competing in the most prominent nations in World Rugby (i.e., according to the most recent Rugby World Cup results in 2019 and the press coverage of domestic competitions). To explore the RAE at the highest levels of competition, for the current study, we arbitrarily focused our analysis on the top 10 nations included into the World Rugby rankings (https://www.world.rugby/tournaments/rankings/mru accessed on 1 December 2021). Thus, only data about senior male professional rugby players competing in the first- and second-division teams of Argentina, Australia, England, France, Ireland, Japan, New Zealand, Scotland, South Africa, and Wales were included. Thus, the birth date and the playing positions of 7144 senior male professional rugby players included in the rosters of the season 2020–2021 were collected with the approval of the local institutional review board. Data are available from the web (public domain), thus no permission was needed.

3. Statistical Analysis

Consistent with the selection year from each participating country (i.e., January to December: Argentina, Australia, France, Ireland, New Zealand, and South Africa; September to August: England, Scotland, and Wales; April to March: Japan), players' birth dates were categorized into four quarters (i.e., Q1, Q2, Q3, and Q4) and semesters (S1 and S2). Moreover, the time of birth (TB) was calculated to identify how far a player was born from the selection date using the following formula: TB = (birth week − 0.5)/52. For more details on this method, please see the works from Brustio and colleagues [6,20,30].

Data were analyzed by merging all the players and grouping them according to countries of the northern (i.e., England, France, Ireland, Japan, Scotland, and Wales) and southern (i.e., Argentina, Australia, New Zealand, and South Africa) hemispheres to test the impact of sociocultural influences. Moreover, players were categorized into their playing position based on backs, forwards, and scrum-halves to examine the influence of playing position.

Differences between the observed (i.e., our data) and expected (i.e., 25% for each quartile) [15] quartile distributions were assessed using chi-square goodness-of-fit tests (χ^2). An expected birth distribution of 25% for each quartile was chosen considering the databases containing the birthdates of different nationality athletes. Cramer's V was calculated to determine the effect of magnitudes. The threshold values for effect size statistics were: $0.06 \leq V$ for a trivial effect; $0.06 < V \leq 0.17$ for a small effect; $0.17 < V < 0.29$ for a medium effect; and $V \geq 0.29$ for a large effect. Comparisons between the first and last quartile (Q1 vs. Q4) and between the first and second semester (S1 vs. S2) were calculated using odds ratios (ORs) and 95% confidence intervals (CIs). Moreover, to investigate the RAE phenomenon further, Poisson regression for analyzing low count data was used to consider birth week distribution as a continuous variable. The relative odds (i.e., index of discrimination—ID) of being selected for a player born in the first week versus the last week of the competition year were calculated [6,30]. All data were analyzed with a custom script written in MATLAB R2020b (MATLAB, R2020b, MathWorks: Natick, MA, USA, 2022). Results were considered statistically significant when $p < 0.05$.

4. Results

Table 1 reports the birth quartile distribution, the chi-square (χ^2) statistics, and the ORs for all players competing in the top 10 national professional rugby union leagues and considering the northern and southern hemispheres and playing position (i.e., all playing positions together as well as backs, forwards, and scrum-halves separately).

When considering all players without distinction of hemisphere and playing position, a birth skewed distribution was observed (χ^2 = 136.044, $p < 0.001$) with a small effect size in the overall samples (V = 0.08; see Figure 1a). The ORs showed an increased likelihood of relatively older players being selected in Q1 compared to the Q4 (OR = 1.42, CI [1.29, 1.56]). Poisson regressions confirmed these results ($y = e^{(5.14-0.44x)}$, $R^2 = 0.64$, $p < 0.001$), whereby the ID showed that, overall, players born in the first week after the selection year were 1.56 times more likely to be included in the senior rosters than those born in the last week of the selection year (Figure 1e). When considering players' positions, there was a significant difference between quartile distribution with a small effect size (V ranged = 0.08–0.09) in backs (χ^2 = 65.524, $p < 0.001$; Figure 1b) and forwards (χ^2 = 75.259, $p < 0.001$; Figure 1c) but not in scrum-halves (χ^2 = 3.973, $p = 0.264$; Figure 1d). The ORs showed an increased likelihood for relatively older players being selected (i.e., players born in Q1) in backs (1.56, CI [1.33, 1.83]) and forwards (1.37, CI [1.21, 1.55]). The Poisson regressions confirm these results for all playing positions, which included: (a) backs ($y = e^{(4.17-0.58x)}$, $R^2 = 0.53$, $p < 0.001$), (b) forwards ($y = e^{(4.54-0.40x)}$, $R^2 = 0.46$, $p < 0.001$), and (c) scrum-halves ($y = e^{(2.52-0.20x)}$, $R^2 = 0.03$, $p = 0.17$). The ID highlighted that backs and forwards born in the first week after the selection date was 1.78 (Figure 1f) and 1.49 (Figure 1g) times more likely to be included in the rosters than those born in the last week of the selection date, respectively. See Figure 1 for a visual inspection of the overall players' data, considering birth quartile and birth week distribution.

Table 1. Birth quartile distribution, chi-square value, and odds ratio analysis considering the different playing positions.

	Population	N	Q1	Q2	Q3	Q4	χ^2	*p*	V	V Category	OR Q1 vs. Q4	OR S1 vs. S2
All playing position	All sample	7144	28.8	23.1	27.8	20.3	136.044	<0.001	0.08	Small	1.42 [1.29, 1.56]	1.08 [1.01, 1.15]
	Northern Hemisphere	4859	28.1	20.8	29.7	21.4	122.551	<0.001	0.09	Small	1.32 [1.18, 1.47]	0.96 [0.88, 1.04]
	Southern Hemisphere	2285	30.2	28.1	23.6	18.1	79.560	<0.001	0.11	Small	1.67 [1.41, 1.98]	1.40 [1.25, 1.57]
Backs	All sample	2545	29.3	24.4	27.5	18.7	65.524	<0.001	0.09	Small	1.56 [1.33, 1.83]	1.16 [1.04, 1.30]
	Northern Hemisphere	1737	29.7	20.6	30.1	19.6	66.574	<0.001	0.11	Small	1.51 [1.25, 1.83]	1.01 [0.89, 1.16]
	Southern Hemisphere	808	28.5	32.7	22.0.	16.8	47.327	<0.001	0.14	Small	1.69 [1.27, 2.26]	1.57 [1.29, 1.92]
Forwards	All sample	4011	28.7	22.3	28.0	21.0	75.259	<0.001	0.08	Small	1.37 [1.21, 1.55]	1.04 [0.95, 1.14]
	Northern Hemisphere	2719	27.6	20.6	29.8	22.0	63.622	<0.001	0.09	Small	1.25 [1.08, 1.46]	0.93 [0.83, 1.03]
	Southern Hemisphere	1292	31.2	25.9	24.2	18.7	40.811	<0.001	0.10	Small	1.67 [1.33, 2.08]	1.33 [1.14, 1.55]
Scrum-Halves	All sample	588	27.0	23.3	27.0	22.6	3.973	0.264	0.05	-	1.20 [0.86, 1.65]	1.01 [0.81, 1.27]
	Northern Hemisphere	403	25.1	23.1	27.5	24.3	1.713	0.634	0.04	-	1.03 [0.70, 1.52]	0.93 [0.70, 1.22]
	Southern Hemisphere	185	31.4	23.8	25.9	18.9	5.935	0.115	0.10	-	1.66 [0.92, 2.98]	1.23 [0.82, 1.85]

Notes: Q1, first quartile percentage; Q2, second quartile percentage; Q3, third quartile percentage; Q4, fourth quartile percentage; χ^2, chi-square value; V, Cramer's V effect size; OR, odds ratio and 95% confidence intervals [95% CI]; Q1 vs. Q4, first versus the last quartile; S1 vs. S2, first versus the last semester.

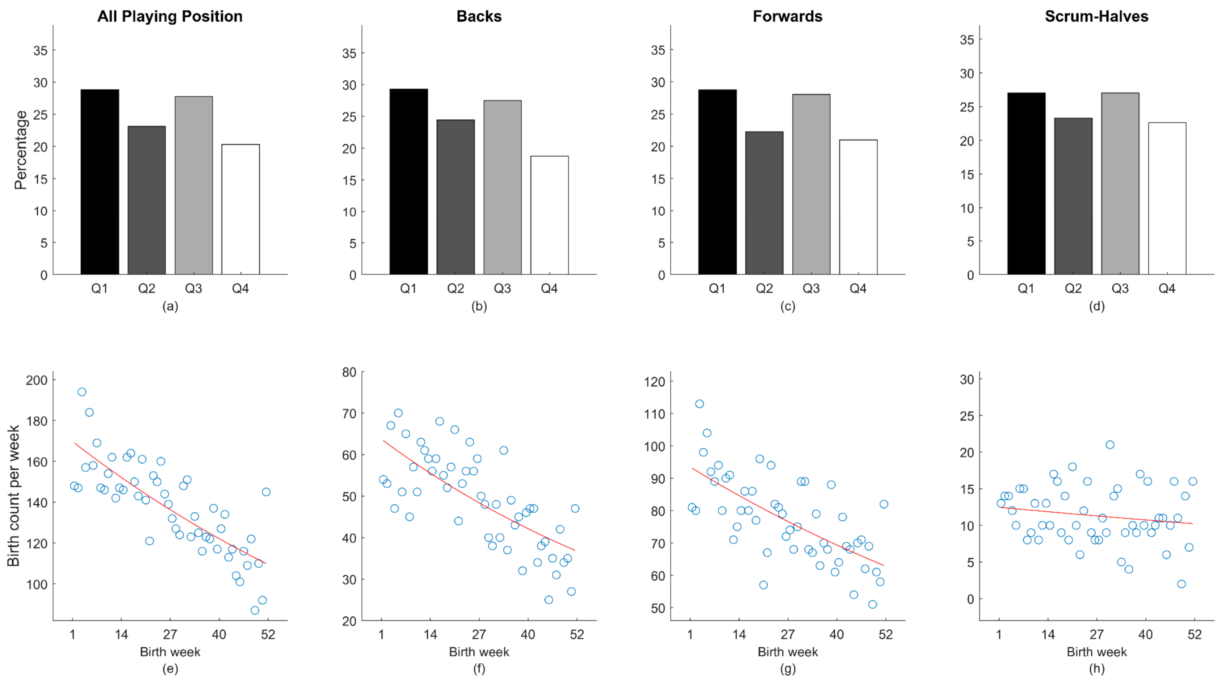

Figure 1. Birth quartile percentage distributions (**a**–**d**) and a scatterplot of birthdate frequency by week (**e**–**h**) presented individually for all playing positions, backs, forwards, and scrum-halves. The red line represents the best fit of the Poisson regression.

Small effect sizes (V ranged = 0.09–0.11) were apparent in the overall sample when comparing the northern and southern hemispheres (see Table 1). In the northern hemisphere, ORs showed that players born in Q1 were 1.32 times more likely to be selected (CI [1.18, 1.47]). Contrastingly, ORs were higher in players competing in the southern hemisphere, where the likelihood of relatively older players being selected in Q1 compared to the Q4 was 1.67 (95% CI [1.41, 1.98]). When comparing the northern and southern hemispheres, data suggested a more pronounced RAE for backs and forwards competing in the southern hemisphere (V ranged = 0.10–0.14) than in the northern hemisphere (V ranged = 0.09–0.11). Accordingly, significant ORs revealed that backs and forwards of the southern hemisphere born in Q1s were approximately 1.7 times more likely to be selected than those born in Q4s ($p < 0.001$). In the northern hemisphere, Q1s were about 1.5 times more likely to be selected than Q4s ($p < 0.001$). A similar percentage trend was observed in Q1s and Q4s when focused on the scrum-halves. The Poisson regressions also showed significant results for backs (northern hemisphere: $y = e^{(3.75-0.50x)}$, $R^2 = 0.33$, $p < 0.001$; southern hemisphere: $y = e^{(3.10-0.75x)}$, $R^2 = 0.29$, $p < 0.001$) and forwards (northern hemisphere: $y = e^{(4.09-0.28x)}$, $R^2 = 0.23$, $p < 0.001$; southern hemisphere: $y = e^{(3.51-0.64x)}$, $R^2 = 0.31$, $p < 0.001$) but not for scrum-halves (northern hemisphere: $y = e^{(2.08-0.07x)}$, $R^2 < 0.01$, $p < 0.67$; southern hemisphere: $y = e^{(1.49-0.29x)}$, $R^2 = 0.02$, $p = 0.28$). The IDs highlighted that northern hemisphere backs and forwards born in the first week after the selection date were 1.65 and 1.33 times more likely to be included in the rosters than those born in the last week of the selection date, respectively. In the southern hemisphere, the ID highlighted that backs and forwards born in the first week after the selection date were 2.12 and 1.89 times more likely to be included in the rosters than those born at the last week of the selection date, respectively.

5. Discussion

The present study aimed to explore the quartile distributions in the teams from the top 10 nations, according to the World Rugby rankings, considering the sociocultural influences (i.e., the northern and southern hemispheres) and playing positions (i.e., backs, forwards, and scrum-halves). The key findings of the study were that: (a) in the teams of top 10 World Rugby rankings, data revealed a skewed birth date distribution (favoring relatively older players), (b) the comparison between northern and southern hemisphere data suggests a weak RAE, both in northern and southern hemisphere, with a more pronounced RAE in the southern hemisphere, and (c) independent of the sociocultural context, the RAE was more prevalent for backs than forwards and inconsistent for scrum-halves.

When considering all teams in the top 10 World Rugby rankings, data suggested a persistent but weak RAE (V = 0.08). Findings revealed a skewed birthdate distribution favoring relatively older players (i.e., approximately 29% and 20% in Q1 and Q4, respectively). Players of Q1 were 1.42 times more likely to achieve professional status at the senior level than those of Q4. Nevertheless, it is necessary to highlight that compared to studies on young national pathways, we found a lower effect size, suggesting a weaker effect at the senior level. Indeed, previous studies at the senior international level have found contrasting results. More specifically, in rugby, current research has showed a persistent RAE [18,24], no RAE [20], and a reversal effect of the RAE [28]. For example, a skewed birthdate distribution favoring relatively older players was found in French [18] and Italian [20] players at the senior level. In comparison, however, there was no significant difference in the quartile distributions within both English senior premiership and international players [22]. Even if we found a weak magnitude of the RAE in this senior context, it can be assumed that, according to the selection and maturation hypothesis [10], the selection process at the senior level that is in favor of relatively older players may be explained, in part, by the critical role of physical characteristics important for achieving successful performances. This may be particularly true considering the nature of rugby union. During competitions, high physical demand is required due to contact and its invasive nature. Consequently, being chronologically older and, thus, probably more physically mature than peers may confer performance advantages [13]. Moreover, based on the theoretical model provided by Hankook et al. [9], different social agents, including parents, coaches, or the athletes themselves may have exacerbated RAE. The implications of the RAE in younger age groups are undoubtedly perpetuated through perceptions of athlete competence, including athletes' perceptions of themselves (i.e., Galatea effect), their coaches (i.e., Pygmalion effect), and their parents (i.e., Matthew effect) [9]. Initially, parents may influence the RAE by encouraging more frequently the relatively older athletes to take up sports (i.e., Matthew effect). Meanwhile, coaches might place greater expectations (e.g., more attention during the training sessions) on relatively older athletes and consequently advantage them (i.e., Pygmalion effect). Finally, older athletes, due to the higher expectation of parents and coaches, may increase their self-efficacy (e.g., perceive themselves as being more gifted) and be more motivated to work harder to meet expectations [30]. Overall, data suggest and confirm that the RAE at the senior international level is symptomatic of selection problems observed at the youth level [20], and thus the RAE mechanisms must be better understood to develop relevant solutions.

When focused on possible sociocultural differences (i.e., comparison between the northern and southern hemispheres), findings suggested that the countries in southern hemisphere (i.e., Argentina, Australia, New Zealand, and South Africa) showed a higher RAE than those from the northern hemisphere (i.e., England, France, Ireland, Japan, Scotland, and Wales). Independent of the players' playing position, the proportion of relatively older players in this study was 1.62 (southern hemisphere) and 1.32 (northern hemisphere) times higher than relatively younger players; however, it is important to note that both hemispheres' RAE showed low magnitude, as well as no difference in effect size. The southern hemisphere represents a test bench for new rules (World Rugby experimental ruleset) and a cutting-edge technical and tactical performance [31]. Thus, it can be speculated that the highest level of international rugby performance requires the greatest level of technical, tactical, physical, and anthropometric skills to be achieved as soon as possible, which likely favors relatively older players with a physical and technical, and tactical advantage. However, this possible explanation is only speculated and needs investigation in further studies. Moreover, despite the various cut-off dates across different countries (i.e., January to December, September to August, April to March), the RAE remained consistent. Indeed, similar findings have shown how the RAE remains prevalent in youth rugby union irrelevant of the change of cut-off date [12]. Therefore, practitioners and policymakers should be cautious of independent cut-off dates and how they can influence player development opportunities at both youth and senior levels.

Findings related to players' position indicated that, independent from the sociocultural context, the RAE appeared in backs and forwards and was inconsistent for scrum-halves. Interestingly, contrasting results are found in the literature when the effect of players' position was evaluated in relation to the RAE. For instance, Jones and colleagues [27] observed differences in the birth distribution concerning players' position among the world's best rugby union players, whereby a skewed birthdate distribution favored relatively older players for backs whereas there was a reversal birthdate distribution for forwards (i.e., favor younger players). In contrast, when analyzing Australian, English, New Zealand, and South African professional players at the senior level, Kearney [15] indicated that the RAE existed for forwards but not backs. In this present study, we found that at the senior level, selections of both backs and forwards were affected by the RAE, but not for scrum-halves. Due to the peculiarities of scrum-halves (e.g., the different game demands in terms of running intensity [32] and collision magnitude [33]) as well as the anthropometric profile differences (e.g., leaner and shorter players) when compared to backs and forwards, both at senior [34] and junior level [35,36], it is possible to suggest that coaches and stakeholders may be more poised to select backs and forwards to benefit from a greater body mass and strength rather than scrum-halves, which may further explain the how physiological characteristics make athletes more vulnerable to the RAE.

6. Limitations

It is important to acknowledge that the present study is affected by some limitations. Firstly, only one competition year (i.e., season 2021–2022) was examined for only top 10 nations. Indeed, results from a longitudinal perspective may have provided more concrete findings, whilst observing more diverse countries could have highlighted more impact on the sociocultural influences (e.g., the impact of sport popularity). Secondly, our dataset only included male international rosters. The difference in the RAE across female cohorts observed in other national contexts highlights the need to investigate gender differences at the international level of rugby union. However, it is also important to highlight that the development of female rugby union talent pathways and senior competition is developing rapidly. Thus, one should learn from some of the male RAE lessons when designing and implementing new organizational structures to create more appropriate settings. Finally, it is necessary to consider that we only investigated the RAE based on sociocultural influences and playing position, and thus did not consider other developmental factors linked with players selection. For example, studying the RAE alongside other individual constraints (e.g., performance match statistics, physical performances, maturation status) may further inform the potential mechanisms in a broader view.

7. Conclusions

The present results add a broader international overview to the RAE in rugby union literature. Overall, our data suggested that relatively older players may be significantly more likely to be selected in the senior rosters than their later-born peers. This effect was consistent in different sociocultural contexts (despite being more pronounced for the southern hemisphere) as well as for playing positions (i.e., more pronounced for backs). According to these findings, decision making during the selection process should favor a long-term vision in both the northern and southern hemispheres. Moreover, selection criteria should consider the athletes' long-term potential rather than their current performance capabilities. As a consequence, this approach could positively reform the RAE by widening the potential talent pool and preventing the risk of hindering relatively younger athletes from reaching their maximum potential.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/children9121941/s1.

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References

1. Williams, A.M.; Ford, P.R.; Drust, B. Talent identification and development in soccer since the millennium. *J. Sport. Sci.* **2020**, *38*, 1199–1210. [CrossRef]
2. Till, K.; Baker, J. Challenges and [Possible] Solutions to Optimizing Talent Identification and Development in Sport. *Front. Psychol.* **2020**, *11*, 664. [CrossRef] [PubMed]
3. Dimundo, F.; Cole, M.; Blagrove, R.; Till, K.; McAuley, A.; Hall, M.; Gale, C.; Kelly, A. Talent identification and development in male rugby union: A systematic review. *J. Expert.* **2021**, *4*, 33–55.
4. Romann, M.; Rüeger, E.; Hintermann, M.; Kern, R.; Faude, O. Origins of Relative Age Effects in Youth Football—A Nationwide Analysis. *Front. Sport. Act. Living* **2020**, *2*, 591072. [CrossRef]

5. Smith, K.L.; Weir, P.L.; Till, K.; Romann, M.; Cobley, S. Relative age effects across and within female sport contexts: A systematic review and meta-analysis. *Sport. Med.* **2018**, *48*, 1451–1478. [CrossRef] [PubMed]
6. Brustio, P.R.; Boccia, G.; De Pasquale, P.; Lupo, C.; Ungureanu, A.N. Small Relative Age Effect Appears in Professional Female Italian Team Sports. *Int. J. Environ. Res. Public Health* **2021**, *19*, 385. [CrossRef] [PubMed]
7. Cobley, S.; Baker, J.; Wattie, N.; McKenna, J. Annual age-grouping and athlete development: A meta-analytical review of relative age effects in sport. *Sport. Med.* **2009**, *39*, 235–256. [CrossRef] [PubMed]
8. Lovell, R.; Towlson, C.; Parkin, G.; Portas, M.; Vaeyens, R.; Cobley, S. Soccer Player Characteristics in English Lower-League Development Programmes: The Relationships between Relative Age, Maturation, Anthropometry and Physical Fitness. *PLoS ONE* **2015**, *10*, e0137238. [CrossRef] [PubMed]
9. Hancock, D.J.; Adler, A.L.; Côté, J. A proposed theoretical model to explain relative age effects in sport. *Eur. J. Sport Sci.* **2013**, *13*, 630–637. [CrossRef] [PubMed]
10. Dixon, J.C.; Liburdi, V.; Horton, S.; Weir, P.L. An examination of the impact of relative age effects and academic timing on intercollegiate athletics participation in women's softball. *J. Intercoll. Sport* **2013**, *6*, 147–163. [CrossRef]
11. Kelly, A.L.; Brown, T.; Reed, R.; Côté, J.; Turnnidge, J. Relative Age Effects in Male Cricket: A Personal Assets Approach to Explain Immediate, Short-Term, and Long-Term Developmental Outcomes. *Sports* **2022**, *10*, 39. [CrossRef] [PubMed]
12. Kelly, A.L.; Jackson, D.T.; Barrell, D.; Burke, K.; Baker, J. Relative age effects in international rugby union: Consequences of changing the cutoff date and exploring youth to senior transitions. *High Abil. Stud.* **2021**, 1–20. [CrossRef]
13. Kelly, A.L.; Barrell, D.; Burke, K.; Till, K. Relative age effects in rugby union. In *Birth Advantages and Relative Age Effects in Sport*; Kelly, A.L., Côté, J., Jeffreys, M., Turnnidge, J., Eds.; Routledge: New York, NY, USA, 2021; p. 17. [CrossRef]
14. Delorme, N.; Boiché, J.; Raspaud, M. The relative age effect in elite sport: The French case. *Res. Q. Exerc. Sport* **2009**, *80*, 336–344. [CrossRef] [PubMed]
15. Kearney, P.E. The influence of nationality and playing position on relative age effects in rugby union: A cross-cultural comparison. *S. Afr. J. Sport. Med.* **2017**, *29*, 1–4. [CrossRef]
16. Kearney, P.E. Playing position influences the relative age effect in senior rugby union. *Sci. Sport.* **2017**, *32*, 114–116. [CrossRef]
17. Kelly, A.L.; Jackson, D.T.; Barrell, D.; Burke, K.; Till, K. The relative age effect in male and female English age-grade rugby union: Exploring the gender-specific mechanisms that underpin participation. *Sci. Med. Footb.* **2022**, *6*, 277–284. [CrossRef]
18. Kelly, A.L.; Till, K.; Jackson, D.; Barrell, D.; Burke, K.; Turnnidge, J. Talent Identification and Relative Age Effects in English Male Rugby Union Pathways: From Entry to Expertise. *Front. Sport. Act Living* **2021**, *3*, 640607. [CrossRef]
19. Lewis, J.; Morgan, K.; Cooper, S.-M. Relative Age Effects in Welsh Age Grade Rugby Union. *Int. J. Sport. Sci. Coach.* **2015**, *10*, 797–813. [CrossRef]
20. Lupo, C.; Boccia, G.; Ungureanu, A.N.; Frati, R.; Marocco, R.; Brustio, P.R. The Beginning of Senior Career in Team Sport Is Affected by Relative Age Effect. *Front. Psychol.* **2019**, *10*, 1465. [CrossRef]
21. Till, K.; Cobley, S.; Wattie, N.; O'Hara, J.; Cooke, C.; Chapman, C. The prevalence, influential factors and mechanisms of relative age effects in UK Rugby League. *Scand J. Med. Sci. Sport* **2010**, *20*, 320–329. [CrossRef] [PubMed]
22. Gibbs, B.G.; Jarvis, J.A.; Dufur, M.J. The rise of the underdog? The relative age effect reversal among Canadian-born NHL hockey players: A reply to Nolan and Howell. *Int. Rev. Sociol. Sport* **2012**, *47*, 644–649. [CrossRef]
23. McCarthy, N.; Collins, D. Initial identification & selection bias versus the eventual confirmation of talent: Evidence for the benefits of a rocky road? *J. Sport. Sci.* **2014**, *32*, 1604–1610. [CrossRef]
24. McCarthy, N.; Collins, D.; Court, D. Start hard, finish better: Further evidence for the reversal of the RAE advantage. *J. Sport. Sci.* **2016**, *34*, 1461–1465. [CrossRef] [PubMed]
25. Smith, K.L.; Weir, P.L. Late Birthday Benefits. The "Underdog Hypothesis". In *Relative Age Effects in Sport International Perspectives*; Dixon, J., Horton, S., Chittle, L., Baker, J., Eds.; Taylor & Francis: New York, NY, USA, 2020; pp. 81–91.
26. Brustio, P.R.; Boccia, G. Corrective procedures remove relative age effect from world-class junior sprinters. *J. Sport. Sci.* **2021**, *39*, 2603–2610. [CrossRef] [PubMed]
27. Jones, B.D.; Lawrence, G.P.; Hardy, L. New evidence of relative age effects in "super-elite" sportsmen: A case for the survival and evolution of the fittest. *J. Sport. Sci.* **2018**, *36*, 697–703. [CrossRef]
28. Jones, T.W.; Smith, A.; Macnaughton, L.S.; French, D.N. Variances in strength and conditioning practice in elite Rugby Union between the northern and southern hemispheres. *J. Strength Cond. Res.* **2017**, *31*, 3358–3371. [CrossRef] [PubMed]
29. Pulling, C.; Stenning, M. Offloads in rugby union: Northern and southern hemisphere international teams. *Int. J. Perform. Anal. Sport* **2015**, *15*, 217–228. [CrossRef]
30. Brustio, P.R.; Kearney, P.E.; Lupo, C.; Ungureanu, A.N.; Mulasso, A.; Rainoldi, A.; Boccia, G. Relative Age Influences Performance of World-Class Track and Field Athletes Even in the Adulthood. *Front. Psychol.* **2019**, *10*, 1395. [CrossRef]
31. Fuller, C.W.; Raftery, M.; Readhead, C.; Targett, S.G.; Molloy, M.G. Impact of the International Rugby Board's experimental law variations on the incidence and nature of match injuries in southern hemisphere professional rugby union. *S. Afr. Med. J.* **2009**, *99*, 232–237.
32. Read, D.B.; Till, K.; Beasley, G.; Clarkson, M.; Heyworth, R.; Lee, J.; Weakley, J.J.S.; Phibbs, P.J.; Roe, G.A.B.; Darrall-Jones, J.; et al. Maximum running intensities during English academy rugby union match-play. *Sci. Med. Footb.* **2019**, *3*, 43–49. [CrossRef]
33. Grainger, A.; McMahon, J.J.; Comfort, P. Assessing the frequency and magnitude of match impacts accrued during an elite rugby union playing season. *Int. J. Perform. Anal. Sport* **2018**, *18*, 507–522. [CrossRef]

34. Fuller, C.W.; Taylor, A.E.; Brooks, J.H.; Kemp, S.P. Changes in the stature, body mass and age of English professional rugby players: A 10-year review. *J. Sport. Sci.* **2013**, *31*, 795–802. [CrossRef] [PubMed]
35. Ungureanu, A.N.; Beratto, L.; Daga, F.A.; Boccia, G.; Lupo, C.; Brustio, P.R. Changes in anthropometric and fitness profile of Italian regional academy rugby union players. *Biol. Sport* **2022**, *39*, 621–628. [CrossRef] [PubMed]
36. Delahunt, E.; Byrne, R.B.; Doolin, R.K.; McInerney, R.G.; Ruddock, C.T.; Green, B.S. Anthropometric profile and body composition of Irish adolescent rugby union players aged 16-18. *J. Strength Cond. Res.* **2013**, *27*, 3252–3258. [CrossRef] [PubMed]

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Article

From Junior to Elite in Soccer: Exploring the Relative Age Effect and Talent Selection in Spanish Youth National Teams

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Abstract: The implications of relative age grouping in sport are known as the Relative Age Effect (RAE). This study has the twofold purpose of analyzing RAE in Spanish youth national soccer teams and examining the prediction value of being selected for national youth teams to be a professional. The sample was composed of 548 players divided into five groups. A descriptive analysis of distribution and participation, frequencies, mean and standard deviation, crosstabs, Sankey charts, coefficient correlation and Cohen's effect size criteria and two regression analyses were performed. Results established that the RAE is present in U'17 to U'21 Spanish youth national teams. Talent detection and selection programs are more reliable the closer they are to adulthood, reaching a success rate of almost 100% at the U'21 stage. The selection of players for such programs should be delayed as much as possible, thus, preventing younger players from dropping out and those selected from thinking they have already reached their goal. To this end, they should focus on long-term improvement, not short-term performance. In addition, factors such as the RAE or the maturity level of the athletes should be monitored.

Keywords: talent selection; Relative Age Effect; maturation; performance; soccer

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1. Introduction

Research and analysis of talent detection and development have grown considerably over the last 20 years [1]. This interest continues due to the unreliability and predictability of talent identification programs [2]. In fact, factors such as relative age, growth, maturation or years of training are still not adequately taken into account, focusing mainly on current performance and not on development [3].

In sport, it is very common to group athletes according to their date of birth, either on an annual or biannual basis, to limit large age differences in competitors [4]. Athletes born at the beginning of the grouping date (usually January 1), have an advantage over those born at the end of the grouping date [5,6]. The consequences of this relative age grouping are known as the Relative Age Effect (RAE) [7]. This results in more athletes born in the first half of the year in the lower sport categories, mainly due to maturational aspects such as anthropometric, physiological or physical/conditional factors. In talent detection and selection programs there is a strong influence of the RAE [4,8]. This is explained by the physical and physiological competitive advantages that players born early in the year have compared to those born later in the same year. These players are selected for what they are in the short term, instead of being selected for what they could be in the future [9,10].

Paradoxically, when the senior level is reached this difference between those born in the first half of the year and those born in the second half lessens and even disappears [11,12]. This phenomenon is known as RAE reversal [12]. Players born later in the year, the oldest players, who make it to the high-performance level, have more successful careers in terms of competitive experiences, longevity in the sport, results or salaries [11]. Being born in the second part of the year, with physical disadvantages compared to those born in the first part, means that young players must develop different skills to be able to compete at the same level as older players [4]. These skills are going to allow them to achieve higher performance at the senior stage, as the physical disadvantages disappear, but not the acquired technical–tactical skills [13], in addition to the psychological ones [14].

The RAE is gradually reduced, without disappearing, up until the senior category [15]. That is, the players who were the best in training categories are gradually being matched and surpassed by other players who were not selected in lower categories. The physical advantage they had when beginning the sport, disappears as the other players mature and, in addition, these differences that were very important during the developmental stages, are no longer so important [16]. In fact, other skills that are decisive for achieving high performance, such as a high degree of resilience [17] or the ability to cope with adversity [18], become evident. Another explanation is the smaller number of injuries presented by these players compared to those who have specialized from a young age [19].

Sport specialization is understood as intense training in one sport to the exclusion of others [20]. This approach to sport practice looks to maximize the performance potential of athletes. Coaches, parents and athletes believe that in this way they will acquire specific skills that will allow them to reach the elite level. Ericsson, Krampe and Tesch-Römer [21] popularized the belief that the greater the amount of specific and intense practice in a sport, the higher the performance. Therefore, one must start at an early age to succeed in a sport [22]. Sport specialization is associated in the long term with overuse injuries and abandonment of sport practice due to burnout [23]. Indeed, the most talented players, capable of becoming elite soccer players, should be identified at the right time [24], not as early as possible.

In view of the above, this study has two differentiated objectives: (a) to analyze the participation of players in the different youth categories of the Spanish national soccer team according to relative age, and (b) to determine the relationship between the youth categories and whether the players who participate in them go on to play soccer professionally.

2. Materials and Methods

2.1. Sample and Population

The population was composed of all the male players who participated, at least once, in national football team competitions, official or friendly matches, in the under 17 (U’17), under 19 (U’19), under 20 (U’20) and under 21 (U’21) categories, and senior national team players born from 1990 to 2005. The sample (n = 548) was distributed as follows: U’17 (n = 112), U’19 (n = 225), U’20 (n = 235), U’21 (n = 335), senior (n = 126). Data were retrieved principally from a specialized webpage of historic and statistical data in soccer (https://www.bdfutbol.com/es/index.html (accessed on 1 March 2020)). In addition, data were checked in other webpages, such as the Spanish football federation webpage, sites of international competitions of each category, sport journals and personal sites.

2.2. Measurements

The study analyzes the following variables: chronological age, the birth quarter of players (Q1 (January, February, March), Q2 (April, May, June), Q3 (July, August, September) and Q4 (October, November, December)) [25,26], specific playing position, seasons in first and second soccer division of the country, games played in each division and national team categories (U’17, U’19, U’20, U’21 and senior national team).

2.3. Data Analysis

First, a descriptive analysis was carried out of the sample distribution and participation in national teams. Different analyses were used according to data nature, frequencies, mean and standard deviation, crosstabs and Sankey charts. The percentages of players who have reached the professional category were also used. The coefficient of correlation was used to identify the participation in different national teams and professional soccer. The statistical significance of Pearson's correlation coefficients depends on sample size, so effect sizes of correlations were reported because of varied sample size, and Cohen's effect size criteria for correlation coefficients was used to interpret them (small: |r| = 0.10–0.29, medium: |r| = 0.30–0.49 and large: |r| = 0.50 [27]). Finally, two regression analyses were carried out to predict the possibilities of being a professional soccer player and participating in the senior national team. Participation in different youth national teams was analyzed to explore its effects on final performance, identified as games played in the first division. The Durbin-Watson test was used to check whether the residuals in the model were independent and look within the data to control collinearity effects. A binary logistic regression was used to predict national team participation in the function of youth national games participation. Four independent dichotomic variables were included in the model: participation in U'17, U'18, U'19 and U'21 youth national teams. The dependent variable used in this model was Y [0, 1]. The values of the dependent variable were 1 for participation in the national team and 0 for players that had not participated in national teams. For this model, the odds ratios (ORs) and a 95% confidence interval (CI) were determined. The ORs explain the increased odds of the outcome occuring. If the value is greater than 1, then the odds are bigger. The statistical analyses were performed using SPSS v.21 software (Inc., Chicago, IL, USA). Statistical significance was set at $p < 0.05$.

3. Results

Table 1 shows how births were distributed across the year in all the analyzed categories. In all cases, the first trimester was when the most births occurred, and the first half of the year establishes that the Relative Age Effect is present in soccer and lasts in all youth categories in Spanish national teams.

Table 1. Birth distribution according to trimester.

	17	19	20	21	TOTAL
1º	28.6% (32)	33.8% (76)	35.7% (84)	30.4% (102)	32.4% (294)
2º	25.9% (29)	23.1% (52)	23.8% (56)	24.2% (81)	24.0% (218)
3º	25.0% (28)	22.2% (50)	25.5% (60)	25.1% (84)	24.4% (222)
4º	20.5% (23)	20.9% (47)	14.9% (35)	20.3% (68)	19.0% (173)
TOTAL	112	225	235	335	907

Figure 1 shows how players' careers developed through national teams before achieving professional status. The Sankey diagram shows how each player's career develops over time.

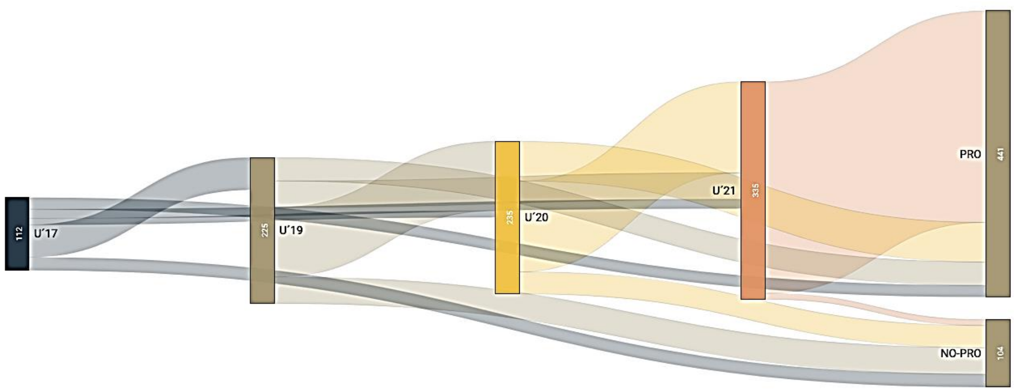

Figure 1. Players' careers across national teams.

The figure indicates the path that the selected players follow until they reach the professional soccer league or not. Among the players called up for the U'17 national team (n = 112), there were 82 players who became professionals, but only 13 players went through all the lower national teams until they became professionals. In addition to the 50 players who went on to U'19, there were another 173 players who were selected for the first time. Of these, 167 made it to the professional level, but only 107 were selected at the senior level. Of the 335 players in the U'21 category, 194 made it to the professional level, some through the senior category (*n* = 140) and others directly (*n* = 54). Of the 335 players selected in the U'21, there were nine who did not become professionals in the first division.

Table 2 shows descriptive statistics (number and percentage) of players' careers till their debut or not in first division soccer. It can be observed that the U'21 category is the most prolific compared with the U'17 or U'19 categories. Figure 2 shows conversion rate to 1st division in each national team according to birth trimester.

Table 2. Descriptive statistics of players' development according to age.

	17	19	20	21
No debut	30 26.80%	58 25.80%	41 17.40%	9 2.70%
Debut	82 73.20%	167 74.20%	194 82.60%	326 97.30%

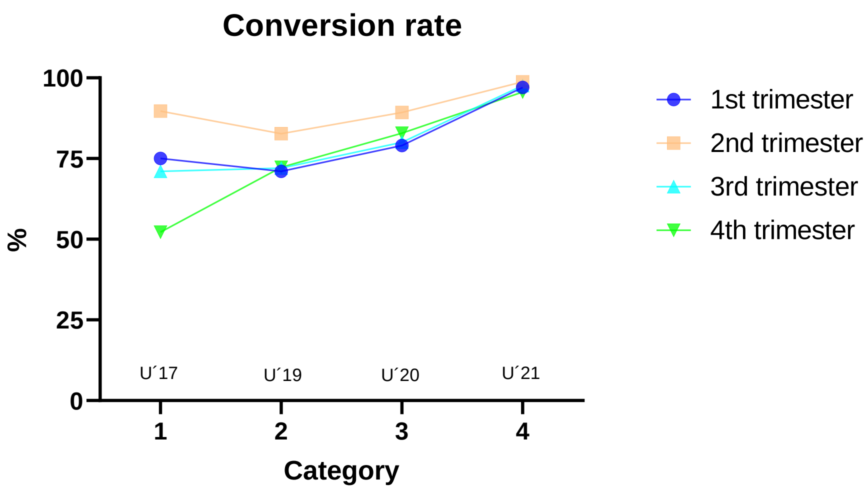

Figure 2. Percentage of players that achieve the professional level according to birth trimester.

Table 3 shows correlation coefficients among different Spanish youth national team players and their first division debut. The U'21 national team is the only category that has a positive impact on being a top professional. Whereas, the U'17 and U'19 national teams have a negative impact.

Table 3. Correlation Coefficient of different categories of Spanish national teams and first division soccer.

	U'19	U'20		U'21		1st Division	
U'17	0.037	−0.147	**	−0.171	**	−0.101	*
U'19		0.79		−0.202	**	−0.145	**
U'20				−0.028		0.034	
U'21						0.521	**

* $p < 0.05$; ** $p < 0.01$.

Lastly, Table 4 shows a logistic regression among all categories. In line with the previous results, being a member of the U'21 national team predicts being a professional in top leagues (R^2 = 0.40). In Table 5, a linear regression shows identical results when predicting games played at top-level soccer. Only the U'21 national team had a positive influence on later performance (R^2 = 0.40).

Table 4. Logistic regression between Spanish national youth teams and playing in first division soccer.

	B	S.E.	Wald	*p*	OR	OR (95% IC)	
						Lower	Upper
U'17	0.038	0.315	0.015	0.903	1.039	0.561	1.925
U'19	0.232	0.273	0.721	0.396	1.261	0.738	2.156
U'20	−0.289	0.282	1.055	0.304	0.749	0.431	1.3
U'21	−3.337	0.374	79.452	0.000	0.036	0.017	0.074
Constant	−0.226	0.3	0.568	0.451	0.798		

$R^2 = 0.40$ (Nagelkerke). $p < 0.001$.

Table 5. Linear regression between Spanish national youth teams and football games played in the first division.

	B(SD)
Constant	2.39 (0.42)
U'17	−0.23(0.46)
U'19	−0.09(0.38)
U'20	0.26(0.37)
U'21	7.2(0.39) **
R^2	0.40
Durbin-Watson	1.83
N	548

** $p < 0.001$.

4. Discussion

The objective of this study was twofold: (a) to analyze the RAE in Spanish youth national teams and (b) to study the prediction value of being selected for national youth teams for being a professional. The results established that the RAE is present in U'17 to U'21 Spanish youth national teams. In addition, the U'21 national team is the only one that predicts professional performance. Talent detection and development programs have a success rate of about 30% [28]. Usually, these processes focus on successful athletes who have excelled at an early age, using short-term performance indicators such as physical or anthropometric parameters. The RAE notably influences these, leaving aside others such as decision-making, perception, etc., [29]. On the other hand, it is known that relatively younger athletes perform better when they reach adulthood [30].

The RAE has previously been studied in sports [4,5,14] with different effects and sizes according to age or type of sport. The literature suggests that this effect tends to disappear with age [31]. This study sample was selected to begin with 17-year-old players, skipping early development stages, when the RAE is more solid. In sports such as soccer, physical maturation influences physical conditions like strength, endurance and speed [12], the key to sporting success. These characteristics allow older players to gain an advantage over their peers [32]. In addition, differences in the maturational development of young players are going to negatively affect talent identification and player selection [15]. Relatively older players are going to enjoy more opportunities to play, better coaches and competitions, which is going to make the gap between those born earlier and later widen. Around 25% of the U'17 and U'19 players analyzed in this study do not become professionals. Aspects such as date of birth must be taken into consideration when selecting players [33]. Current proposals, such as organized bio-banding competitions, will allow talent detection to be based on technical–tactical issues and not on pure maturation.

Paradoxically, it has been previously shown in basketball that being selected for the junior teams of the national basketball team had a negative impact on players' subsequent development [34]. In fact, being selected at these ages does not predict high performance [35]. These results support the findings of this study. Participating in the lower national team categories does not have a positive impact on the final development of young soccer players. In these national teams, players are chosen for what they can do in this moment, seeking performance over other characteristics. When the physical advantages at those ages are matched by the rest of their peers, the skills that others have had to develop to be at the same level, are going to make that initial advantage disappear [13]. In addition, the pursuit of early performance is associated with increased dropout when athletes are under high levels of pressure [36]. This early specialization, in some cases, has a positive influence on subsequent performance. In the case of swimming, junior swimmers who go on to compete at the international level as seniors achieve good results [37].

In fact, clubs select players born earlier in the year for their physical and anthropometric power [38]. This is going to cause the selected boys and girls to dedicate many more hours to sport-specific practice, a highly structured practice known as deliberate practice and what Ericsson [21] points out as fundamental to achieving excellence. This initial push in sport expertise means that the rest of the motor experiences or sport skills are scarce, limiting motor development [39]. It seems clear that the soccer players in this study have undergone an early specialization to become international players in training categories at 16 or 17 years of age which has limited their future development and participation in professional competitions.

5. Conclusions

Talent detection and selection programs are more reliable the closer they are to adulthood, reaching a success rate of almost 100% at the U'21 stage. The earlier these programs are carried out, the fewer the selected players will arrive at the professional level. In addition, the training processes of talented athletes are complex and multifactorial, so the decisions made must help players stay in the sport. For example, these TID (talent identification and development) programs are strongly influenced by the RAE, which can cause unselected athletes to drop out of the sport.

Practical Applications

The selection of players for talent programs should be delayed as much as possible, thus, avoiding younger players dropping out and those selected thinking that they have already achieved their goal. TID programs should be focused on long-term improvement, not short-term performance. In addition, factors such as the RAE or the maturity level of the athletes should be monitored.

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References

1. Sarmento, H.; Anguera, M.T.; Pereira, A.; Araújo, D. Talent Identification and Development in Male Football: A Systematic Review. *Sports Med.* **2018**, *48*, 907–931. [CrossRef] [PubMed]
2. Leite, N.; Calvo, A.L.; Cumming, S.; Goncalves, B.; Calleja-Gonzalez, J. Editorial: Talent Identification and Development in Sports Performance. *Front. Sports Act. Living* **2021**, *3*, 729167. [CrossRef] [PubMed]
3. Arede, J.; Cumming, S.; Johnson, D.; Leite, N. The effects of maturity matched and un-matched opposition on physical performance and spatial exploration behavior during youth basketball matches. *PLoS ONE* **2021**, *16*, e0249739. [CrossRef] [PubMed]

4. Ibáñez, S.J.; Mazo, A.; Nascimento, J.; García-Rubio, J. The Relative Age Effect in under-18 basketball: Effects on performance according to playing position. *PLoS ONE* **2018**, *13*, e0200408. [CrossRef] [PubMed]
5. Sá, P.; Resende, R.; Gomes, A.R.; Saavedra, M.; Fernández, J.J. A idade relativa nos jogadores de andebol em Portugal. *Rev. Cienc. Deporte* **2020**, *16*, 93–102.
6. Wattie, N.; Cobley, S.; Baker, J. Towards a unified understanding of relative age effects. *J. Sports Sci.* **2008**, *26*, 1403–1409. [CrossRef]
7. Musch, J.; Grondin, S. Unequal Competition as an Impediment to Personal Development: A Review of the Relative Age Effect in Sport. *Dev. Rev.* **2001**, *21*, 147–167. [CrossRef]
8. Yagüe, J.M.; de la Rubia, A.; Sánchez-Molina, J.; Maroto-Izquierdo, S.; Molinero, O. The Relative Age Effect in the 10 Best Leagues of Male Professional Football of the Union of European Football Associations (UEFA). *J. Sports Sci. Med.* **2018**, *17*, 409–416.
9. Simonton, D.K. Talent Development as a Multidimensional, Multiplicative and Dynamic Process. *Curr. Dir. Psychol. Sci.* **2001**, *10*, 39–43. [CrossRef]
10. Romann, M. Improving Talent Identification through Analysis and Consideration of Biological and Relative Age. 2020. Available online: https://www.researchgate.net/profile/Michael-Romann/publication/347240903_Improving_talent_identification_through_analysis_and_consideration_of_biological_and_relative_age/links/5fd8cc8845851553a0bb7aad/Improving-talent-identification-through-analysis-and-consideration-of-biological-and-relative-age.pdf (accessed on 1 June 2022).
11. De la Rubia, A.; Lorenzo-Calvo, J.; Lorenzo, A. Does the Relative Age Effect Influence Short-Term Performance and Sport Career in Team Sports? A Qualitative Systematic Review. *Front. Psychol.* **2020**, *11*, 1947. [CrossRef]
12. Cobley, S.; Baker, J.; Wattie, N.; McKenna, J. Annual age-grouping and athlete development. *Sports Med.* **2009**, *39*, 235–256. [CrossRef] [PubMed]
13. Torres-Unda, J.; Zarrazquin, I.; Gravina, L.; Zubero, J.; Seco, J.; Gil, S.M.; Gil, J.; Irazusta, J. Basketball Performance Is Related to Maturity and Relative Age in Elite Adolescent Players. *J. Strength Cond. Res.* **2016**, *30*, 1325–1332. [CrossRef] [PubMed]
14. Kelly, A.L.; Wilson, M.R.; Gough, L.A.; Knapman, H.; Morgan, P.; Cole, M.; Jackson, D.T.; Williams, C.A. A longitudinal investigation into the relative age effect in an English professional football club: Exploring the 'underdog hypothesis'. *Sci. Med. Footb.* **2020**, *4*, 111–118. [CrossRef]
15. Brustio, P.R.; Lupo, C.; Ungureanu, A.N.; Frati, R.; Rainoldi, A.; Boccia, G. The relative age effect is larger in Italian soccer top-level youth categories and smaller in Serie A. *PLoS ONE* **2018**, *13*, e0196253. [CrossRef]
16. Augste, C.; Lames, M. The relative age effect and success in German elite U-17 soccer teams. *J. Sports Sci.* **2011**, *29*, 983–987. [CrossRef]
17. Sarkar, M.; Fletcher, D.; Brown, D.J. What doesn't kill me . . . : Adversity-related experiences are vital in the development of superior Olympic performance. *J. Sci. Med. Sport* **2015**, *18*, 475–479. [CrossRef]
18. Collins, D.; MacNamara, Á. The rocky road to the top. *Sports Med.* **2012**, *42*, 907–914. [CrossRef]
19. Bjørndal, C.T.; Andersen, S.S.; Ronglan, L.T. Successful and unsuccessful transitions to the elite level: The youth national team pathways in Norwegian handball. *Int. J. Sports Sci. Coach.* **2018**, *13*, 533–544. [CrossRef]
20. Kliethermes, S.A.; Nagle, K.; Côté, J.; Malina, R.M.; Faigenbaum, A.; Watson, A.; Feeley, B.; Marshall, S.W.; LaBella, C.R.; Herman, D.C.; et al. Impact of youth sports specialization on career and task-specific athletic performance: A systematic review following the American Medical Society for Sports Medicine (AMSSM) Collaborative Research Network's 2019 Youth Early Sport Specialization Summit. *Br. J. Sports Med.* **2020**, *54*, 221–230. [CrossRef]
21. Ericsson, K.A.; Krampe, R.T.; Tesch-Römer, C. The role of deliberate practice in the acquisition of expert performance. *Psychol. Rev.* **1993**, *100*, 363–406. [CrossRef]
22. Ford, P.R.; Williams, A.M. Sport activity in childhood: Early specialization and diversification. In *Routledge Handbook of Talent Identification Development in Sport*, 1st ed.; Routledge: London, UK, 2017; pp. 116–132.
23. DiFiori, J.P.; Benjamin, H.J.; Brenner, J.S.; Gregory, A.; Jayanthi, N.; Landry, G.L.; Luke, A. Overuse injuries and burnout in youth sports: A position statement from the American Medical Society for Sports Medicine. *Br. J. Sports Med.* **2014**, *48*, 287–288. [CrossRef] [PubMed]
24. Sieghartsleitner, R.; Zuber, C.; Zibung, M.; Conzelmann, A. "The Early Specialized Bird Catches the Worm!"—A Specialised Sampling Model in the Development of Football Talents. *Front. Psychol.* **2018**, *9*, 188. [CrossRef] [PubMed]
25. Helsen, W.F.; Baker, J.; Michiels, S.; Schorer, J.; van Winckel, J.; Williams, A.M. The relative age effect in European professional soccer: Did ten years of research make any difference? *J. Sports Sci.* **2012**, *30*, 1665–1671. [CrossRef] [PubMed]
26. Pérez-González, B.; León-Quismondo, J.; Bonal, J.; Burillo, P.; Fernández-Luna, Á. The New Generation of Professional Soccer Talent Is Born under the Bias of the RAE: Relative Age Effect in International Male Youth Soccer Championships. *Children* **2021**, *8*, 1117. [CrossRef] [PubMed]
27. Cohen, J.W. *Statistical Power Analysis for the Behavioral Sciences*, 2nd ed.; Lawrence Erlbaum Associates: New York, NY, USA, 1988.
28. Koz, D.; Fraser-Thomas, J.; Baker, J. Accuracy of professional sports drafts in predicting career potential. *Scand. J. Med. Sci. Sports* **2012**, *22*, 64–69. [CrossRef] [PubMed]
29. Hyllegard, R.; Radlo, S.J.; Early, D. Attribution of athletic expertise by college coaches. *Percept. Mot. Skills* **2001**, *92*, 193–207. [CrossRef] [PubMed]
30. Güllich, A.; Emrich, E. Considering long-term sustainability in the development of world class success. *Eur. J. Sport Sci.* **2014**, *14*, 383–397. [CrossRef]

31. Rees, T.; Hardy, L.; Güllich, A.; Abernethy, B.; Côté, J.; Woodman, T.; Montgomery, H.; Laing, S.; Warr, C. The Great British Medalists Project: A Review of Current Knowledge on the Development of the World's Best Sporting Talent. *Sports Med.* **2016**, *46*, 1041–1058. [CrossRef]
32. Carling, C.; le Gall, F.; Reilly, T.; Williams, A.M. Do anthropometric and fitness characteristics vary according to birth date distribution in elite youth academy soccer players? *Scand. J. Med. Sci. Sports* **2009**, *19*, 3–9. [CrossRef]
33. Deaner, R.O.; Lowen, A.; Cobley, S. Born at the wrong time: Selection bias in the NHL draft. *PLoS ONE* **2013**, *8*, e57753. [CrossRef]
34. Ibáñez, S.J.; Sáenz-López, P.; Feu, S.; Giménez, J.; García, J. Progression of Spanish National Team Basketball Players by Age and Sex. *Open Sports Sci. J.* **2010**, *3*, 118–128. [CrossRef]
35. Werneck, F.; Coelho, E.; de Oliveira, H.; Júnior, D.R.; Almas, S.; de Lima, J.; Matta, M.O.; Figueiredo, A.J. Relative age effect in Olympic basketball athletes. *Sci. Sports* **2016**, *31*, 158–161. [CrossRef]
36. Gould, D.; Tuffey, S.; Udry, E.; Loehr, J. Burnout in competitive junior tennis players: II. Qualitative analysis. *Sport Psychol.* **1996**, *10*, 341–366. [CrossRef]
37. Yustres, I.; Santos del Cerro, J.; Martín, R.; González-Mohíno, F.; Logan, O.; González-Ravé, J.M. Influence of early specialization in world-ranked swimmers and general patterns to success. *PLoS ONE* **2019**, *14*, e0218601. [CrossRef]
38. Delorme, N.; Raspaud, M. The relative age effect in young French basketball players: A study on the whole population. *Scand. J. Med. Sci. Sports* **2009**, *19*, 235–242. [CrossRef]
39. Wiersma, L.D. Risks and benefits of youth sport specialization: Perspectives and recommendations. *Pediatr. Exerc. Sci.* **2000**, *12*, 13–22. [CrossRef]

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Men Are from Quartile One, Women Are from? Relative Age Effect in European Soccer and the Influence of Age, Success, and Playing Status

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Abstract: The relative age effect (RAE) is characterised by an overrepresentation of athletes born earlier in the selection year. Whilst an RAE is consistently evident in male soccer, examinations in female players remain limited. The aim of the present study was to examine the influence of sex, as well as age, success, and playing status in European soccer players. The sample consisted of a total of 6546 soccer players from 55 soccer nations that competed in recent European Championship qualification campaigns. Results indicated an evident RAE in male [$p = 0.017$] but not female [$p = 0.765$] players. Male players were over-represented by players born in the first quartile for the U17 [$p < 0.001$] and U19 [$p = 0.001$] levels, however, this over-representation did not transfer to senior levels. No RAE was observed at any level for female players. Inside each age group, a slight selection bias towards those born in the first quartile for successful squads was observed but did not significantly differentiate between qualification status for either male or female players. Results from this study highlight the disparity in RAE prevalence between male and female players and raise further questions regarding the value of selecting relatively older players to metrics of success, transition, and selection for senior international soccer.

Keywords: talent; identification; development; selection; football

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1. Introduction

Soccer is one of the most popular sports worldwide, particularly in Europe. Recently, female participation and popularity have increased exponentially. Between 2016–2017, the number of registered female youth players within Europe increased by ~130,000 (14%; [1]. Female soccer has also experienced an increase in both attendance figures (live and television) and sponsorship, as demonstrated by the creation of relatively new professional leagues (e.g., The FA Women's Super League in England), resulting in a rise of professionalism in the sport [1]. Accordingly, approaches to talent identification in female soccer may have evolved, but research examining these approaches is limited [2]. Resultant of this exponential growth, approaches to talent identification and causality have been incorrectly extrapolated to the female game, which may be erroneous [3]. Though a continuous growth in research attention on female soccer has been seen, the numbers are not equal to outputs in male soccer. Thus, calls for a growth of research within female soccer; particularly talent identification, have been made (e.g., [2,4]).

For male soccer, a contentious issue related to talent identification is the relative age effect (RAE; [5]). The RAE is characterised by an overrepresentation of players born earlier in the selection year [5]. Researchers suggest that chronologically older athletes may be selected for talent development programmes due to acute anthropometrical and physical advantages or perception of increased skill [6]. However, these advantages often dissipate or reverse at the senior level [7], raising awareness of this process relative to long-term development and success. In contrast, negative implications for relatively younger athletes have been identified, such as higher drop-out rates and limited selection opportunities [8,9]. While this phenomenon has been extensively examined in male players over the last few decades with consistent results (e.g., [10]), examinations in female soccer have been less consistent (e.g., [11]). For example, there was no RAE observed for female US Olympic development program players [12], Division 1 Féminine (France) players [8], or Swiss national team players [13]. Yet others report a significant RAE in female youth international players from Europe and North and Central America [14] and domestic players in Spain [15]. Recently, Götze and Hoppe [16] compared the prevalence of a RAE bias in 1763 male and female national and domestic level players in Germany. Results indicated that an RAE was only prevalent in senior female players competing in the second tier, compared to significant RAE in both male first and second tiers and at youth international level. The inconsistency in observed RAE prevalence, combined with disparities in male samples, raise questions around the pervasiveness of the RAE as an issue related to talent identification and selection in female soccer.

Though Götze and Hoppe [16] directly compared male and female soccer players, they, and other previous reports, focus on a single soccer nation. Most published reports explore RAE prevalence and draw conclusions related to talent identification and development practices in established soccer nations. Acknowledging the substantial differences in talent pools, participation rates, domestic competition, and financial resources it is possible that the RAE prevalence may differ across soccer nations [17]. Typically, reports from established soccer nations report RAE bias at youth levels [16,18,19] but not at senior levels [7] and suggest that RAE prevalence may influence the competitive success [20]. For example, a significant correlation was identified between RAE and success (final league position) in U17 soccer players in Germany [21]. In contrast, only a select number of studies have examined prevalence of an RAE in less established or developing soccer nations. Finnegan et al. [22] examined the birth dates of 1936 U14 male players from Ireland that had been selected for the 'emerging talent programme'. The authors observed that 68% of selected players were born in the first half of the selection year. Moreover, Dugdale et al. [23] examined birthdate distributions of male soccer players across varying age groups and performance levels in Scotland. These authors observed a significant RAE for players within academy structures but not at the senior professional level. Unsurprisingly, given the paucity of published reports investigating RAE prevalence in female compared to male players, limited data are available concerning RAE for female soccer players across diverse soccer nations.

Lastly, one factor that may moderate RAE prevalence, yet has received little attention, is players that are deemed to possess the skills to compete at higher age levels, also referred to as 'playing up'. Many studies have independently examined RAE in youth-level soccer and investigations into 'playing up' (e.g., [24]); however, research merging these two topics of interest remains scarce. It may be suggested that players that are moved up a chronological age grouping to account for biases typically exacerbated by RAE prevalence and allow for a more appropriate 'challenge point' for players at both ends of the selection spectrum (i.e., Q1 and Q4). Subjective evidence posits that athletes that 'play up' engage in practice and competition that has a higher yet appropriate challenge point and can have important implications for their developmental outcomes [25]. Whilst theoretically sensical, limited data examine this phenomenon across comprehensive samples of male and female soccer players [24,26].

Accordingly, the aim of the present study was to examine the prevalence of RAE in international female European soccer players. To provide a comparison, we also examined RAE in equivalent international male European soccer players. It was hypothesised that a significant RAE bias would be observed in European male, but not female, players. Furthermore, we hypothesised that an RAE would be prevalent in younger (i.e., U17; U19) but not senior male players, comparable to previous reports [7,23]. Acknowledging the inconsistency in female RAE prevalence, we hypothesised that this observation would not translate to female international players. Given the limited research examining the influence of competition level and 'playing up' on RAE in soccer, we forgo making a priori hypotheses.

2. Materials and Methods

2.1. Participants

Birthdates of 6546 active European soccer players were obtained in March 2021 from the official data centres of the Union of European Football Association [27] and individual nations. Birthdates were collected from all 55 associations under the UEFA governing body and from the qualification squads/teams for the most recent European Championship campaign, respectively (2019 women's U17 Championships, Bulgaria; 2019 men's U17 Championships, Ireland; 2019 women's U19 Championships, Scotland; 2019 men's U19 Championships, Armenia; 2022 women's senior Championships, England; 2020 men's senior Championships, Europe). Players were categorised by sex: female (2387); male (4159), competition level (i.e., age group): U17 (Female = 324; Male = 1187); U19 (Female = 293; Male = 1229); senior (Female = 1770; Male = 1743), qualification status (i.e., did they qualify for the knockout round(s) of their respective competitions): qualified (Female = 994; Male = 1405); non-qualified (Female = 1393; Male = 2754), and by playing status (i.e., they are playing inside, or above their chronological age group): age group (Female = 337; Male = 2020); playing up (Female = 280; Male = 396). Any players that were listed twice (e.g., making appearances at U17 and U19) were categorised based on the most appearances. Because data were freely available via the internet, no approval by an ethical committee was required. The study was conducted in accordance with the declaration of Helsinki. For a full breakdown of the categories and definitions, please see Table 1.

Table 1. Categories, subcategories, and definitions of independent variables.

Category	Subcategory	*n*	Definition
Sex	Female	2387	Represented their respective nation's female soccer team.
	Male	4159	Represented their respective nation's male soccer team.
Competition Level	U17	1511	Represented their nation during the U17 qualification campaign.
	U19	1522	Represented their nation during the U19 qualification campaign.
	Senior	2513	Represented their nation during the Senior qualification campaign.
Qualification Status	Qualified	2399	Qualified for the knockout round(s) of their respective competitions.
	Non-Qualified	4147	Did not qualify for the knockout round(s) of their respective competitions.
Playing Status	Age Group	2357	Playing inside their age group (e.g., 16/17 years playing at U17 level).
	Playing Up	676	Playing above their age group (e.g., 16/17 years playing at U19 level).

2.2. Procedure

The birth month for each player was used to define the birth quarter- and half-year distribution per semester [5]. We adopted cut-off dates defined as: Q1 = Jan-Mar; Q2 = Apr-Jun; Q3 = Jul-Sep; Q4 = Oct-Dec, and semesters: S1 = Jan-Jun; S2 = Jul-Dec. Due to England having different selection cut-off dates to other European countries, we adjusted their quartiles/semesters, specifically (Q1 = Sep-Nov; Q2 = Dec-Feb; Q3 = Mar-May; Q4 = Jun-Aug, and semesters: S1 = Sep-Feb; S2 = Mar-Aug). A failure to be aware of this difference can lead to skewed results within large-scale RAE studies [28].

2.3. Data Analysis

The Chi-squared (χ^2) test was used to assess differences between observed and expected birthdate distributions across quartiles for: (1) Each sex irrespective of age or playing level; (2) Each sex, age group, and qualification status; and (3) Each sex and playing status. Expected birthdates were obtained from a European database [29]. They reflected the average population birthdate distributions for all available nations under the UEFA governing body from 1978–2004, capturing the population records for the birth years of the oldest to youngest players within the sample. Population birthdate distributions were identified as: Q1 = 24.4%; Q2 = 25.4%; Q3 = 26.0%; Q4 = 24.2%. Odds ratios (ORs) and 95% confidence intervals (95% CI) were calculated to compare the odds of the frequency of a quartile/semester to another with a reference group consisting of the relatively youngest players (Q4 or S2, respectively). An OR of 1.0 indicated that the frequency is equal in both quarters/semesters whilst an OR of 2.0 indicated that the frequency of one quarter/semester is twice as high as the other [11,16]. ORs were considered significant if the 95% CI range did not include a value <1.00. Furthermore, effect sizes (Cohen's W) were calculated to determine the magnitude of chi-squared tests, Cohen [30] proposed that where $w = 0.10$, $w = 0.30$, and $w = 0.50$, they specified small, medium, and large effect sizes, respectively. Where appropriate, alpha was set at $p < 0.05$. Data were analysed via SPSS Statistics Version 26.0 for Windows (IBM, Chicago, Illinois, United States).

3. Results

There was a statistically significant RAE for male players [$\chi^2 = (n = 4159) = 10.2$, $p = 0.017$], but not female players [$\chi^2 = (n = 2387) = 1.2$, $p = 0.765$]. Male players born in the first quartile were over-represented (Q1 vs. Q4, *OR* = 2.4, *CI* = 0.8–3.7 Figure 1), and the ORs declined marginally for comparisons later in the year, with Q4 being inferior for each case (Q2 vs. Q4, OR = 1.7; Q3 vs. Q4, OR = 1.4).

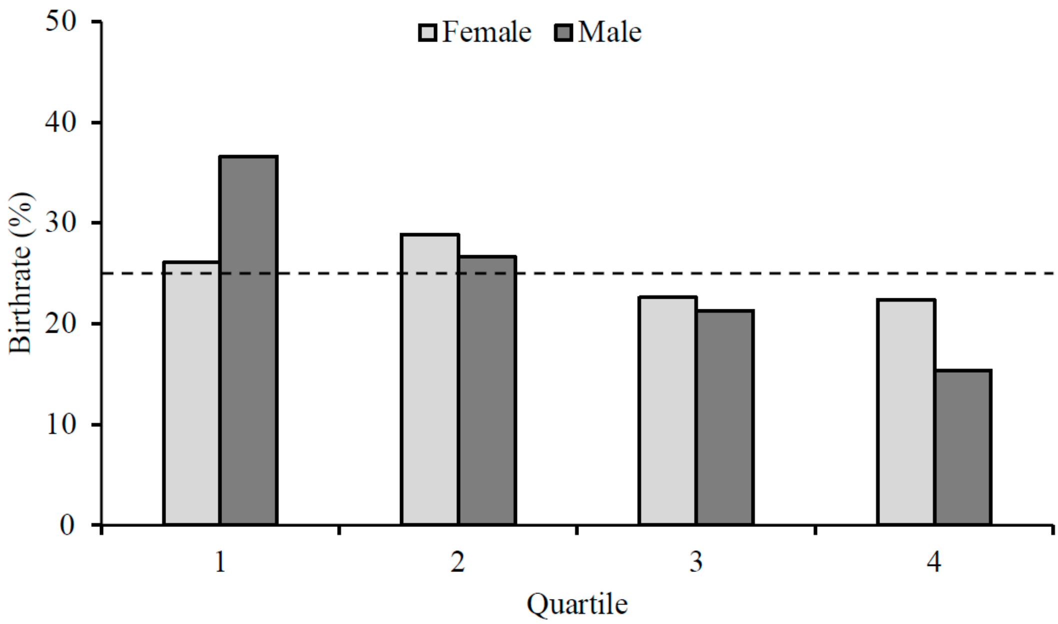

Figure 1. Birth quartile distribution for female (light grey) and male (dark grey) soccer players.

The frequency and percentage distributions of players' birth quartiles for competition level and qualification status are presented in Table 2. For competition level, irrespective of qualification status, there were statistically significant RAEs for male [U17s: $\chi^2 = (n = 1187) = 24.6$, $p < 0.001$; U19s: $\chi^2 = (n = 1229) = 15.7$, $p = 0.001$; Senior: $\chi^2 = (n = 1743) = 2.3$, $p = 0.506$], but not female players [U17s: $\chi^2 = (n = 324) = 1.5$, $p = 0.680$; U19s: $\chi^2 = (n = 293) = 4.8$, $p = 0.187$; Senior: $\chi^2 = (n = 1101) = 1.1$, $p = 0.788$]. In male players, the chi-squared test indicated significant deviations in birth quartiles for the U17 and U19 levels only, with players born in the first quartile (U17 = 43.2%; U19 = 39.6%) being over-represented (Q1 vs. Q4, U17: *OR* = 4.3, *CI* = 1.8–10.4; U19: *OR* = 2.6, *CI* = 1.2–5.9, Table 2), and the ORs decreased for comparisons later in the year, with Q4 (U17 = 10.0%; U19 = 15.1%) being inferior for each case (Q2 vs. Q4, U17: *OR* = 2.7, *CI* = 1.1–6.8; U19: *OR* = 1.8, *CI* = 0.8–4.2, Q3 vs. Q4, U17: *OR* = 1.9, *CI* = 0.8–5.0; U19: *OR* = 1.2, *CI* = 0.5–2.9). Analysis revealed that although Q1 were over-represented, a significant RAE did not exist for senior players. Further analysis on male U17 and U19 players indicated significant deviations in birth quartiles for both players that had qualified [U17s: $\chi^2 = (n = 323) = 32.9$, $p < 0.001$; U19s: $\chi^2 = (n = 159) = 19.3$, $p < 0.001$] and did not qualify [U17s: $\chi^2 = (n = 864) = 21.9$, $p < 0.001$; U19s: $\chi^2 = (n = 1070) = 15.3$, $p = 0.002$] for their respective competitions. For players that had qualified, a progressive decrease in birth quartiles from Q1 to Q4 was observed (Q1 vs. Q4, U17: *OR* = 6.1; U19: *OR* = 3.5, Q2 vs. Q4, U17: *OR* = 3.9; U19: *OR* = 2.2, Q3 vs. Q4, U17: *OR* = 2.4; U19: *OR* = 1.7, Table 2), with players that did not qualify following the same pattern (Q1 vs. Q4, U17: *OR* = 3.9; U19: *OR* = 2.5, Q2 vs. Q4, U17: *OR* = 2.4; U19: *OR* = 1.8, Q3 vs. Q4, U17: *OR* = 1.8; U19: *OR* = 1.1, Table 2).

Table 2. Birth quartile distribution by sex, age group, and qualification status (* Significant at an alpha level of $p < 0.05$).

				Birthdate Distribution (%)				**Odds Ratio (95% CI)**					
			n	**Q1**	**Q2**	**Q3**	**Q4**	**Q1 vs. Q4**	**Q2 vs. Q4**	**Q3 vs. Q4**	**S1 vs. S2**	χ^2	***p***
Female	U17	Qual	165	42 (25.5)	52 (31.5)	37 (22.4)	34 (20.6)	1.2 (0.6–2.8)	1.5 (0.7–3.4)	1.1 (0.5–2.5)	1.3 (0.8–2.3)	2.6	0.467
		Non	159	45 (28.3)	42 (23.3)	37 (23.3)	35 (22.0)	1.3 (0.6–2.8)	1.2 (0.5–2.7)	1.1 (0.5–2.4)	1.2 (0.7–2.1)	1.3	0.735
		All	324	87 (26.9)	94 (29.0)	74 (22.8)	69 (21.3)	1.3 (0.6–2.8)	1.4 (0.6–3.0)	1.1 (0.5–2.4)	1.3 (0.7–2.2)	1.5	0.68
	U19	Qual	160	51 (31.9)	37 (23.1)	37 (23.1)	35 (21.9)	1.5 (0.7–3.2)	1.1 (0.5–2.4)	1.1 (0.5–2.4)	1.2 (0.7–2.1)	3.0	0.383
		Non	133	46 (34.6)	39 (29.3)	26 (19.5)	22 (16.5)	2.1 (0.9–4.7)	1.8 (0.8–4.0)	1.2 (0.5–2.8)	1.8 (1.0–3.1)	8.9 *	0.03
		All	293	97 (33.1)	76 (25.9)	63 (21.5)	57 (19.5)	1.7 (0.8–3.7)	1.3 (0.6–3.0)	1.1 (0.5–2.5)	1.4 (0.8–2.5)	4.8	0.187
	Sen	Qual	669	165 (24.7)	201 (30.0)	144 (21.5)	159 (23.8)	1.1 (0.5–2.3)	1.3 (0.6–2.7)	0.9 (0.4–2.0)	1.2 (0.7–2.1)	1.6	0.654
		Non	1101	275 (25.0)	317 (28.8)	259 (23.5)	250 (22.7)	1.1 (0.5–2.4)	1.3 (0.6–2.8)	1.0 (0.5–2.3)	1.2 (0.7–2.0)	0.8	0.849
		All	1770	440 (24.9)	518 (29.3)	403 (22.8)	409 (23.1)	1.1 (0.5–2.4)	1.3 (0.6–2.8)	1.0 (0.4–2.2)	1.2 (0.7–2.1)	1.1	0.788
Male	U17	Qual	323	147 (45.5)	94 (29.1)	58 (18.0)	24 (7.4)	6.1 (2.4–15.9)	3.9 (1.5–10.4)	2.4 (0.9–6.7)	2.9 (1.6–5.3)	32.9 *	<0.001
		Non	864	366 (42.4)	230 (26.6)	173 (20.0)	95 (11.0)	3.9 (1.6–9.2)	2.4 (1.0–5.9)	1.8 (0.7–4.6)	2.2 (1.3–4.0)	21.9 *	<0.001
		All	1187	513 (43.2)	324 (27.3)	231 (19.5)	119 (10.0)	4.3 (1.8–10.4)	2.7 (1.1–6.8)	1.9 (0.8–5.0)	2.4 (1.3–4.3)	24.6 *	<0.001
	U19	Qual	159	66 (41.5)	41 (25.8)	33 (20.8)	19 (11.9)	3.5 (1.5–8.1)	2.2 (0.9–5.2)	1.7 (0.7–4.3)	2.1 (1.2–3.7)	19.3 *	<0.001
		Non	1070	421 (39.3)	297 (27.8)	186 (17.4)	166 (15.5)	2.5 (1.1–5.7)	1.8 (0.8–4.1)	1.1 (0.5–2.7)	2.0 (1.2–3.6)	15.3 *	0.002
		All	1229	487 (39.6)	338 (27.5)	219 (17.8)	185 (15.1)	2.6 (1.2–5.9)	1.8 (0.8–4.2)	1.2 (0.5–2.9)	2.0 (1.2–3.6)	15.7 *	0.001
	Sen	Qual	923	295 (32.0)	239 (25.9)	219 (23.7)	170 (18.4)	1.7 (0.8–3.9)	1.4 (0.6–3.2)	1.3 (0.6–2.9)	1.4 (0.8–2.4)	4.0	0.265
		Non	820	229 (27.9)	208 (25.4)	215 (26.2)	168 (20.5)	1.4 (0.6–3.0)	1.2 (0.6–2.8)	1.3 (0.6–2.9)	1.1 (0.7–2.0)	1.1	0.784
		All	1743	524 (30.1)	447 (25.6)	434 (24.9)	338 (19.4)	1.6 (0.7–3.4)	1.3 (0.6–3.0)	1.3 (0.6–2.9)	1.3 (0.7–2.2)	2.3	0.506

The frequency and percentage distributions of players' birth quartiles for playing status are presented in Table 3. The chi-squared test indicated significant deviations in birth quartiles for male players playing inside their age group [$\chi^2 = (n = 2020) = 20.6$, $p < 0.001$], or 'playing up' [$\chi^2 = (n = 396) = 15.8$, $p = 0.001$]. Players born in the first quartile were over-represented (Q1 vs. Q4, Age-Group: *OR* = 3.3; Playing Up: *OR* = 3.2), and the ORs decreased marginally for comparisons later in the year, with Q4 being inferior for each case (Q2 vs. Q4, Age-Group: *OR* = 2.1; Playing up: *OR* = 2.6, Q3 vs. Q4, Age-Group: *OR* = 3.3; Playing up: *OR* = 3.2, Table 3). Analysis revealed that for female players, although there was a greater representation of players in Q1 for playing inside the age groups (Q1 vs. Q4, *OR* = 1.7), this was not significant [$\chi^2 = (n = 337) = 4.5$, $p = 0.212$]. Moreover, RAE did not exist for players 'playing up' [$\chi^2 = (n = 280) = 1.0$, $p = 0.806$].

Table 3. Birth quartile distribution by sex and playing status (* Significant at an alpha level of $p < 0.05$).

			Birthdate Distribution (%)				Odds Ratio (95% CI)					
		n	Q1	Q2	Q3	Q4	Q1 vs. Q4	Q2 vs. Q4	Q3 vs. Q4	S1 vs. S2	χ^2	*p*
Female	Age Group	337	106 (31.5)	96 (28.5)	72 (21.4)	63 (18.7)	1.7 (0.8–3.7)	1.5 (0.7–3.4)	1.1 (0.5–2.6)	1.5 (0.9–2.6)	4.5	0.212
	Playing Up	280	78 (27.9)	74 (26.4)	64 (22.9)	64 (22.9)	1.2 (0.6–2.7)	1.2 (0.5–2.5)	1.0 (0.5–2.2)	1.2 (0.7–2.1)	1.0	0.806
Male	Age Group	2020	851 (42.1)	542 (26.8)	369 (18.3)	258 (12.8)	3.3 (1.4–7.6)	2.1 (0.9–5.0)	1.4 (0.6–3.5)	2.2 (1.3–4.0)	20.6 *	<0.001
	Playing Up	396	149 (37.6)	120 (30.3)	81 (20.5)	46 (11.6)	3.2 (1.4–7.7)	2.6 (1.1–6.3)	1.8 (0.7–4.4)	2.1 (1.2–3.8)	15.8 *	0.001

4. Discussion

The present study explores RAE prevalence in a comprehensive, multi-national sample of both males and females, considering the implications of sex, age, success, and playing status. Our main findings were: (1) Almost no prevalent RAE was observed for female players within our sample; (2) a typical RAE prevalence was observed for equivalent male players within our study, demonstrating a strong RAE bias for youth players and diminishing at senior level; (3) RAE prevalence did not distinguish between qualification status for either male or female players within our sample; (4) RAE prevalence did not distinguish between those who were competing at a higher chronological age level (i.e., 'playing up') for either male or female players within our sample.

Analysis of our entire sample (all presently active European female and male soccer players, representing their UEFA nation at all ages) showed a relatively equal birthdate distribution in female soccer players (Figure 1). This finding is only partially consistent with previous literature [8,12,14,15]. Published reports suggest that a lack of RAE prevalence in female soccer could, historically, be due to the reduced popularity of the sport, compared to male soccer, resulting in a smaller talent pool and potentially lower competition for team places [16]. For example, Korgaoker et al. [31] postulated that the strong and consistent RAE in youth female soccer in the United States was due to the popularity of the sport and competition for places within that specific nation. Furthermore, Lagestad et al., [32] found that RAE prevalence increased as females progressed from local to regional teams in Norway. As the popularity of female soccer continues to grow exponentially, we urge those primarily responsible for the identification, development and (de)selection of players, such as coaches and scouts, should be cognisant of this bias as the popularity and participation of female soccer continues to grow. They may look towards other potential predictors of future expert performance, such as physical, skill, psychological and sociological [2], rather than using processes that are evident in the male game and extrapolating them to the female game, which may be erroneous [3].

Other possible explanations for the sex-specific differences in RAE prevalence may be related to the interaction of chronological age, development, and training age [12,33]. For example, female players born in the first half of the year may be more likely to begin playing soccer earlier than their younger counterparts [14], with parents often more hesitant to register a later-born female player into soccer [34]. Although different constructs [35], a 'maturation-selection' explanation is often suggested regarding RAE prevalence. [33,35]. Delorme et al., [8] suggests advancing physical development may act as a socially constructed disadvantage for young females, which could lead to dropping out due to feelings of shyness regarding body changes or social pressures to conform to socially constructed sex roles of stereotyped femininity [12]. Moreover, the observed lack of RAE across all ages of competition for female players suggests that talented youth female soccer players are identified through other known predictors of adult high performance in soccer, such as sociological (e.g., hours of practice) or skill (e.g., technical skill) predictors [2]. We propose that additional factors may influence RAE prevalence in female soccer players and encourage researchers and practitioners to be mindful of these considerations when working with this population.

To provide a comparison, we also examined RAE prevalence in equivalent international male European soccer players. Analysis of the entire male sample showed that players that were born in the first quartile of their selection year were over-represented (Figure 1). This finding is consistent with previous reports of male soccer players across various European domestic leagues and national teams [16,18,19]. We also posited that selection bias would be evident in younger (i.e., U17) male soccer players, yet the advantages of being born earlier in the selection year would not translate to senior levels. In line with this hypothesis, our data indicate an unequal birthdate distribution for U17 male soccer players. This unequal distribution continued until the senior level where it was no longer evident. The strong RAE in male soccer players competing at U17 and U19 competition levels suggests that a selection bias continues to favour chronologically older players despite weakening maturation advantages and disparities in accumulated practice hours. This demonstrates a 'cascading' effect of RAE prevalence and suggests a continuation of bias, favouring chronologically older players due to talent identification and (de)selection processes earlier in development [23,35]. The lack of RAE observed in senior male players as they transition from youth to senior level is consistent with previous observations of soccer nations such as Germany [7]. When considering the selection bias at the youth level (e.g., U17, U19), this reduction in RAE prevalence at senior levels challenges the efficacy of this (un)conscious bias and raises awareness of this process relative to long-term development and success [7,36,37].

Analysis of qualification status showed an over-representation of players born at the beginning of the year for squads qualifying for men's U17 and U19 competitions [16,17,19,21]. Importantly, there were also differences in RAE prevalence for squads that did not qualify for the same competitions. This finding is consistent with previous reports from self-defined smaller and less-established soccer nations [22,23]. It could be suggested that despite differences in population size, participation rate, domestic competition level, and financial resources [17], similar approaches to talent identification and (de)selection might be being adopted [2], demonstrating the pervasiveness of RAE in youth male soccer.

Furthermore, we observed a prominent RAE in male players competing at their chronological age group and those who were 'playing up'. Recently, Kelly et al. [26] examined factors differentiating youth academy players in England from foundation (U9–U11) or youth (U12–U16) development phases that were either competing at or above their chronological age. Differences were reported for technical and tactical skills for both phases, as well as differences in physical and psychological characteristics within the youth development phase. However, it was noted that ~80% of players that were 'playing up' were born in the first half of their initial selection year. In the youth development phase in England, enhanced maturity status (greater percentage of estimated adult height attained) is suggested to contribute to 'playing up' [26]. Within youth sports, it is possible to have two players with the same relative age yet have a wide variance in biological age [38]. Early maturing players in youth soccer have been found to be taller and heavier than late-maturing players [39]. Relatively high numbers of early-maturing athletes within chronologically younger athlete samples have been identified [40]. This suggests that the relatively younger players who exhibit advanced growth and maturation have an increased likelihood of selection into soccer development pathways [41], perhaps nullifying the negative impact of a later birthdate for early maturing players. Finally, Kelly et al. [26] suggest that when 'playing up', players were at least a full chronological year younger than their peers which may create an 'underdog' effect. This may result in relatively young athletes engaging in higher levels of practice and play to match/surmount greater technical/tactical or psychological performance of their older peers [24]. Consequently, it has been reported that younger athletes who progress to being professional have been awarded more accolades and have longer-lasting careers compared to their older peers [42]. We propose that multidimensional factors associated with RAE prevalence may influence both initial selection and decisions pertaining to 'playing up' in male youth soccer.

This study is not without its limitations. First, due to obtaining birth data from external sources, we did not obtain any anthropometric data. Thus, our supposition of chronologically older players possessing greater physical, cognitive, and psychosocial attributes and other skills was based on previous theoretical assumptions rather than original data. Though some researchers have questioned whether it is conducive to continue to examine the relative age effect [43], findings from the present study provide a comprehensive evaluation of female players across multiple nations and an equivalent male comparison. Further, the present study explores the influence of RAE bias on previously identified areas of interest to talent identification and development (i.e., 'playing up' and competitive success).

5. Conclusions

In summary, our results demonstrate that the RAE exists in male, but not female, soccer players participating in UEFA European tournaments between 2019–2022. Male soccer players competing at U17 and U19 levels were over-represented by players born at the beginning of their selection year. This bias did not transition into senior level, questioning the efficacy of this (un)conscious bias. However, these advantages often dissipate or reverse at the senior level [7]. Furthermore, within these age groups, this selection bias did not discriminate against those that qualified for their respective competitions or whether players were playing at a higher chronological age (i.e., 'playing up').

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References

1. Women's Football across the National Sssociations 2017. Available online: https://www.uefa.com/multimediafiles/download/officialdocument/uefaorg/women%27sfootball/02/51/60/57/2516057 (accessed on 12 October 2021).
2. Williams, A.M.; Ford, P.R.; Drust, B. Talent identification and development in soccer since the millennium. *J. Sports Sci.* **2020**, *38*, 1199–1210. [CrossRef] [PubMed]
3. Emmonds, S.; Heyward, O.; Jones, B. The challenge of applying and undertaking research in female sport. *Sports Med.-Open* **2019**, *5*, 51. [CrossRef] [PubMed]
4. Kryger, K.O.; Wang, A.; Mehta, R.; Impellizzeri, F.M.; Massey, A.; McCall, A. Research on women's football: A scoping review. *Sci. Med. Footb.* **2021**, 1–10. [CrossRef]
5. Cobley, S.; Baker, J.; Wattie, N.; McKenna, J. Annual age-grouping and athlete development: A meta-analytical review of relative age effects in sport. *Sports Med.* **2009**, *39*, 235–256. [CrossRef] [PubMed]
6. Wattie, N.; Schorer, J.; Baker, J. The relative age effect in sport: A developmental systems model. *Sports Med.* **2015**, *45*, 83–94. [CrossRef]
7. Skorski, S.; Skorski, S.; Faude, O.; Hammes, D.; Meyer, T. The relative age effect in elite German youth soccer: Implications for a successful career. *Int. J. Sports Physiol. Perform.* **2016**, *11*, 370–376. [CrossRef]

8. Delorme, N.; Boiché, J.; Raspaud, M. The relative age effect in elite sport: The French case. *Res. Q. Exerc. Sport* **2009**, *80*, 336–344. [CrossRef]
9. Hancock, D.J.; Ste-Marie, D.M.; Young, B.W. Coach selections and the relative age effect in male youth ice hockey. *Res. Q. Exerc. Sport* **2013**, *84*, 126–130. [CrossRef]
10. Helsen, W.F.; Baker, J.; Michiels, S.; Schorer, J.; Van Winckel, J.; Williams, A.M. The relative age effect in European professional soccer: Did ten years of research make any difference? *J. Sports Sci.* **2012**, *30*, 1665–1671. [CrossRef]
11. Smith, K.L.; Weir, P.L.; Till, K.; Romann, M.; Cobley, S. Relative age effects across and within female sport contexts: A systematic review and meta-analysis. *Sports Med.* **2018**, *48*, 1451–1478. [CrossRef]
12. Vincent, J.; Glamser, F.D. Sex differences in the relative age effect among US Olympic development program youth soccer players. *J. Sports Sci.* **2006**, *24*, 405–413. [CrossRef] [PubMed]
13. Romann, M.; Fuchslocher, J. Influence of the selection level, age and playing position on relative age effects in Swiss women's soccer. *Talent. Dev. Excell.* **2011**, *3*, 239–247.
14. Romann, M.; Fuchslocher, J. Influences of player nationality, playing position, and height on relative age effects at women's under-17 FIFA World Cup. *J. Sports Sci.* **2013**, *31*, 32–40. [CrossRef] [PubMed]
15. Sedano, S.; Vaeyens, R.; Redondo, J.C. The relative age effect in Spanish female soccer players. Influence of the competitive level and a playing position. *J. Hum. Kinet.* **2015**, *46*, 129. [CrossRef] [PubMed]
16. Götze, M.; Hoppe, M.W. Relative age effect in elite German soccer: Influence of sex and competition level. *Front. Psychol.* **2021**, *11*, 3725. [CrossRef]
17. Bennett, K.J.; Vaeyens, R.; Fransen, J. Creating a framework for talent identification and development in emerging football nations. *Sci. Med. Footb.* **2019**, *3*, 36–42. [CrossRef]
18. Salinero, J.J.; Pérez, B.; Burillo, P.; Lesma, M.L. Relative age effect in European professional football. Analysis by position. *J. Hum. Sport Exerc.* **2013**, *8*, 966–973. [CrossRef]
19. Yagüe, J.M.; de la Rubia, A.; Sánchez-Molina, J.; Maroto-Izquierdo, S.; Molinero, O. The relative age effect in the 10 best leagues of male professional football of the Union of European Football Associations (UEFA). *J. Spo. Sci. Med.* **2018**, *17*, 409–416.
20. Söderström, T.; Brusvik, P.; Lund, S. Factors underlying competitive success in youth football. A study of the Swedish national U15 football talent system. *Scand. Sport Stud. Forum* **2019**, *10*, 139–162.
21. Augste, C.; Lames, M. The relative age effect and success in German elite U-17 soccer teams. *J. Sports Sci.* **2011**, *29*, 983–987. [CrossRef]
22. Finnegan, L.; Richardson, D.; Littlewood, M.; McArdle, J. The influence of date and place of birth on youth player selection to a National Football Association elite development programme. *Sci. Med. Footb.* **2017**, *1*, 30–39. [CrossRef]
23. Dugdale, J.H.; McRobert, A.P.; Unnithan, V.B. "He's just a wee laddie": The relative age effect in male Scottish soccer. *Front. Psychol.* **2021**, *12*, 103. [CrossRef] [PubMed]
24. Kelly, A.L.; Wilson, M.R.; Gough, L.A.; Knapman, H.; Morgan, P.; Cole, M.; Jackson, D.T.; Williams, C.A. A longitudinal investigation into the relative age effect in an English professional football club: Exploring the 'underdog hypothesis'. *Sci. Med. Footb.* **2020**, *4*, 111–118. [CrossRef]
25. Malina, R.M. Early sport specialization: Roots, effectiveness, risks. *Curr. Sports Med. Rep.* **2010**, *9*, 364–371. [CrossRef]
26. Kelly, A.; Wilson, M.R.; Jackson, D.T.; Goldman, D.E.; Turnnidge, J.; Côté, J.; Williams, C.A. A multidisciplinary investigation into "playing-up" in academy football according to age phase. *J. Sports Sci.* **2021**, *39*, 854–864. [CrossRef]
27. Member Associations. Available online: https://www.uefa.com/insideuefa/member-associations/ (accessed on 21 October 2021).
28. Padrón-Cabo, A.; Rey, E.; García-Soidán, J.L.; Penedo-Jamardo, E. Large Scale Analysis of Relative Age Effect on Professional Soccer Players in FIFA Designated Zones. *Int. J. Perform. Anal. Sport* **2016**, *16*, 332–346. [CrossRef]
29. Live Births by Months. Available online: https://ec.europa.eu/eurostat/ (accessed on 15 January 2022).
30. Cohen, J. A power primer. *Psychol. Bull.* **1992**, *112*, 55–159. [CrossRef]
31. Korgaokar, A.D.; Farley, R.S.; Fuller, D.K.; Caputo, J.L. Relative age effect among elite youth female soccer players across the United States. *Sport Mont* **2018**, *16*, 37–41. [CrossRef]
32. Lagestad, P.; Steen, I.; Dalen, T. Inevitable relative age effects in different stages of the selection process among male and female youth soccer players. *Sports* **2018**, *6*, 29. [CrossRef]
33. Baker, J.; Cobley, S.; Montelpare, W.J.; Wattie, N.; Faught, B.E. Exploring proposed mechanisms of the relative age effect in Canadian minor hockey. *Int. J. Sport Psychol.* **2010**, *41*, 148–159.
34. Smith, K.L.; Weir, P.L. An examination of the relative age effect in developmental girls' hockey in Ontario. *High Abil. Stud.* **2013**, *24*, 171–184. [CrossRef]
35. Lovell, R.; Towlson, C.; Parkin, G.; Portas, M.; Vaeyens, R.; Cobley, S. Soccer player characteristics in English lower-league development programmes: The relationships between relative age, maturation, anthropometry and physical fitness. *PLoS ONE* **2015**, *10*, e0137238. [CrossRef] [PubMed]
36. Brustio, P.R.; Lupo, C.; Ungureanu, A.N.; Frati, R.; Rainoldi, A.; Boccia, G. The relative age effect is larger in Italian soccer top-level youth categories and smaller in Serie A. *PLoS ONE* **2018**, *13*, e0196253. [CrossRef] [PubMed]
37. Gil, S.M.; Bidaurrazaga-Letona, I.; Martin-Garetxana, I.; Lekue, J.A.; Larruskain, J. Does birth date influence career attainment in professional soccer? *Sci. Med. Footb.* **2020**, *4*, 119–126. [CrossRef]

38. Malina, R.M.; Rogol, A.D.; Cumming, S.P.; Coelho-e-Silva, M.J.; Figueiredo, A.J. Biological maturation of youth athletes: Assessment and implications. *Br. J. Sports Med.* **2015**, *49*, 852–859. [CrossRef]
39. Gouvea, M.A.; Cyrino, E.S.; Valente-dos-Santos, J.; Ribeiro, A.; Silva, D.R.P.; Ohara, D.; Coelhoe-Silva, M.J.; Ronque, E. Comparison of skillful vs. less skilled young soccer players on anthropometric, maturation, physical fitness and time of practice. *Int. J. Sport. Med.* **2017**, *38*, 384–395. [CrossRef]
40. Müller, L.; Gonaus, C.; Perner, C.; Müller, E.; Raschner, C. Maturity status influences the relative age effect in national top level youth alpine ski racing and soccer. *PLoS ONE* **2017**, *12*, e0181810. [CrossRef]
41. Patel, R.; Nevill, A.; Cloak, R.; Smith, T.; Wyon, M. Relative age, maturation, anthropometry and physical performance characteristics of players within an Elite Youth Football Academy. *Int. J. Sports Sci. Coach.* **2019**, *14*, 714–725. [CrossRef]
42. Ford, P.R.; Williams, A.M. The acquisition of skill and expertise: The role of practice and other activities. In *Science and Soccer*, 3rd ed.; Williams, A.M., Ed.; Routledge: London, UK, 2013; pp. 122–196.
43. Roberts, S.J.; McRobert, A.P.; Rudd, J.; Enright, K.; Reeves, M.J. Research in another un-examined (RAE) context. A chronology of 35 years of relative age effect research in soccer: Is it time to move on? *Sci. Med. Footb.* **2021**, *5*, 301–309. [CrossRef]

children

Review

Push and Pull Factors: Contextualising Biological Maturation and Relative Age in Talent Development Systems

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Abstract: In this conceptual paper, we contextualise ongoing attempts to manage challenge dynamics in talent systems in sport. Firstly, we review the broad literature base related to biological maturation, relative age, and the proposed interventions to mitigate effects. We suggest that the relative age effect may be a population level effect, indicative of deeper phenomena, rather than having a direct effect on challenge levels. In contrast, we suggest that biological maturation has a direct effect on challenge at the individual level. Therefore, our main critique of many existing approaches to the management of challenge is a lack of individual nuance and flexibility. We suggest the necessity for talent systems to adopt a more holistic approach, conceptualising biological maturation and relative age within a broader field of "push and pull factors" that impact challenge dynamics in talent development in sport. Finally, we provide practical guidance for talent systems in their approach to relative age and biological maturation, recognising that there is no "gold standard". Instead, there is a need to recognize the highly individual and contextual nature of these concepts, focusing on strategic coherence through talent systems for the management of selection and development processes.

Keywords: talent development; talent identification; bio-banding; relative age effect; talent development systems; sport performance; challenge

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1. Introduction

In the competitive landscape of high-performance sport, there is significant pressure for talent systems to select and develop athletes to the senior elite standard [1]. On this basis, how limited resources are strategically used by talent systems has become a key issue in practice [2]. Reflecting this, thousands of young athletes across sports are selected to engage in often well-resourced development systems. The selection of young athletes into such programmes often occurs at young ages, and in sports like soccer, for example, can take place from as young as five years of age [3]. Those selected receive professional coaching and sports science and medical support, access to superior training equipment and facilities, and exposure to increased levels of competitive challenge when compared to non-selected peers [4,5]. The selection of the highest potential athletes into such a development programme is proposed to facilitate their long-term progress and increase probability of senior success [6]. Conversely, athletes who are not considered to show sufficient sporting promise at the time of selection are not recruited into these selective pathways and are denied access to such opportunities.

Recently, the means by which talent systems focus their resources has come under increasing scrutiny, with data challenging the established paradigms of talent development (TD) [6,7]. Of significant and ongoing debate is the timing of and access to selection, along with the way athletes are developed. Indeed, the predictive accuracy of early selection remains low, and even the best performing young athletes often fail to attain elite senior status [6]. Put simply, maximising efficiency through the early identification of athletes may come at the cost of effective practice as talent systems fail to invest resources in appropriate ways [1].

Two factors that have been examined in depth by the extant literature as influencing selection and development dynamics are biological maturation and relative age, e.g., [4,8–14]. Whilst the relative age effect (RAE) and biological maturation are often incorrectly interpreted as synonymous, more recent literature has emphasised that relative age and biological maturation are independent and individualised concepts [10–13]. Indeed, a recent qualitative study suggested that the RAE may be a population-level consequence of a constellation of factors less measurable than maturation alone [14]. Given the impact of relative age and biological maturation on the psychosocial development of young athletes, a key practical question across talent development systems and contexts is how these dynamics should influence practice. Traditionally, in respect to relative age and biological maturation, research and practice has tended to focus on the relative make-up of selection cohorts within TD systems and the impact of each concept on current performance status. Notably lacking, however, are discussions surrounding how these two concepts can be contextualised within the range of complex biopsychosocial factors that impact long-term development at the individual level.

Reflecting these limitations, in this review, we aim to contextualise relative age and biological maturation more broadly in TD systems and subsequently offer ways in which talent systems may choose to engage in challenge management strategies. In the TD context, a developmental challenge is an experience perceived by a performer to have the potential of disrupting development and/or performance in sport [15]. Challenge dynamics are, therefore, the complex biopsychosocial factors that influence an individual's experience of and interaction with challenge [16]. We begin this review by summarising biological maturation and relative age, then consider the various strategies that have been suggested to 'counter' their effects, before considering the broader range of challenge factors in development. We conclude by suggesting ways forward for talent systems regarding the management of these concepts.

There is a significant gender bias in TD research [17], particularly in relation to the RAE and biological maturation. Reflecting on the disproportionate lack of research on female athletes, the differential male/female dynamics (e.g., physiological changes resulting from biological maturation, traditional ages of the onset of puberty, anthropometric profiles [18,19]) and potential differences in recommendations, our discussion in this review is delimited to male athletes.

1.1. The Relative Age Effect

Relative age represents chronological age relative to the individual birthdate and competition cut-off dates [12]. The RAE is a selection bias in favour of those born earlier in the selection year, whereby those born toward the start of the selection year, who are chronologically older than those born toward the end of the selection year, are overrepresented within talent systems [4,12]. The RAE has attracted significant research attention and has been shown to exist across contexts and sports, with athletes born in the first two quartiles of the year disproportionately overrepresented at the expense of those born in the third and fourth quartiles [9,12,20–25]. For example, players born in the first quartile have been shown to constitute 56% of some soccer academy cohorts, with players born in quartile four comprising just 10% [9]. The literature has proposed that the multitude of attributes influencing the RAE are primarily related to age, experience, and developmental differences (e.g., game knowledge and understanding, decision making, neuromuscular development, cognition, behavioural and psychological development, social development) [12,25]. In youth sport, the RAE is present from early childhood and remains relatively stable throughout adolescent selection cohorts [10–12]. To this point, much of the RAE literature has emphasised the negative effects of chronological age groupings at the point of selection (e.g., [26,27]). Indeed, the consensus has been that there is the need to eradicate the RAE through developmental interventions [28] to prevent large numbers of young athletes from being excluded from talent systems [8]. Consequently, comparatively limited attention has been paid to the significant dropout of athletes in later selection cohorts [14] and the theoretical base underpinning the RAE [29].

1.2. Biological Maturation

Another factor influencing early advantage and selection is biological maturation, which, importantly, is a distinct construct to the RAE [10–13]. Biological maturation is the process of progression toward the mature adult state and can be defined in terms of status (the stage of maturation that the individual has attained at the time of observation), timing (the chronological age at which specific maturation events occur), and tempo (the rate at which maturation progresses) [30,31]. Of relevance to selection and development dynamics, children of the same chronological age can vary substantially in maturation status, timing, and tempo [4,32]. For instance, children of the same chronological age can vary by as much as five-to-six years in skeletal age, an established index of maturation status in youth [33–35]. Early maturation elicits numerous physiological, physical, and functional advantages (e.g., increased lean muscle mass, ability to reach faster peak speeds and perform more high-speed running, increased muscular strength and power) that transfer directly into performance environments [35–41]. Earlier maturation also generally confers greater body stature and mass [36,40]. These factors provide early maturing athletes with an advantage over peers and increases the likelihood of selection in contexts where these attributes are desirable. From the onset of puberty, biological maturation seems to have a stronger influence on selection than relative age in such contexts [10–13]. For instance, early biologically maturing athletes have been shown to constitute as many as 72% of youth soccer cohorts [11]. Late maturing athletes are frequently underrepresented, and in some instances, are absent from TD systems by age 14–15 years [11,12]. Reflecting this finding, TD practitioners and stakeholders have expressed concerns over the extent to which biological maturation influences selection and development in talent systems [42,43]. In addition, early maturation may confer enhanced self-efficacy and social status, alongside physical and functional performance advantages. Yet, if these advantages dissipate later, there may be maladaptive consequences for early maturing athletes when exposed to higher challenge levels at later stages of the pathway [44]. Contrastingly, if later maturing athletes lack the ability to cope with chronically low levels of early success, the likelihood of those athletes dropping out of the system is increased [45].

Importantly, maturation-related advantages are context-dependent; for example, in sports where prepubescent attributes are desirable for successful performance, such as some gymnastic events, delayed maturation may be advantageous for early performance and selection [30]. Maturation-related selection advantages are also influenced by other factors including the level of competition and even playing position in youth soccer [11,46]. Similar to relative age, the majority of research on biological maturation in respect to talent identification has tended to focus on the associated early selection advantages, with findings highlighting that the overrepresentation of early maturing youth within talent systems (i.e., soccer academies) emerges at the onset of puberty and increases in magnitude with chronological age and the level of competition [10–12]. Like the RAE, maturation-related selection biases are generally viewed as something to eradicate as a means of widening developmental opportunities for later maturing athletes. The desire for eradication, we would argue, does not have as simple a solution.

2. Interventions Targeted at Equalising Selection

Building on this assumption, the RAE and maturation biases have been seen as representing systemic selection error and, therefore, something to solve. Multiple interventions have been suggested to "level the playing field" and counteract RAEs and maturation-related selection biases in youth sports.

2.1. Selection Interventions Aimed at RAE

The first category of interventions predominantly views the RAE as the result of selection error, with a disproportionate population of relatively older athletes being given opportunities in talent systems. One intervention proposed to resolve this is age-ordered shirt numbering [27]. This intervention requires the number on the back of each player's shirt to correspond with their order of relative age (in soccer, for example, the oldest player would wear number one and the youngest would wear number eleven) so that the ascending relative age order of each player is explicitly displayed to coaches during match-play, training, and assessments. Although suggested to eliminate the selection biases associated with the RAE in youth soccer [27], research is yet to be conducted to provide evidence to support the long-term validity or efficiency of age-ordered shirt numbering concerning either talent identification or development. By making relative age the focal point in the selection process, this strategy also seems to incorrectly view relative age as conferring universal advantage or disadvantage. Indeed, Mann and Van Ginneken [27] state that the intervention:

> "May help coaches to provide more age-appropriate coaching and instructions so that it is tailored to each player's expected skill level based on their age and/or maturation. Second, the age ordered shirt numbering could even help to make the individual players more aware of the differences in skill that should be expected as a result of their relative differences in age" (p. 788).

We suggest that if deployed in this manner, the assumption is ill-founded. In reality, those born at the start of the selection year can still be significantly disadvantaged relative to peers based on other factors [10–13]. Put simply, challenge dynamics cannot be assumed on the basis of a single variable [10–13]. Moreover, despite being advocated as an intervention that also influences biological maturation [27], the RAE and maturation are two independent constructs and an intervention targeted at mitigating one will not have a direct impact on the other [10–13]. It is also important to acknowledge that the inter-individual differences in relative age between players (a non-linear ascending function) cannot be accounted for using the linear ascending function of shirt numbers [27].

From a statistical standpoint, Cobley et al. designed a corrective adjustment procedure using longitudinal reference data from swimming performance metrics that were shown to remove the RAE in Australian state- and national-level swimmers [47]. Such corrective adjustments were calculated by generating accurate estimates of the relationship between decimal age and swimming performance based on repeated years of longitudinal cross-sectional performance data as a reference. When correctively adjusted swim times were examined, RAEs were absent across age-group and selection levels. Similar corrective adjustments have been utilised in athletics, with the suggestion that pre-existing RAEs can be effectively removed from all performance levels with such formulae [48]. Although an interesting proposition, we propose that (even if validated, effective and supported with longitudinal data) such a method would be limited to centimetres, grams, and seconds (CGS) sports (e.g., running, swimming, cycling) and is likely ineffective in sports where there are broader internal and external influences on performance outcomes (i.e., team sports, racquet sports). This is not to suggest that relative age strongly influences physical and functional performance in youth athletes, but rather that it is more difficult to control for the broader variety of confounding factors that influence performance outcomes in team and racquet sports, as opposed to the comparatively fewer in CGS sports. If such a corrective adjustment procedure were to be considered, it would be important to first identify the associations between relative age and performance in a given context before correcting for them. In addition, the second-order effects of levelling the challenge landscape are unknown, especially as challenge dynamics are experienced at the individual level and periods of high and low challenge appear desirable [43,45].

Several other interventions have been put forward to counteract RAEs. The establishment of quotas, where talent systems are required to select a minimum number of athletes from each birth quartile, has been suggested [49,50]. Another similar approach is an average age team rule, where the average age of the team is one-half of the age group range [51]. To date, however, and reflecting general limitations in TD research, there is a paucity of longitudinal data to support the impact of these inventions both on selection and, perhaps more importantly, on long-term development. By implementing these approaches, the RAE will be reduced and the number of athletes from each birth quartile will be more evenly distributed. Yet, a consequence of enforcing selection based purely on date of birth is that it removes the flexibility for coaches to make selection and deselection decisions based upon other biopsychosocial factors. Moreover, these structural approaches may remove the flexibility for the individual approach that might be required based on the unique set of circumstances in which an athlete finds themselves (e.g., play up or down). Indeed, all these approaches suffer from the assumption that the cause for disproportionate selection cohorts is a result of biased decision making. This perspective is focused on talent "identification" and the need to select the "right" people [52] but resultantly misses the broader picture of developmental dynamics that influence the route to selection and beyond [14]. It may be based on this perspective that no interventions have been sought to address the significant deselection of early born athletes, compared to their relatively younger peers [53,54].

2.2. Selection Interventions Aimed at Biological Maturation

Similar to the age-ordered shirt numbering intervention proposed to mitigate the selection biases associated with the RAE [27], player labelling has been suggested as a solution to overcome the selection biases associated with advanced biological maturation [55]. Player labelling requires the number on the back of each player's shirt to correspond to the ascending order of players by maturity status. In practicality, during soccer training or competition, the most mature player would wear number one and the least mature player would wear number eleven so that coaches and scouts are aware of the variations in maturation status between players. When player labelling has been adopted in Swiss youth soccer, scouts at the regional level were shown to be less likely to rank the more biologically mature players as those with the most potential and, instead, were more likely to select the less mature players [55]. Crucially, however, when player labelling was not adopted (e.g., coaches were not provided maturation details of the players), there was no maturation selection bias in favour of either population [55]. By making biological maturation the sole focus in selection processes, and by incorrectly perceiving maturation status as conferring universal advantage or disadvantage, this intervention may create selection biases in favour of late maturing players based upon one single variable. Much like age-ordered shirt numbering, player labelling is also still in its relative infancy and no research has been conducted to produce findings to support the long-term validity or efficiency of the intervention concerning selection or development. Moreover, the inter-individual differences in maturation status between players (a non-linear ascending function) cannot be accounted for using the linear ascending function of shirt numbers [55]. Although providing coaches with visual cues to indicate the individual maturation statuses of the athletes within their care provides a progressive step forward from pre-existing methods, it is likely that the utility of the intervention will remain limited without the provision of coach education within this domain [11]. Ongoing educational support for practitioners in growth and maturation would help to support staff to support individual players based upon their physical needs and strengthen the utility of such interventions [46].

3. Interventions Targeted at Levelling the Developmental Playing Field

Although with some overlap with selection interventions and depending on how strategies are deployed, a second broad group of strategies have been designed to address not only selection biases but also the developmental dynamics experienced by athletes.

3.1. Developmental Interventions Focused on Relative Age

The second block of interventions have centred on presenting athletes with varying challenge levels and the opportunity to compete in different chronological age bandings. One such strategy is Birthday Banding, which aims to provide a range of developmental experiences in training and competition, where athletes move up to their next birthdate group on their birthday to remove fixed selection points and chronological age groups [56]. Under these conditions, an athlete can experience being the relatively youngest and oldest over a year, something that is proposed to confer a more diverse developmental experience. In one study, Birthday Banding was found to contribute to an insignificant RAE in a national squash TD system [56]. Although this is unlikely to be *the* single cause, it does suggest that this strategy can have a significant impact on the challenge level across a population. However, given the nature of challenge dynamics [57], and the advantages that variations in challenge levels offer, e.g., [45], Birthday Banding may remove the flexibility that might be required for the individual. For example, although some players may be of the chronological age to move up an age group, they may not have the psychosocial maturity or technical-tactical competency to cope with the challenge of the higher age group. In this sense, if such a policy is to be effective, flexibility within a TD system is required to allow coaches and practitioners to account for the individual developmental needs of each child and make such decisions (e.g., keep a player down an age group, move a player up before their birthday) on an individual basis. In addition, there may be maladaptive consequences for the application of Birthday Banding in team sports with significant turnover of groups and the consequent challenges of coherence and social dynamics. On the other hand, Birthday Banding may present one relatively low-resource intervention to provide fluctuations in challenge levels in individual sports. Given that it appears desirable for periods of both high and low challenge to be pulsed through a pathway [45], Birthday Banding may offer a window into how challenge dynamics might be manipulated.

A comparable strategy is the rotation of selection cut-off dates to reduce the number of relatively older athletes selected into the TD system [58]. Similarly, Hurley et al. proposed the Relative Age Fair Cycle, in which the cut-off dates for each year of competition are changed by three months between seasons of competition so that athletes experience being in all four quartiles of the year throughout development [59]. The advantage of this approach again seems to be the variety in competitive level faced by athletes. Yet, the implementation of such interventions seems to pose a variety of complex problems, requiring significant restructuring and potentially hindering coherence.

Another proposition to counter the RAE has been to delay selection until 15–16 years of age [8]. Critically, this proposition fails to take account of the dynamics that are at play regardless of selection into a talent system and how these might impact development. Indeed, there are National Governing Bodies that do not begin selection processes until these ages, and the RAE is still present in these systems upon selection, e.g., [53]. Crucially, removing the provision of high-quality TD processes until later stages of development (e.g., high-quality coaching, increased contact hours, and periodised challenge) may have detrimental effects on long-term development [45,60]. The likelihood of many TD systems (e.g., soccer academies) delaying selection until late adolescence is also very unlikely given the socio-political realities of professional sport [60]. In short, assuming that it is desirable to level the relative age playing field, macro strategies can only be part of the approach.

3.2. Developmental Interventions Focused on Biological Maturation

A variety of approaches have been suggested to counter the distinct advantages conferred by advanced biological maturation. Bio-banding is the most common and frequently investigated intervention to counteract the selection and performance advantages associated with variations in biological maturation. Bio-banding is proposed as an adjunct to, and not a replacement for, age group competition, forming just one part of a diverse developmental approach [31,61]. Bio-banding involves grouping and/or evaluating athletes based on maturity status rather than chronological age [31]. It is designed to promote competitive equity and athlete safety by limiting maturity-related variation in size and athleticism [31]. There are a number of proposed ways to bio-band athletes, including grouping them into maturity bands based upon their percentage of predicted adult height at the time of observation (e.g., 80–85%; 86–90%; 91–95% predicted adult stature [62]) and determining maturity offset (estimating the number of years athletes are from undergoing peak height velocity [63]).

There are several factors to consider regarding the evidence of the impact of bio-banding. Firstly, it is important to note that most research on bio-banding has tended to be soccer-specific and more research is required to understand its utility across a broader range of sporting contexts [31]. However, at specific time points, bio-banding has been perceived by some youth soccer players to generate greater physical, tactical, and technical challenges [32,41]. Early maturing players have described bio-banded competition as more physically challenging, reducing size and strength dependence and placing more emphasis on technical and tactical characteristics [41]. Conversely, later maturing players describe experiencing a greater opportunity to use, develop, and demonstrate their physical, social, technical, and psychological competencies in a less physically challenging environment [32,41]. Increased expression of technical-tactical characteristics because of bio-banded soccer competition/training has been found elsewhere, i.e., [64–66]. Moreover, bio-banding is perceived by some players of varying maturity statuses to promote differential social dynamics (e.g., leadership opportunities) [32,67]. Older children can benefit from taking up these teaching and leadership roles during bio-banded competition and may not get such opportunities in their own chronological age groups [68].

Bio-banded training camps have been introduced in sports such as cricket, with players again describing differential social and challenge dynamics [69]. Bio-banding has also been favourably received by various stakeholders in a youth soccer academy in relation to its impact on the psychological, social, and technical-tactical characteristics of the later maturing athletes [67]. Given that the risk of injury is influenced by maturation status (i.e., pre-, mid-, and post-peak height velocity) [31], bio-banding may also offer a method to prescribe maturity-specific training loads which may reduce injury risk and optimise conditioning effects in adolescent athletes [31]. However, in a recent commentary, Towlson and Cumming [61] argue that further research is required to determine when and how to best adjust training programmes to mitigate the risk of specific injuries and how this varies relative to the distal-to-proximal growth gradient.

Despite these positive findings, and whilst acknowledging that biological maturation clearly has a significant effect on challenge dynamics, it is important to note that bio-banding is not designed or expected to consider technical, tactical, cognitive, emotional, or social development [31,70]. For optimal development, there is a need to consider not just size- and maturity-related characteristics when grouping athletes by maturation status but also the plethora of complex factors, and their potential interactions, that influence individual development [31,70]. For this reason, in previous bio-banded competition events in youth soccer, participating teams were asked to consider each player's psychological and technical-tactical competencies and to consider the exclusion of those individual players of the desired maturity statuses who may not benefit from bio-banded competition [41]. For instance, some athletes advanced in maturation may be capable of withstanding the physical demands of competing with chronologically older athletes, but they may not be of the required technical-tactical standard or psycho-social skills to cope [31,71]. As an example, whilst some athletes perceive bio-banding to provide the opportunity to make new friends across different age groups [41], other young athletes have previously reported feelings of apprehension brought about by the potential for social isolation when moving between different groups and not being with friends or other players whom they were familiar with [67]. Feelings of apprehension should in no way be considered as a universal negative and may be highly appropriate for some. Therefore, whilst there are examples of how TD systems have twinned bio-banding with offered psychological provision during periods of bio-banding [68], regardless of support offered, what may be appropriate for one athlete will not be for another. There is, therefore, a necessity to weigh up complex individual biopsychosocial factors to decide what is appropriate.

Furthermore, whilst some authors have quantitatively shown seemingly positive effects of bio-banding on aspects of technical-tactical performance in soccer (i.e., increased number of short passing sequences, reduced number of long passes [65]), others have observed a more limited effect on technical-tactical characteristics of players during bio-banded competition [72]. In addition, research from Spanish soccer academies has shown that matching players by maturity status alone in small-sided games formats elicited no skill differences displayed between groups [73]. This would seem to reiterate that biological maturation has no direct influence on technical skill levels and any intervention that focuses on grouping athletes solely by biological maturation will fail to account for such individual differences. On the other hand, using smaller training areas and pitch sizes presents one viable option to limit the extent to which earlier maturing athletes (e.g., soccer players, rugby players) can utilise their athletic advantages at the expense of other performance elements (e.g., technical-tactical characteristics) [41,73]. In this regard, Cumming et al. suggest a "hybrid approach" to bio-banding, consisting of monthly or bi-monthly bio-banded competitions, alongside existing games programmes [31].

Reflecting arguments offered earlier about RAE interventions, adopting blanket and routine bio-banding may fail to recognise the individualised and biopsychosocial nature of TD [31,74]. For example, a late maturing athlete that is relatively advantaged based on other factors (e.g., technical and tactical ability and social skills) may not benefit from competitive challenge being reduced even further [31]. Taken as a simplified example, if such steps are taken purely to level the playing field, this reduction in challenge may act as a barrier to long-term development [75–77]. Yet, if the intervention has other foci, such as the development of low-level psycho-behavioural skills, then it may be perfectly appropriate. In essence, this is a highly individualised matter, and we need to consider the intended impacts against the needs of the individual [78].

In addition to the challenges of individual dynamics, whilst acknowledging that the tracking of maturation is an essential feature of a talent system, the implementation of bio-banding can be resource intensive, both in terms of administration (e.g., the necessity of changing groups) and coaches understanding a wider range of individual needs. For many sports, whilst maturation testing itself can be reasonably simple depending on the method employed, it does require practitioners to conduct reliable measurements and track these longitudinally. Providing large populations of athletes with bio-banded training and competition opportunities at all stages of a talent system presents a significant challenge. It is also important to acknowledge that due to resource limitations (e.g., reduced access to skeletal X-ray assessments), coincided with the invasive nature of other predictive equations, non-invasive predictive equations to determine maturity status are commonly utilised (i.e., percentage of predicted adult height [62] or predicted maturity offset [63]). Due to the non-invasive and predictive nature of these equations, and as with all predictive equations, these methods are associated with a degree of error (e.g., [63,79–81]). Whilst the median error bounds between actual and predicted adult height using the Khamis-Roche method is just 2.2 cm in males aged between 4 to 17.5 years [62], this predictive equation is derived from retrospective datasets of American youth of European ancestry, and this must be acknowledged when applied to populations of differing nationalities and ethnicities. Moreover, both the updated and original equations for the predictive maturity offset method are suggested to be unreliable for both early- and late-maturing males and females, with an overestimation of the predicted ages at peak height velocity in early-maturing youth and an underestimation in late-maturing youth [81]. This inability to differentiate between early- and late-maturing youth using the maturity offset equation can lead to athletes being categorised incorrectly.

A suggested complement to bio-banding is Discreet Performance Banding (DPB), where athletes are grouped based on the performance of a discreet skill or ability that is highly valuable in their sport (e.g., change of direction ability in soccer), rather than using a marker of implied performance (e.g., maturation alone) [73]. DPB using change of direction ability in youth soccer has been suggested to differentiate variations in skill levels (passing, shooting, ball control), with the suggestion that it may hold the potential to level competition in youth sport from a skill perspective [73]. Therefore, it has been proposed that bio-banding, alongside DPB and chronological age group competition, may diversify the experiences of young athletes and expose them to new and varied challenges. However, the validity of a single discreet marker to differentiate between athletes seems highly questionable. We would suggest that it presents an overly blunt instrument that fails to take account of the broader biopsychosocial influences on performance. As an example, change of direction ability is a poor proxy for technical ability, tactical understanding, or psychological skills. This is especially the case as research on DPB is in its infancy and the method remains largely conceptual and untested [73].

Although not specifically an intervention for biological maturation or relative age, "playing up" athletes who have early advantages against chronologically older or higher-performing peers has been suggested to facilitate more appropriate levels of challenge and individual development [26]. Playing up has been perceived by youth soccer players to elicit improvements in fitness and sport-specific skill, social capital, and social adaptability, as well as being rewarding when recognition and success are experienced [82]. Indeed, these findings are somewhat unsurprising given the social status conferred by selection. Whilst "playing up" at face value may present athletes with a higher level of challenge, conferring some technical-tactical benefits [26], it may also lead to individuals relying on previously developed strengths, rather than developing potentially career-limiting weaknesses [44]. Athletes who play up may also face difficulties in coping with the increased intensity of competition and when fitting in with older teammates [82]. Somewhat counter intuitively, playing up can also provide a level of validation and reduced performance expectation that may actually reduce the perception of challenge [43]. Therefore, whilst it is clear that playing up or down significantly affects the perception of challenge, qualitatively, its impact cannot be assumed, with effects depending on a range of individual and environmental factors. In this sense, further qualitative and longitudinal research is required to understand the experiences of those who play up and the long-term benefits of developing expertise [26]. As with previous interventions, the application of these approaches is likely to be a highly individual matter.

4. Challenge Dynamics

The range of developmental interventions reviewed in this paper are aimed at the management of challenge dynamics through a pathway. To build a case for practical approaches it is, therefore, important to contextualise these dynamics within the existing literature. The importance of developing a range of psycho-behavioural skills to learn from and cope with challenges is well-established as an important requisite for developing excellence in sport [43–45,75–77,83–86]. Crucially, without the early acquisition and development of an adequate psychological skillset (that challenges can generate), athletes *can be* derailed by step changes in challenge that can occur towards the higher echelons of performance [43,44]. In contrast, if athletes develop psycho-behavioural skills, subsequently tested by a range of appropriate challenges, the consequent emotional disturbance, when coupled with appropriate support, can provoke further refinement of these skills [45].

Following this line of research, literature has challenged the assumption that being relatively younger or biologically late-maturing is unequivocally detrimental to development, instead identifying the potential later advantages of early disadvantage, e.g., [4,53,87–89]. One example is the reversal of relative age advantage, where relatively younger athletes are proportionately more likely to reach elite senior status despite a disproportionate number of relatively older athletes being selected at the youth level [7]. This is something now replicated across sporting contexts, e.g., [53,54]. Importantly, this is a reversal of advantage rather than the RAE reversing, suggesting that relatively younger athletes are less likely to be deselected than their relatively older counterparts [7]. Various mechanisms have been suggested to explain advantage reversals, including that relatively younger athletes are thought to benefit from the increased levels of competitive challenge when competing with their older counterparts who possess age- and experience-associated advantages (e.g., superior game knowledge and understanding). This increased level of competitive challenge has been proposed to benefit the relatively younger athletes, stimulating their adaptive development, and facilitating long-term progress. This has specifically been referred to as the "underdog hypothesis" [87]. Similarly, the comparatively greater challenge that is experienced by later maturing athletes within a development environment where they are competing against early-maturing athletes with physical, physiological, and functional advantages has been proposed to encourage the development of superior technical-tactical and psychological skills [4]. The development of these superior technical-tactical and psychological skills is proposed to allow the later-maturing athletes to survive and thrive in an environment where they are physically disadvantaged [4,87]. Although these superior technical, tactical, and psychological attributes may be less obvious throughout childhood and early adolescence, they are proposed to become salient in late adolescence and early adulthood once the physical advantages associated with advanced biological maturity become attenuated [4]. However, it is possible that many younger/late-maturing athletes always possessed such superior abilities which has allowed them to be initially selected into and remain within the system. Indeed, it is equally plausible that many early-maturing players also possess and/or develop superior technical-tactical and psychological skills within the same TD system despite not being exposed to the same physical challenges [90].

There is some evidence to suggest that late-maturing soccer and rugby academy players and relatively younger rugby players are proportionately more likely to progress to the elite adult level than early-maturing/relatively older players if retained within the system [53,54,88,89]. Whilst in support of the underdog hypothesis, it is also important to recognise the opposing methods used to estimate/examine maturity status (i.e., maturity offset method [63] vs. TW3 method [91]) within these biological maturation-specific investigations, as well as the different criteria used to classify early, late, and on-time athletes [88,89]. Contrasting evidence from Swiss national-level youth soccer also suggests that many late-maturing players, despite possessing superior technical abilities and being exposed to the "underdog challenges", are still deselected from the TD system by age 15 years [90]. However, this does not suggest that these players still did not progress to become elite senior athletes; there is no longitudinal data to indicate how these challenges influenced long-term development through to the senior level [90]. Critically, however, if the underdog hypothesis were to exist, potential "underdog" effects of being relatively younger or biologically late-maturing would only hold if relatively younger/late-maturing athletes are retained within the system.

Contrasting with the original underdog hypothesis [87], it is not the provision of higher challenge but, instead, how the individual responds to challenge that is a key determinant of success [15,77]. Rather than directly causing development, challenge acts to test previously developed psycho-behavioural skills [85,92]. As we have previously discussed [11], it is important to note that late-maturing players likely remain underrepresented at the adult level in absolute terms due to a smaller initial representation within the academy system. Indeed, a prime example of this in a relative age context has been presented in U17-, U19-, and senior-level international male soccer players [54]. Reflecting general limitations in biological maturation and RAE research, there is a lack of longitudinal data to support this proposition across contexts. End-stage conversion rates are often used as a metric for the underdog hypothesis [87], but caution is advised when examining end-stage conversion rates as a metric for career outcomes as some populations *may* still be over- or underrepresented in absolute terms [11].

Push and Pull Factors

Being born late in the selection year or being late-maturing biologically does not serve as a direct advantage or disadvantage; instead, the dynamics of challenge events are highly individual. Presenting a holistic view of challenge dynamics, McCarthy et al. suggested the concept of push and pull factors to conceptualise factors that may confer relative advantage or disadvantage for the athlete [14]. Their hypothesis is that at the population level, the average early-born athlete will be subject to more push factors—those factors that act to accelerate early performance—whereas the later-born athlete will be subject to more pull factors—factors that act to retard early performance. Abundant push factors will encourage early performance at the junior level but may hinder later progress. In contrast, those athletes who experience a greater prevalence of pull factors *may* experience a more developmentally optimal experience [75]. Importantly, however, those athletes who are subject to an overwhelming volume of "pull" factors might also become chronically disadvantaged, especially if these are external to the sport [93]. This seems to support the notion that significant challenge factors in an individual's life outside of sport are not an adaptive feature of development [76,77]. There is, therefore, a practical necessity for strategic consideration and a subtle balance in how this approach is applied. An overabundance of pull factors may risk derailment, with repeated performance setbacks, negative feedback, and resultant negative emotional states unlikely to build an athlete's motivational resources [44,45,94]. In essence, pull factors are not necessarily positive for overall development, especially if preventing athletes from ever being selected (e.g., [11,12]). In the context of the literature presented earlier in this paper, later-born athletes will, on average, be subject to more pull factors. As a result, the typical later-born selected athletes will be provided with a higher frequency and intensity of challenge to navigate as they progress. Reflecting the distinction between relative age and maturation, this suggests that early maturation is, in itself, an independent push factor, whereas late maturation is a pull factor. Thus, early-maturing athletes are more likely to have significant physical, physiological and functional advantages and consequently are more likely to be selected in contexts where these attributes provide advantages relative to peers. However, competing against less-mature peers may prevent the testing of psychological skills for the early-maturing athletes [4,41]. Indeed, late biological maturation appears to be one of the most prominent pull factors in the TD context (e.g., [10–12,46]).

Based on the review of research presented, which consistently identifies early selection advantages based on push factors, a narrative in TD practice has been the desire to "level the playing field" and prevent inequalities of outcome in talent systems. These discussions are symptomatic of what could be framed as a "wicked" problem: one with no ultimate solution or stopping point, where better or worse is a value judgement based on desired state [95]. Reflecting these complex dynamics and our review of existing approaches, we will now address the second aim of this paper by presenting considerations for talent systems seeking to utilise challenge dynamics in an evidence informed manner [96].

5. Implications for Practice in Talent Systems

Seeking to present implications for practice, we would suggest a need to conceptualise the interventions that are critiqued within the broader whole. In doing so, we suggest that push and pull factors may offer the potential for a holistic and practical view of challenge in talent systems in sport. For those seeking to operationalise these factors, there is the need for a highly context-dependent and, ideally, individualised approach. Talent systems can be considered at three levels. The macro represents the interactions between organisations, typically at the national/international level (e.g., NSOs). The meso is typically a collection of microsystems or 'all aspects of the coaching situation' [97] (p. 345) (e.g., an academy). The micro level represents the individual interactions that occur day-to-day in practice [2]. Thus, rather than looking at single variables, there is a need for talent systems to frame their actions in a deeper understanding of the effects and potential side effects of interventions. This requires maximum flexibility at each level of a system.

5.1. Micro-Level Implications

Reflecting the emphasis on individual dynamics, we refer first to the micro level. This contrasts with the majority of reviewed interventions, which predominantly aim at the macro or meso level. At the micro level, if individuals are to be presented with appropriate challenge levels, there is a necessity to adapt to inter- and intra-individual differences with a focus on the perceptions and needs of the individual athlete. This relies on a granular understanding of athletes' circumstances and the empathic accuracy necessary to notice change, e.g., [98]. In all instances, an understanding of the maturational status of athletes is a useful data point for the coach and practitioner to make sense of the needs of a particular athlete. Yet, it should not be the only matter for consideration, nor should assumptions be made regarding relative advantage or disadvantage based on a single data point. Take the example presented earlier: a late-maturing athlete that holds a technical advantage relative to their age group is unlikely to be further challenged under the same circumstances playing against peers who are chronologically younger but matched in maturation [31]. However, if the goal was to expand their tactical understanding, develop leadership skills [41], or provide a metacognitive challenge [99], playing down an age group might facilitate the social circumstances necessary to support this process. Likewise, an early-maturing sprinter who has dominated in their chronological age group might strongly dislike the experience of competing against older, but more capable athletes. It may also be the experience that facilitates a refocus on weaknesses in their approach. Whilst competing at a higher level may seem like an appropriate intervention to provide additional levels of challenge, if an athlete does not have the psycho-behavioural competencies required to benefit, such a step change in challenge may be too great for that athlete to handle. Most importantly, in all these circumstances, it is not the event itself that will automatically confer development. Instead, it is the athlete's perspective and use of psychological skills, actively shaped by coaches and peers, that is critical [100].

On a broader note, at the micro level, it is also important to understand the individual context of each athlete from the totality of their experience and their lives, rather than solely age or maturity status alone. Take, for example, an athlete that is facing an abundance of pull factors outside of sport; after all, maturation or relative age is not the only important consideration, particularly in instances where an athlete is overwhelmed by an abundance of pull factors outside of the athletic domain. This approach is something which, despite some debate, is increasingly acknowledged as undesirable for TD [77,93,101]. In essence, this becomes a more holistic and individual process, understanding a range of different push and pull factors and how they impact individual talent trajectories along with the ability of individual practitioners to make effective decisions about what is needed for those athletes. This will require a broader approach than, for example, playing up/down or finding alternate means of grouping athletes. It necessitates fundamental changes to practice, requiring the coach or practitioner to actively present individuals with appropriate levels of challenge. Reflecting our previous points in respect to bio-banding, this presents a necessity for a level of expertise to respond to individual developmental needs and experiences of each athlete as they arise [102]. In this sense, the Professional Judgement and Decision Making (PJDM) of the individual coach or TD practitioner becomes a key facilitator of learning and progress [78,103].

5.2. Meso-Level Implications

To enable these processes at the individual level, we offer several key considerations at the organisational level beyond those made previously in the literature regarding recommendations for effective practice (e.g., [78,104,105]). Specifically, we make suggestions for the operationalisation of push and pull factors in terms of selection and challenge management. The identification and selection of athletes has received significant attention in both the literature and practice, often being viewed as distinct from challenge dynamics. We suggest that rather than a search for athletes most likely to progress to the elite level, a more developmental and practical lens is applied to selection processes. This requires a focus not only on current performance, but also on the likelihood of further development [52] and contribution to the further development of peers. In this regard, it is likely that the previous successful navigation of sport-based challenges, such as a high prevalence of pull factors like late biological maturation, relative to current performance, may signal what Baker et al. referred to as "high potential" [52]. That is, despite being subject to significant challenge, an athlete is "sticking in there". This raises several practical questions: how can we know about these factors if our approach to selection is the "talent scout" observing performance alone? Similarly, we cannot rely on single-variable interventions (e.g., [27]) used as a proxy for the complex web of dynamic challenge factors that seem to play a central role in development. Strategically this will require systems to hold a contextually defined view of the purpose and function of selection. At the meso level, this would see organisations (e.g., individual academies) moving away from traditional talent spotting, something that is consistently doubted in the literature [6,106], towards a more pragmatic, contextualised view with decisions made based on a broader picture of biopsychosocial factors [107]. For example, in some sports, early selection is a political necessity and one that affords the opportunity to shape a developmental journey [60]. In others, macro national systems have legislated to limit the timing of selection and for a broader population to be selected (e.g., English rugby union regional academies [53]), yet with less opportunity to shape athlete development over time. In other contexts, like Norwegian handball, selection is seen as supplementary, with participation, development and performance contexts running in parallel; an approach that promotes a breadth of engagement opportunities but presents additional challenges to the shaping of athlete experience [108,109]

Whilst we do not believe that there is a need for organisations to move towards a complete equity of push and pull factors, if selection processes at the organisational level exclude cohorts of athletes, this should warrant deliberate attention. This attention should include a pragmatic discussion regarding the relative weighting of resources needed to address the disparity. For example, data presented by Sweeney et al. suggest a near total exclusion of late-maturing soccer players in Ireland [11]. This is a significant issue, especially where there are limited routes back into the pathway, or where there is a marked difference in development provision between those who are in or out of the system. Yet, given that there is no optimal balance of what selection should look like (e.g., the proportion of early-, on-time-, and late-maturing players within an academy), organisations should be encouraged to critically reflect on the desirability of selection cohorts being strongly weighted towards push factors like early biological maturation [10–12].

Moving beyond the reasoning that the function of talent systems is simply to select the right athletes, the second core meso-level concern is the management of challenge throughout development. Many of the foci for proposed solutions suggest the benefit of an overall fluctuation of challenge level for the individual athlete, elsewhere referred to as periodised challenge [76]. Rather than relying on targeting single variables, at the organisational level, the focus should be placed on challenge management. The ideal output of this approach would be the integration of systems and support figures to maintain coherence for the athlete [43]. In high-resource organisations (e.g., category one soccer academies), this may be multiple staff feeding into a development plan for an athlete directing the types of experiences appropriate for their development, informed by an assessment of push and pull factors. At the lower resourcing end (e.g., smaller Olympic sports), this profiling might be done by an individual coach. Where a range of support figures are present (e.g., coaches, practitioners, parents), there is a need for a shared understanding of individual challenge dynamics, especially if athletes are to move between different levels of performance and training groups. It is for this reason that shared mental models (SMMs) have been proposed as a vehicle to support integrated practice [110]. SMMs refer to an organised and common understanding among team members regarding the essential aspects of work and how they should behave in specific situations [111]. SMMs among coaching and support staff would allow coaches to understand each athlete's individual needs and adapt their decisions based on individual circumstances. Ongoing case conferencing, coaching communities of practice and review processes that are designed for the co-construction and sharing of knowledge amongst staff becomes essential, especially as SMMs cannot be assumed as a function of time spent together [112,113].

We should also recognise that such flexibility at the meso level poses a challenge to integrated practice, especially in resource-intensive systems with large numbers of staff where risks of a lack of vertical and horizontal coherence exist (e.g., [42]). For example, if a dominant early-maturing adolescent athlete is selected for a senior competition, we cannot assume this selection automatically confers a higher level of challenge. Instead, it is how the athlete's experience is curated that matters. This requires multiple people to hold a shared understanding of the purpose and plan. It could be done in a manner that confers the athlete with enhanced self-efficacy or lower pressure based on role clarity [100]. In contrast, it could also be used to highlight weaknesses, generating feedback in areas that have previously not been challenged with and against age-matched peers.

Therefore, we suggest a necessity for organisations to monitor the prevalence of push and pull factors for their athletes on a longitudinal basis, utilising individual biological maturation along with other suggested push and pull factors that have been identified in the literature (e.g., familial influence [114], socio-economic status [115], and quality of previous coaching [116]). In contrast, we suggest that relative age data should be used differently, given that at the individual level it might not indicate individual challenge dynamics. Instead, it could be used to understand the relative make-up of selection cohorts over time, or to consider the efficacy of challenge management processes if higher proportions of players with greater early advantages continue to be deselected [7,53].

5.3. Macro-Level Implications

Building from the micro and meso, our main critique thus far of most existing and well-intentioned approaches to the management of challenge is the lack of individual flexibility of approach. We would suggest that any strategic approach to relative advantage or disadvantage should be focused at the meso and micro level, rather than at the macro level. Consequently, we suggest the necessity of a more fine-grained approach to the grouping of young athletes and the provision of challenge [14]. As noted by Cumming et al., if approaches like bio-banding are to be adopted wholesale, then we may simply advantage and disadvantage a different group based on less-measurable constellations of characteristics [31]. Implementing blanket strategies to mediate against disproportionately high pull factors is overly simplistic and lacks holistic consideration of the biopsychosocial factors that influence relative advantage or disadvantage. Many existing approaches also focus on attempting to "level out" challenge level which, based on the existing evidence base and applied at the population level, may be suboptimal given that it may be desirable for periods of high and low challenge levels to be pulsed through a pathway [45]. Indeed, talent systems may also ask if it is desirable for those who experience more push factors in development to be grouped together for appropriate challenge, so long as there is a vehicle for others to receive appropriately high-quality development.

Ultimately, rather than a bureaucratic regulatory approach, flexible systems should allow for practitioners to make decisions and respond to individual athlete needs. Therefore, we suggest the need for maximum flexibility and informed decision making for organisations and individuals. As is currently the case in the vast majority of systems, it may be easier for the top-down mandating of one approach for all, rather than encouraging informed flexibility. However, based on a model of a top-down *and* bottom-up approach to talent strategy [2], we suggest that as far as possible, national systems remove barriers to optimising individual challenge, as well as provide high-quality input to individual organisations to enhance their approaches. As an example, the Royal Belgian Football Association's Futures Programme is a meso approach to provide developmental opportunities for later-maturing athletes [117]. It enables opportunities for late-maturing players to be retained within the system and experience training, competition, coaching, and travel as part of a national team. In this instance, the strategy still means that selection is based on players being identified as technically, tactically, and psychologically able for youth international soccer. However, if this approach was adopted as a policy requirement on a broader scale, it would prevent existing organisations from adopting strategies appropriate to their unique context.

In terms of "fairness", it is here that macro systems characterised without a step change in the quality of environment between those who are selected and not seem to hold an advantage (e.g., [109]). Yet, this also means the provision of high-quality support to a large population which is highly resource-intensive [2]. A key feature of our position is that there are no value-free judgements to be made in this area. At all levels, we need to recognise the various trade-offs inherent to managing the dynamics of development. If the more holistic approach we suggest is to be adopted, there is also a need to promote decision making and integrated action through intelligent mediums. As such, any strategic approach should be enabled by the macro, but should be targeted at the meso and micro level of a TD system. This necessitates macro support for coach and practitioner development on a holistic and evidence informed basis. In addition, the need to generate SMMs of outcome and performance is likely a necessity, especially where multiple stakeholders impact on the curriculum of an athlete [107–109].

6. Conclusions

In this conceptual paper, we have reviewed the literature that seeks to negate some of the various selection and challenge dynamics in talent systems. We have suggested that whilst many of these biases may come at the population level, the dynamics of challenge effects are highly individual. In all cases, we suggest that research and practice view the use of challenge mitigation approaches, like bio-banding, as tools to use at the individual level rather than strategies to deploy at the macro or meso level. There is no "gold standard" approach to challenge management. What constitutes effective practice in this regard is highly contextual and determined by a myriad of other biopsychosocial factors that extend far beyond date of birth or current maturation status alone. As a consequence, whilst there is of course a need to understand the dynamics illustrated by the vast literature in biological maturation and relative age, there is also a need for the research to investigate less quantifiable factors that might impact development. In addition, we suggest the need for researchers to appreciate this broader and perhaps interdisciplinary picture, along with the value proposition of interventions in talent systems. Thus, a key recommendation in regard to challenge dynamics would be an end to the focus on "levelling the playing field" of a phenomenon that has so many complex factors at play. In practice, there is an opportunity for talent systems to adopt a more holistic approach by conceptualising biological maturation and relative age within a broader spectrum of challenge dynamics and considering how other, less-measurable factors also impact athlete development.

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References

1. MacNamara, Á. Talent Development. In *Sport Psychology Essentials*; Collins, D., Cruickshank, A., Eds.; Human Kinetics: Champaign, IL, USA, 2022.
2. Taylor, J.; MacNamara, Á.; Taylor, R.D. Strategy in talent systems: Top-down and bottom-up approaches. *Front. Sports Act. Living* **2022**, *4*, 988631. [CrossRef] [PubMed]
3. Read, P.J.; Oliver, J.L.; De Ste Croix, M.B.A.; Myer, G.D.; Lloyd, R.S. The scientific foundations and associated injury risks of early soccer specialisation. *J. Sports Sci.* **2016**, *34*, 2295–2302. [CrossRef] [PubMed]
4. Cumming, S.P.; Searle, C.; Hemsley, J.K.; Haswell, F.; Edwards, H.; Scott, S.; Gross, A.; Ryan, D.; Lewis, J.; White, P.; et al. Biological maturation, relative age and self-regulation in male professional academy soccer players: A test of the underdog hypothesis. *Psychol. Sport Exerc.* **2018**, *39*, 147–153. [CrossRef]
5. Hill, M.; Scott, S.; McGee, D.; Cumming, S.P. Are relative age and biological ages associated with coaches' evaluations of match performance in male academy soccer players? *Int. J. Sports Sci. Coach.* **2021**, *16*, 227–235. [CrossRef]
6. Güllich, A. Selection, de-selection and progression in German football talent promotion. *Eur. J. Sport Sci.* **2014**, *14*, 530–537. [CrossRef]
7. McCarthy, N.; Collins, D.; Court, D. Start Hard, Finish Better: Further Evidence for the Reversal of the RAE Advantage. *J. Sports Sci.* **2016**, *34*, 1461–1465. [CrossRef]
8. Cobley, S.; Baker, J.; Wattie, N.; McKenna, J. Annual age-grouping and athlete development: A meta-analytical review of relative age effects in sport. *Sports Med.* **2009**, *39*, 235–256. [CrossRef]
9. Lovell, R.; Towlson, C.; Parkin, G.; Portas, M.; Vaeyens, R.; Cobley, S. Soccer player characteristics in English lower-league development programmes: The relationships between relative age, maturation, anthropometry and physical fitness. *PLoS ONE* **2015**, *10*, e0137238. [CrossRef]
10. Johnson, A.; Farooq, A.; Whiteley, R. Skeletal maturation status is more strongly associated with academy selection than birth quarter. *Sci. Med. Footb.* **2017**, *1*, 157–163. [CrossRef]
11. Sweeney, L.; Cumming, S.P.; MacNamara, Á.; Horan, D. A tale of two selection biases: The independent effects of relative age and biological maturity on player selection in the Football Association of Ireland's national talent pathway. *Int. J. Sports Sci. Coach.* **2022**, 17479541221126152. [CrossRef]
12. Hill, M.; Scott, S.; Malina, R.; McGee, D.; Cumming, S.P. Relative age and maturation selection biases in academy football. *J. Sports Sci.* **2020**, *38*, 1359–1367. [CrossRef] [PubMed]
13. Towlson, C.; MacMaster, C.; Parr, J.; Cumming, S. One of these things is not like the other: Time to differentiate between relative age and biological maturity selection biases in soccer? *Sci. Med. Footb.* **2022**, *6*, 273–276. [CrossRef] [PubMed]
14. McCarthy, N.; Taylor, J.; Cruickshank, A.; Collins, D. Happy Birthday? Relative Age Benefits and Decrements on the Rocky Road. *Sports* **2022**, *10*, 82. [CrossRef] [PubMed]
15. Collins, D.; MacNamara, Á.; Cruickshank, A. Research and Practice in Talent Identification and Development—Some Thoughts on the State of Play. *J. Appl. Sport Psychol.* **2018**, *31*, 340–351. [CrossRef]
16. Nash, C.; Taylor, J. 'Just Let Them Play': Complex Dynamics in Youth Sport, Why It Isn't So Simple. *Front. Psychol.* **2021**, *12*, 700750. [CrossRef]
17. Curran, O.; MacNamara, A.; Passmore, D. What About the Girls? Exploring the Gender Data Gap in Talent Development. *Front. Sports Act. Living* **2019**, *1*, 3. [CrossRef]
18. Malina, R.M.; Bouchard, C. *Growth, Maturation, and Physical Activity*; Human Kinetics: Champaign, IL, USA, 1991.
19. Albaladejo-Saura, M.; Vaquero-Cristóbal, R.; García-Roca, J.A.; Esparza-Ros, F. The Effect of Age, Biological Maturation and Birth Quartile in the Kinanthropometric and Physical Fitness Differences between Male and Female Adolescent Volleyball Players. *Children* **2022**, *9*, 58. [CrossRef]
20. Till, K.; Cobley, S.; Wattie, N.; O'Hara, J.; Cooke, C.; Chapman, C. The prevalence, influential factors and mechanisms of relative age effects in UK Rugby League. *Scand. J. Med. Sci. Sports* **2010**, *20*, 320–329. [CrossRef]
21. Lewis, J.; Morgan, K.; Cooper, S.M. Relative age effects in Welsh age grade Rugby Union. *Int. J. Sports Sci. Coach.* **2015**, *10*, 797–813. [CrossRef]
22. González-Víllora, S.; Pastor-Vicedo, J.C.; Cordente, D. Relative Age Effect in UEFA Championship Soccer Players. *J. Hum. Kinet.* **2015**, *47*, 237–248. [CrossRef]
23. del Campo, D.G.D.; Vicedo, J.C.P.; Villora, S.G.; Jordan, O.R.C. The relative age effect in youth soccer players from Spain. *J. Sports Sci. Med.* **2010**, *9*, 190–198.
24. Brustio, P.R.; Lupo, C.; Ungureanu, A.N.; Frati, R.; Rainoldi, A.; Boccia, G. The relative age effect is larger in Italian soccer top-level youth categories and smaller in Serie A. *PLoS ONE* **2018**, *13*, e0196253. [CrossRef] [PubMed]
25. Parr, J.; Winwood, K.; Hodson-Tole, E.; Deconinck, F.J.A.; Hill, J.P.; Teunissen, J.W.; Cumming, S.P. The Main and Interactive Effects of Biological Maturity and Relative Age on Physical Performance in Elite Youth Soccer Players. *J. Sports Med.* **2020**, *2020*, 1957636. [CrossRef]
26. Kelly, A.; Wilson, M.; Jackson, D.; Goldman, D.; Turnnidge, J.; Côté, J.; Williams, C.A. A multidisciplinary investigation into "playing-up" in academy football according to age phase. *J. Sports Sci.* **2020**, *39*, 854–864. [CrossRef] [PubMed]
27. Mann, D.L.; van Ginneken, P.J.M.A. Age-ordered shirt numbering reduces the selection bias associated with the relative age effect. *J. Sports Sci.* **2017**, *35*, 784–790. [CrossRef]

28. Roberts, S.J.; McRobert, A.P.; Rudd, J.; Enright, K.; Reeves, M.J. Research in Another un-Examined (RAE) context. A chronology of 35 years of relative age effect research in soccer: Is it time to move on? *Sci. Med. Footb.* **2021**, *5*, 301–309. [CrossRef]
29. Hancock, D.J.; Adler, A.L.; Côté, J. A proposed theoretical model to explain relative age effects in sport. *Eur. J. Sport Sci.* **2013**, *13*, 630–637. [CrossRef]
30. Malina, R.M.; Rogol, A.D.; Cumming, S.P.; Coelho E Silva, M.J.; Figueiredo, A.J. Biological maturation of youth athletes: Assessment and implications. *Br. J. Sports Med.* **2015**, *49*, 852–859. [CrossRef]
31. Cumming, S.P.; Lloyd, R.S.; Oliver, J.L.; Eisenmann, J.C.; Malina, R.M. Bio-banding in sport: Applications to competition, talent identification, and strength and conditioning of youth athletes. *Strength Cond. J.* **2017**, *39*, 34–47. [CrossRef]
32. Bradley, B.; Johnson, D.; Hill, M.; McGee, D.; Kana-ah, A.; Sharpin, C.; Sharp, P.; Kelly, A.; Cumming, S.P.; Malina, R.M. Bio-banding in academy football: Player's perceptions of a maturity matched tournament. *Ann. Hum. Biol.* **2019**, *46*, 400–408. [CrossRef]
33. Borms, J. The child and exercise: An overview. *J. Sports Sci.* **1986**, *4*, 3–20. [CrossRef] [PubMed]
34. Johnson, A. Monitoring the Immature Athlete. *Aspetar Sports Med. J.* **2015**, *4*, 114. Available online: http://www.aspetar.com/journal/upload/PDF/2015419144822.pdf (accessed on 12 May 2022).
35. Gundersen, H.; Riiser, A.; Algroy, E.; Vestbøstad, M.; Saeterbakken, A.H.; Clemm, H.H.; Grendstad, H.; Hafstad, A.; Kristoffersen, M.; Rygh, C.B. Associations between biological maturity level, match locomotion, and physical capacities in youth male soccer players. *Scand. J. Med. Sci. Sports* **2022**, *32*, 1592–1601. [CrossRef] [PubMed]
36. Brown, K.A.; Patel, D.R.; Darmawan, D. Participation in sports in relation to adolescent growth and development. *Transl. Pediatr.* **2017**, *6*, 150–159. [CrossRef] [PubMed]
37. Malina, R.M.; Eisenmann, J.C.; Cumming, S.P.; Ribeiro, B.; Aroso, J. Maturity-associated variation in the growth and functional capacities of youth football (soccer) players 13-15 years. *Eur. J. Appl. Physiol.* **2004**, *91*, 555–562. [CrossRef]
38. Meylan, C.; Cronin, J.; Oliver, J.; Hughes, M. Talent identification in soccer: The role of maturity status on physical, physiological and technical characteristics. *Int. J. Sports Sci. Coach.* **2010**, *5*, 571–592. [CrossRef]
39. Radnor, J.M.; Staines, J.; Bevan, J.; Cumming, S.P.; Kelly, A.L.; Lloyd, R.S.; Oliver, J.L. Maturity has a greater association than relative age with physical performance in english male academy soccer players. *Sports* **2021**, *9*, 171. [CrossRef]
40. Buchheit, M.; Mendez-Villanueva, A. Effects of age, maturity and body dimensions on match running performance in highly trained under-15 soccer players. *J. Sports Sci.* **2014**, *32*, 1271–1278. [CrossRef]
41. Cumming, S.P.; Brown, D.J.; Mitchell, S.; Bunce, J.; Hunt, D.; Hedges, C.; Crane, G.; Gross, A.; Scott, S.; Franklin, E.; et al. Premier League academy soccer players' experiences of competing in a tournament bio-banded for biological maturation. *J. Sports Sci.* **2018**, *36*, 757–765. [CrossRef]
42. Sweeney, L.; MacNamara, A.; Horan, D. The Irish Football Player Pathway: Examining Stakeholder Coherence Throughout and Across the Player Development System. *Front. Sports Act. Living* **2022**, *4*, 834633. [CrossRef]
43. Taylor, J.; Collins, D. Getting in the way: Investigating barriers to optimizing talent development experience. *J. Expert.* **2021**, *4*, 315–332.
44. Taylor, J.; Collins, D. Shoulda, Coulda, Didnae—Why Don't High-Potential Players Make it? *Sport Psychol.* **2019**, *33*, 85–96. [CrossRef]
45. Taylor, J.; Collins, D. The Highs and the Lows—Exploring the Nature of Optimally Impactful Development Experiences on the Talent Pathway. *Sport Psychol.* **2020**, *34*, 319–328. [CrossRef]
46. Sweeney, L.; Cumming, S.P.; MacNamara, Á.; Horan, D. The Selection Advantages Associated with Advanced Biological Maturation Vary According to Playing Position in National-Level Youth Soccer. *Biol. Sport* **2022**, *40*, 715–722. [CrossRef]
47. Cobley, S.; Abbott, S.; Eisenhuth, J.; Salter, J.; McGregor, D.; Romann, M. Removing relative age effects from youth swimming: The development and testing of corrective adjustment procedures. *J. Sci. Med. Sport* **2019**, *22*, 735–740. [CrossRef] [PubMed]
48. Romann, M.; Cobley, S. Relative age effects in athletic sprinting and corrective adjustments as a solution for their removal. *PLoS ONE* **2015**, *10*, e0122988. [CrossRef]
49. Helsen, W.F.; Starkes, J.L.; Van Winckel, J. The Influence of Relative Age on Success and Dropout in Male Soccer Players. *Am. J. Hum. Biol.* **1998**, *10*, 791–798. [CrossRef]
50. Bennett, K.J.M.; Vaeyens, R.; Fransen, J. Creating a framework for talent identification and development in emerging football nations. *Sci. Med. Footb.* **2019**, *3*, 36–42. [CrossRef]
51. Helsen, W.F.; Starkes, J.L.; Van Winckel, J. Effect of a change in selection year on success in male soccer players. *Am. J. Hum. Biol.* **2000**, *12*, 729–735. [CrossRef]
52. Baker, J.; Schorer, J.; Wattie, N. Compromising Talent: Issues in Identifying and Selecting Talent in Sport. *Quest* **2018**, *70*, 48–63. [CrossRef]
53. Kelly, A.L.; Till, K.; Jackson, D.; Barrell, D.; Burke, K.; Turnnidge, J. Talent Identification and Relative Age Effects in English Male Rugby Union Pathways: From Entry to Expertise. *Front. Sports Act. Living* **2021**, *3*, 640607. [CrossRef] [PubMed]
54. Andrew, M.; Finnegan, L.; Datson, N.; Dugdale, J.H. Men Are from Quartile One, Women Are from ? Relative Age Effect in European Soccer and the Influence of Age, Success, and Playing Status. *Children* **2022**, *9*, 1747. [CrossRef] [PubMed]
55. Lüdin, D.; Donath, L.; Cobley, S.; Mann, D.; Romann, M. Player-labelling as a solution to overcome maturation selection biases in youth football. *J. Sports Sci.* **2022**, *40*, 1641–1647. [CrossRef]

56. Kelly, A.L.; Jackson, D.T.; Taylor, J.J.; Jeffreys, M.A.; Turnnidge, J. "Birthday-Banding" as a Strategy to Moderate the Relative Age Effect: A Case Study Into the England Squash Talent Pathway. *Front. Sports Act. Living* **2020**, *2*, 573890. [CrossRef] [PubMed]
57. Taylor, J.; Collins, D. Navigating the Winds of Change on the Smooth Sea—The Interaction of feedback and emotional disruption on the talent pathway. *J. Appl. Sport Psychol.* **2021**, *34*, 886–912. [CrossRef]
58. Helsen, W.F.; Baker, J.; Michiels, S.; Schorer, J.; van Winckel, J.; Williams, A.M. The relative age effect in European professional soccer: Did ten years of research make any difference? *J. Sports Sci.* **2012**, *30*, 1665–1671. [CrossRef] [PubMed]
59. Hurley, W.; Lior, D.; Tracze, S. A proposal to reduce the age discrimination in canadian minor hockey. *Can. Public Policy* **2001**, *27*, 74–75. [CrossRef]
60. Sweeney, L.; Horan, D.; MacNamara, Á. Premature Professionalisation or Early Engagement? Examining Practise in Football Player Pathways. *Front. Sports Act. Living* **2021**, *3*, 660167. [CrossRef]
61. Towlson, C.; Cumming, S.P. Bio-banding in soccer: Past, present, and future. *Ann. Hum. Biol.* **2022**. [CrossRef]
62. Khamis, H.J.; Roche, A.F. Predicting adult stature without using skeletal age: The Khamis-Roche method. *Pediatrics* **1994**, *94*, 504–507, Erratum in *Pediatrics* **1995**, *95*, 457.
63. Mirwald, R.L.; Baxter-Jones, A.D.G.; Bailey, D.A.; Beunen, G.P. An assessment of maturity from anthropometric measurements. *Med. Sci. Sports Exerc.* **2002**, *34*, 689–694. [CrossRef] [PubMed]
64. Lüdin, D.; Donath, L.; Cobley, S.; Romann, M. Effect of bio-banding on physiological and technical-tactical key performance indicators in youth elite soccer. *Eur. J. Sport Sci.* **2022**, *22*, 1659–1667. [CrossRef] [PubMed]
65. Abbott, W.; Williams, S.; Brickley, G.; Smeeton, N.J. Effects of bio-banding upon physical and technical performance during soccer competition: A preliminary analysis. *Sports* **2019**, *7*, 193. [CrossRef] [PubMed]
66. Romann, M.; Lüdin, D.; Born, D.P. Bio-banding in junior soccer players: A pilot study. *BMC Res. Notes* **2020**, *13*, 240. [CrossRef]
67. Reeves, M.; Enright, K.; Dowling, J.; Roberts, S. Stakeholders' understanding and perceptions of bio-banding in junior-elite football training. *Soccer Soc.* **2018**, *19*, 1166–1182. [CrossRef]
68. Hill, M.; Spencer, A.; McGee, D.; Scott, S.; Frame, M.; Cumming, S.P. The psychology of bio-banding: A Vygotskian perspective. *Ann. Hum. Biol.* **2020**, *47*, 328–335. [CrossRef]
69. Walters, S.R.; Renshaw, I.A.N.; Whatman, C.; Zoellner, A.; Harrison, C.; Millar, S.; Pithey, R. Maturity status, relative age and bio-banding in youth cricket. *New Zealand Cricket Rep.* **2021**, *48*, 66–75.
70. Malina, R.M.; Cumming, S.P.; Rogol, A.D.; Coelho-e-Silva, M.J.; Figueiredo, A.J.; Konarski, J.M.; Kozieł, S.M. Bio-Banding in Youth Sports: Background, Concept, and Application. *Sports Med.* **2019**, *49*, 1671–1685. [CrossRef] [PubMed]
71. Thurlow, F.G.; Kite, R.J.; Cumming, S.P. Revisiting youth player development in Australian Rules Football: Is there a place for bio-banding? *Int. J. Sports Sci. Coach.* **2022**, *17*, 637–646. [CrossRef]
72. Towlson, C.; MacMaster, C.; Gonçalves, B.; Sampaio, J.; Toner, J.; MacFarlane, N.; Barrett, S.; Hamilton, A.; Jack, R.; Hunter, F.; et al. The effect of bio-banding on technical and tactical indicators of talent identification in academy soccer players. *Sci. Med. Footb.* **2022**, *6*, 295–308. [CrossRef]
73. Moran, J.; Cervera, V.; Jones, B.; Hope, E.; Drury, B.; Sandercock, G. Can discreet performance banding, as compared to bio-banding, discriminate technical skills in male adolescent soccer players? A preliminary investigation. *Int. J. Sports Sci. Coach.* **2022**, *17*, 325–333. [CrossRef]
74. Abbott, A.; Collins, D. Eliminating The Dichotomy Between Theory And Practice In Talent Identification And Development: Considering The Role Of Psychology. *J. Sports Sci.* **2004**, *22*, 395–408. [CrossRef] [PubMed]
75. Collins, D.; MacNamara, Á. The Rocky road to the top: Why talent needs trauma. *Sports Med.* **2012**, *42*, 907–914. [CrossRef] [PubMed]
76. Collins, D.J.; Macnamara, A.; McCarthy, N. Putting the bumps in the rocky road: Optimizing the pathway to excellence. *Front. Psychol.* **2016**, *7*, 1482. [CrossRef] [PubMed]
77. Collins, D.; MacNamara, Á.; McCarthy, N. Super Champions, Champions, and Almosts: Important Differences and Commonalities on the Rocky Road. *Front. Psychol.* **2016**, *6*, 2009. [CrossRef]
78. Martindale, R.J.J.; Collins, D.; Abraham, A. Effective talent development: The elite coach perspective in UK sport. *J. Appl. Sport Psychol.* **2007**, *19*, 187–206. [CrossRef]
79. Malina, R.M.; Dompier, T.P.; Powell, J.W.; Barron, M.J.; Moore, M.T. Validation of a Noninvasive Maturity Estimate Relative to Skeletal Age in Youth Football Players Setting: Two communities in central Michigan. *Clin. J. Sport Med.* **2007**, *17*, 362–368. [CrossRef]
80. Malina, R.M.; Silva, M.J.C.E.; Figueiredo, A.J.; Carling, C.; Beunen, G.P. Interrelationships among invasive and non-invasive indicators of biological maturation in adolescent male soccer players. *J. Sports Sci.* **2012**, *30*, 1705–1717. [CrossRef]
81. Kozieł, S.M.; Malina, R.M. Modified Maturity Offset Prediction Equations: Validation in Independent Longitudinal Samples of Boys and Girls. *Sports Med.* **2018**, *48*, 221–236. [CrossRef]
82. Goldman, D.E.; Turnnidge, J.; Kelly, A.L.; deVos, J.; Côté, J. Athlete perceptions of playing-up in youth soccer. *J. Appl. Sport Psychol.* **2022**, *34*, 862–885. [CrossRef]
83. MacNamara, Á.; Button, A.; Collins, D. The role of psychological characteristics in facilitating the pathway to elite performance part 1: Identifying mental skills and behaviors. *Sport Psychol.* **2010**, *24*, 52–73. [CrossRef]
84. MacNamara, Á.; Button, A.; Collins, D. The Role of Psychological Characteristics in Facilitating the Pathway to Elite Performance Part 2: Examining Environmental and Stage-Related Differences in Skills and Behaviors. *Sport Psychol.* **2010**, *24*, 74–96. [CrossRef]

85. Savage, J.; Collins, D.; Cruickshank, A. Exploring Traumas in the Development of Talent: What Are They, What Do They Do, and What Do They Require? *J. Appl. Sport Psychol.* **2017**, *29*, 101–117. [CrossRef]
86. Taylor, J.; Ashford, M.; Collins, D. The role of challenge in talent development: Understanding impact in response to emotional disturbance. *Psych* **2022**, *4*, 668–694. [CrossRef]
87. Gibbs, B.; Jarvis, J.; Dufur, M. The rise of the underdog? The relative age effect reversal among Canadian-born NHL hockey players: A reply to Nolan and Howell. *Int. Rev. Sociol. Sport* **2012**, *47*, 644–649. [CrossRef]
88. Ostojic, S.M.; Castagna, C.; Calleja-González, J.; Jukic, I.; Idrizovic, K.; Stojanovic, M. The biological age of 14-year-old boys and success in adult soccer: Do early maturers predominate in the top-level game? *Res. Sports Med.* **2014**, *22*, 398–407. [CrossRef] [PubMed]
89. Till, K.; Cobley, S.; Morley, D.; O'hara, J.; Chapman, C.; Cooke, C. The influence of age, playing position, anthropometry and fitness on career attainment outcomes in rugby league. *J. Sports Sci.* **2016**, *34*, 1240–1245. [CrossRef]
90. Zuber, C.; Zibung, M.; Conzelmann, A. Holistic patterns as an instrument for predicting the performance of promising young soccer players—A3-years longitudinal study. *Front. Psychol.* **2016**, *7*, 1088. [CrossRef]
91. Tanner, J.M.; Whitehouse, R.H.; Cameron, N.; Marshall, W.A.; Healy, M.J.R.; Goldstein, N.H. *Assessment of Skeletal Maturity and Prediction of Adult Height (TW3 Method)*, 3rd ed.; W.B. Saunders: London, UK, 2001.
92. Barnes, F.B.; Fletcher, D.; Neely, K. Stress-Related Growth in Elite Sport Performers: Qualitative Differentiators in Psychosocial Mechanisms. *Sport Psychol.* **2021**, *35*, 293–304. [CrossRef]
93. Book, R.T.; Henriksen, K.; Stambulova, N.; Storm, L.K. "All they have seen is a model for failure:" Stakeholder's perspectives on athletic talent development in American underserved communities. *J. Appl. Sport Psychol.* **2022**, *34*, 1037–1057. [CrossRef]
94. Williams, G.; MacNamara, Á. Challenge is in the eye of the beholder: Exploring young athlete's experience of challenges on the talent pathway. *J. Sport Sci.* **2022**, *40*, 1078–1087. [CrossRef]
95. Rittel, H.W.; Webber, M. Dilemmas in a general theory of planning. *Policy Sci.* **1973**, *4*, 155–169. [CrossRef]
96. Neelen, M.; Kirschner, P. *Evidence-Informed Learning Design: Use Evidence to Create Training which Improves Performance*; KoganPage: London, UK, 2020.
97. Martindale, R.J.; Collins, D.; Daubney, J. Talent development: A guide for practice and research within sport. *Quest* **2005**, *57*, 353–375. [CrossRef]
98. Lorimer, R.; Jowett, S. Feedback of information in the empathic accuracy of sport coaches. *Psychol. Sport Exerc.* **2010**, *11*, 12–17. [CrossRef]
99. Price, A.; Collins, D.; Stoszkowski, J.; Pill, S. Strategic Understandings: An Investigation of Professional Academy Youth Soccer Coaches' Interpretation, Knowledge, and Application of Game Strategies. *Int. Sport Coach. J.* **2020**, *7*, 151–162. [CrossRef]
100. Taylor, J.; Ashford, M.; Collins, D. Tough Love—Impactful, Caring Coaching in Psychologically Unsafe Environments. *Sports* **2022**, *10*, 83. [CrossRef]
101. John, J.M.; Gropper, H.; Thiel, A. The Role of Critical Life Events in the Talent Development Pathways of Athletes and Musicians: A Systematic Review. *Psychol. Sport Exerc.* **2019**, *45*, 101565. [CrossRef]
102. Collins, D.; Burke, V.; Martindale, A.; Cruickshank, A. The Illusion of Competency Versus the Desirability of Expertise: Seeking a Common Standard for Support Professions in Sport. *Sports Med.* **2015**, *45*, 1–7. [CrossRef]
103. Abraham, A.; Collins, D. Taking the Next Step: Ways Forward for Coaching Science. *Quest* **2011**, *63*, 366–384. [CrossRef]
104. Henriksen, K.; Stambulova, N. Creating Optimal Environments for Talent Development: A Holistic Ecological Approach. In *Routledge Handbook of Talent Identification and Development in Sport*; Baker, J., Cobley, S., Schorer, J., Wattie, N., Eds.; Routledge: London, UK, 2017.
105. Taylor, J.; Collins, D. The Talent Development Curriculum. In *Practical Sport Coaching*; Nash, C., Ed.; Routledge: London, UK, 2022.
106. Abbott, A.; Button, C.; Pepping, G.J.; Collins, D. Unnatural selection: Talent identification and development in sport. *Nonlinear Dyn. Psychol. Life Sci.* **2005**, *9*, 61–88.
107. Bailey, R.P.; Collins, D.; Ford, P.A.; MacNamara, Á.; Pearce, G.; Toms, M. Participant development in sport: An academic literature review. In *Commissioned Report for Sports Coach UK*; Sports Coach UK: Leeds, UK, 2010.
108. Bjørndal, C.; Ronglan, L.T. Athlete Development in Norwegian Handball. In *Talent Identification and Development in Sport: International Perspectives*; Baker, J., Cobley, S., Schörer, J., Eds.; Routledge: London, UK, 2020.
109. Bjørndal, C.; Ronglan, L.T. Orchestrating Talent Development: Youth Players' Developmental Experiences in Scandinavian Team Sports. *Sports Coach. Rev.* **2018**, *7*, 1–22. [CrossRef]
110. Taylor, J.; Collins, D.; Cruickshank, A. Too Many Cooks, Not Enough Gourmets: Examining Provision and Use of Feedback for the Developing Athlete. *Sport Psychol.* **2021**, *36*, 89–100. [CrossRef]
111. Sinval, J.; e Pina, J.A.; Sinval, J.; Marôco, J.; Santos, C.M.; Uitdewilligen, S.; Maynard, M.T.; Passos, A.M. Development of the Referee Shared Mental Models Measure (RSMMM). *Front. Psychol.* **2020**, *11*, 550271. [CrossRef] [PubMed]
112. Price, A.; Collins, D. Contributing to a Coaching Team's Shared Mental Model of Player Game Understanding: An Intervention within High-Level Youth Soccer. *J. Sport Psychol. Action* **2022**, 1–15. [CrossRef]
113. Bowles, R.; O'Dwyer, A. Identifying learning in a coaching community of practice: A collaborative self-study. *Eur. J. Sport Soc.* **2022**, *19*, 214. [CrossRef]
114. Côté, J. The influence of the family in the development of talent in sport. *Sport Psychol.* **1999**, *13*, 395–417. [CrossRef]

115. Rowley, S.; Graham, P. Intensive training in youth sport: An example of unequal opportunity. *Child. Soc.* **2006**, *13*, 119–129. [CrossRef]
116. Li, C.; Wang, J.; Pyun, D.Y. Talent development environmental factors in sport: A review and taxonomic classification. *Quest* **2014**, *66*, 433–477. [CrossRef]
117. Royal Belgian Football Association. Available online: https://s3.eu-central-1.amazonaws.com/belgianfootball/s3fs-public/rbfa/docs/pdf/U16futures_fournationstournament_2019.pdf (accessed on 1 February 2022).

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Article

To Sample or to Specialise? Sport Participation Patterns of Youth Team Sport Male Players

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Abstract: This study characterised the sport participation patterns of 546 male youth team sport players. A retrospective questionnaire was used to identify the sport starting age (general sports and main sport) and the quantity and type of sports undertaken during the early years of development. A mixed-ANOVA and Chi-square tests were implemented. All participants started involvement in sports at the same age (~5 years) and participated in the same number of sports during their early years (1 to 2 sports). However, football players started participating mainly in team games (football, futsal) and water polo players in CGS sports (swimming). Participants reported different ages for initial participation in: (i) main sport (football players started participating earlier, around 5–6 years), (ii) onset of specialisation (football players specialised earlier, around 7 or 8 years), (iii) types of sports engaged in (football players were involved in more team games and water polo in more CGS sports), and (iv) variations in weekly training hours (water polo reported more hours of training). This study provided empirical evidence for understanding the effects of different sporting pathways on long-term athlete development. Some key incongruities between contemporary knowledge and practice are acknowledged. Further investigations should be developed by examining the trajectories in different sports, countries, genders, and cultural contexts.

Keywords: athlete development; pathways; early diversification; early specialisation; practice; play; youth sports

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1. Introduction

Early years of sport participation correspond to an important stage of long-term athlete development since they may define the trajectory of an athlete in sport, based on the quantity and type of practice undertaken [1]. Accordingly, two contrasting developmental pathways in sport have emerged in the literature and can be observed in practice: "early specialisation" and "early diversification" [2]. They differ in the exclusivity of focus in early, sport-specific practice (one sport vs. multiple sports), the quantity and quality of practice (proportion of structured/formal or unstructured/informal activities), and the level of engagement (usually expressed as number of hours of practice in a gross measure). Although they are often discussed within a dichotomic categorisation, they should be considered as two extremes of a possible continuum of other developmental pathways that are not yet known or (at least) defined in the literature.

Early specialisation involves participation in one sport, often to the exclusion of other sports, pursuing development in the chosen sport. Typically, this approach results in year-round participation and an early intensification of sport-specific, coach-led practice in a single sport, with the exclusion of peer-led play and involvement in other sports [3,4]. This approach to the development of expertise is exemplified by the deliberate practice approach, proposing a relationship between the quantity of specific, intense, and not inherently enjoyable, practice and performance [5,6]. Early specialisation is still a common pathway in sports where peak performance is achieved before adulthood/maturity (e.g., gymnastics, figure skating), and in some team sports like football (for a review, see [1]). Some researchers have suggested some negative long-term consequences associated with early specialisation such as physical and mental health problems including insufficient sleep, increased overuse injuries rates, overtraining, eating disorders, decreased sport enjoyment, depression, boredom, burnout, and dropout [1,7,8].

Despite such concerns, the prevalence of highly specialised youth athletes remains a concerning trend in the academic and practical domains of youth sport. For example, professional football clubs still invest time and money to recruit children as early as preschool ages (e.g., a 4-year-old 'footballer' scouted by Arsenal FC while still at nursery school in the UK: https://www.bbc.com/news/av/uk-58988254 (accessed on 21 October 2021)).

Alternatively, evidence continues to emerge demonstrating the benefits of an early diversification approach (reflected in the Developmental Model of Sport Participation [2,9]). This is characterised by participation in diverse youth sport activities in coach-led, structured, and organised practice as well as recommendations for greater involvement in child-led, unstructured, and informal activities [2,10]. Early diversification typically occurs during childhood, usually between 6 and 12 years of age (sampling years), before a gradual decrease in the number of activities undertaken and an 'investment' in one sport during mid to late adolescence [2].

The diversity of sporting experiences during the early years of development (6–12 years) occurs primarily for enjoyment and as a by-product, enriches functional athletic development, establishing the foundation for future participation in sport and further specialisation in a target sport [11,12]. Participating in a rich variety of sporting experiences (both formal and informal) allows children to experience diversified learning contexts, possibly leading to physical, cognitive, affective, and psychosocial enrichment [11]. This breadth and depth of experience is likely to enhance the intrinsic motivation that stems from the fun, enjoyment, and competence children experience in sport and physical activity [13,14]. Additionally, diversification may benefit skill performance as well as personal and social development (for a review, please see [12]).

Indeed, evidence continues to suggest that early diversification of sport experiences might promote skills transfer by exploiting affordance fields shared between sports and activities [13,14]. The Athletic Skills Model (ASM) [14,15], for example, is a pedagogical approach emanating from high performance sport, which is aligned with these ideas. Its principles encourage children to participate in multiple different sports to acquire relevant perceptual, cognitive, and movement competencies that can provide a powerful basis for later specialisation [15]. Many sports could be considered as "*donors*", since they act as complementary enriching activities that may promote the transfer of global and specific skills and behaviours across a range of play and practice environments, supporting performance functionality at the specific moment of specialisation [15–17]. Important abilities that are critical to the development of an athlete can be "donated" by the participation in other sports that share adjacent fields of an affordance landscape, which can support skills transfer from a donor sport to a target sport [15–17].

The mix of research and theoretical understanding discussed so far suggests that the initial years of participation in play, physical activity, and sport are therefore an important phase in long-term athlete development. A diverse range of play and competitive experiences can support an athlete's successful (or not) sport involvement as well as their motor, physical, psychological, and social development. Despite its relevance, little is known about how contemporary theories and knowledge may be filtering to the sporting pathways of youth team sport players, shaping the experiences of child participants. Such information is important to comprehend how practice in youth team sports is currently developing in accordance with contemporary knowledge and research on talent development regarding the need to engage in diversified sport practice and avoid the possible negative effects of early specialisation. This type of data analysis could provide important evidence to coaches, clubs, and sport systems to understand the effects of different sporting pathways on long-term athlete development in distinct sports from different countries and contexts.

In line with these ideas, the purpose of this study was to characterise the sport participation trajectories of male youth team sport players during the early years of sport development (6 to 12 years of age). Specifically, this study sought to characterise the sport starting age (of sports in general and in a main target sport) as well as the quantity and type of sport undertaken during this initial period of sport involvement.

2. Materials and Methods

2.1. Participants

The data for this paper came from the *In Search of Excellence in Sport–a mixed-longitudinal study in young male athletes* (INEX) research project carried out in Porto, Portugal, from 2017 through to 2019. The INEX study design is described in detail elsewhere [18]. The INEX study initially intended to analyse ~1000 players. Due to the dimension of the project and its characteristics, the final sample of the INEX study was ~600 players. The present study examined 546 youth male players from five team sports who demonstrated an availability to participate in this study. The sample included 166 basketball players, 113 football players, 111 handball players, 79 volleyball players, and 84 water polo players (average age of the overall players was 13.87 ± 1.9 years). These players came from 42 clubs affiliated with the Regional Sport Associations (basketball—13 clubs, football—8 clubs, handball—7 clubs, volleyball—6 clubs, water polo—5 clubs) and were selected to participate in this study by their coaches and/or club team managers since they had at least one year of specialised training and competitive experience in one of the team sports considered in this study. The five team sports (handball, basketball, football, volleyball, and water-polo) were considered since they were a convenience sample [18].

Ethical approval was granted by the Research Ethics Committee of the first author's institution, guided by the Declaration of Helsinki (process number CEFADE 13.2017). Participants and parents were informed about the study's purpose, their scope of involvement, and of their right to withdraw at any time. Data confidentiality was ensured, and informed consent forms were signed by both.

2.2. Data Collection

A retrospective questionnaire was designed to collect detailed information about the participants' sport participation history including the quantity and type of sporting activities that they were involved in between the ages of 6 to 12 years. Three strategies were used to develop the questionnaire, fulfilling the requirements for validity and reliability. First, the underlying theoretical framework and a review of the literature examining similar related questions using available questionnaires was undertaken. This process contributed to item generation and the design of the first version of our questionnaire. Second, a panel of four experts in this research field evaluated whether the initial pool of questionnaire items represented the totality of the problems that may relate to the aims of this study. To estimate the content validity of the questionnaire, the panel of experts was asked to indicate whether each question was "essential" to measure the sport activities under analysis. The experts' input relating to the assessment of each question was then used to measure the content validity ratio (CVR) [19]. The requirements of content validity were met since a value of 1.00 was reached in our analysis [19]. Finally, the revised version of the questionnaire was subjected to a pilot study with a sub-sample of 20 players to test the clarity and accuracy of the items, and the feasibility of the questionnaire. These data were not included in this study.

The initial part of the questionnaire was devoted to establishing a comprehensive set of variables related to the: (i) age of first sport participation, (ii) first sport participated in, (iii) age of first participation in the main sport, and (iv), age of specialisation in the main sport (i.e., the age when athletes start to be involved only in the target sport). The second part of the questionnaire recorded the range (number and type) of sports that the participants undertook during their initial stage of sport development (6 to 12 years of age) in an open answer question format. Moreover, the participants were asked about the amount of time (i.e., recorded as training hours) spent per week in those sport activities.

The participants' reports referred to their involvement in formal organised sports (clubs/federations) only. Involvement in physical education classes or personal physical leisure was not considered. To analyse the type of sports participated in, a categorisation of such information was required. In line with some previous research [20], this study considered the categorisation of sports based on their competition rules, since they structure movement activity by defining the performance goal, providing modes of action and criteria for valuation. Therefore, the following types of formal competitive activities were considered: team games (e.g., badminton, volleyball, handball, field hockey, etc.), CGS (centimetres, grams, or seconds) sports (e.g., athletics, cycling, rowing, swimming, etc.), artistic composition sports (e.g., artistic gymnastics, figure skating, synchronised swimming, etc.), and combat sports (e.g., boxing, judo, taekwondo, karate, etc.) (for a complete definition of each categorisation, please see [21]).

For the data collection procedures, the participants recorded their retrospective reflections in writing, in a quiet classroom setting, under the supervision of one research team member. Due to the time constraints, the participants completed the questionnaire in a small group setting (six participants per group), although independently. After assuring the participants of the confidentiality and anonymity of their data, detailed verbal instructions were given. Explanations about the questions and the variables under analysis were also provided whenever needed. The questionnaire completion process lasted around 60 min.

2.3. Data Analysis

Descriptive statistics were computed to calculate frequencies, percentages, means, and standard deviation values. The normality and homogeneity of variance were checked through the Kolmogorov–Smirnov test and Levene's test. A mixed-ANOVA was performed to test for statistical differences between groups in the following variables: sport starting age, age of first participation in the main sport, age of specialisation, number of sports practised (at all ages considered), and number of hours of training per week (at all ages considered). The effect size values were determined by the partial eta squared (η^2_P), considered as small ($\eta^2_P < 0.06$), moderate ($0.06 \leq \eta^2_P < 0.15$), or large ($\eta^2_P \geq 0.15$) [22]. Post hoc analyses were conducted using Bonferroni tests (Bonferroni adjusted alpha of $p = 0.001$).

Chi-square was performed to test for statistical differences in participation frequencies between groups when considering the type of sports practised. The effect size values were calculated through Cramer's V [23] and interpreted as a correlation [24] using arbitrary thresholds: very weak (0–0.19), weak (0.2–0.39), moderate (0.40–0.59), strong (0.6–0.79), and very strong (0.8–1) [25]. To assess the specific cells where differences emerged, adjusted standardised residuals (R) were calculated, with values $\geq |1.96|$, implying that the cell had a number of cases significantly larger (or smaller, if negative) than expected [26]. Monte Carlo correction methods were used in the case where >20% of the cells had expected counts <5 [26]. An alpha level of $p < 0.05$ was considered statistically significant for all analyses. In addition to this quantitative data examination, a content analysis procedure was also undertaken to gain a better understanding of the type of sports practised when the previous quantitative analysis resulted in a statistically significant outcome.

To assess the reliability of the retrospective information provided by the participants, ~10% of the sample (i.e., 55 players—11 from each of the team sports considered) filled in the same questionnaire one month after the first moment of data collection. Pearson product-moment correlation values were calculated between the information collected at time one and time two. Correlation coefficient values were calculated as a function of the variables considered (i.e., sport starting age, age of first participation in the main sport, age of specialisation, number of sports practised, and hours of training per week from 6 to 12 years of age, and type of sports). The values were interpreted using the previously reported thresholds [25]. Reliability assessments showed strong correlation coefficients for all variables, with values ranging from $r = 0.762$ and $r = 0.984$. All of the reliability coefficients were statistically significant ($p \leq 0.001$).

3. Results

3.1. Sport Starting Age, First Participation in the Main Sport, and Age of Specialisation

Descriptive and inferential statistics for sport starting age, age of first participation in the main sport, and age of specialisation in the main sport are presented in Table 1. Participants did not differ significantly in sport starting age, which occurred for all around 5–6 years of age. Notwithstanding, significant differences between participants were found concerning the type of sports practised in their first involvement in sport, although with weak correlations ($\chi^2 = 103.48$; $p \leq 0.001$; V = 0.251). Football players started mainly participating in team games (adj.res. = 6.7), with qualitative content analysis showing that these were football and futsal activities. On the other hand, water polo players started sport involvement mainly with CGS sports (adj.res. = 7.9), with qualitative content analysis showing that these were swimming activities.

Table 1. Ages of first participation in sport (general and specific) and specialisation according to the sport.

	Basketball	Football	Handball	Volleyball	Water Polo	F (pη^2)^2	*p*
Sport starting age	5.47 ± 2.20	5.15 ± 1.74	5.28 ± 1.93	5.36 ± 2.40	5.05 ± 2.25	0.73 (0.01)	0.57
First participation in the main sport	8.56 ± 2.36	5.81 ± 1.98 *	9.11 ± 2.72	8.97 ± 3.18	9.83 ± 1.87	42.65 (0.24)	<0.001
Age of specialisation	9.64 ± 2.51	7.93 ± 3.11 *	10.04 ± 2.92	10.21 ± 2.86	10.60 ± 1.90	15.26 (0.10)	<0.001

* $p < 0.05$.

Concerning the age of initial participation in the main sport and age of specialisation, large significant differences were observed between participants. Football players started participating in football earlier ($F_{(4,541)} = 42.647$, $p \leq 0.001$, $\eta^2_P = 0.241$), around 5–6 years of age, while other participants start engaging in their main sports around 8–9 years of age. Football players specialised earlier in football ($F_{(4,543)} = 15.257$, $p \leq 0.001$, $\eta^2_P = 0.102$), which occurred around 7–8 years of age, whereas other participants specialised around 9–11 years of age.

3.2. Quantity and Type of Practice

Descriptive and inferential statistics for number of sports practised from 6 to 12 years of age are presented in Table 2. The participants did not differ significantly in the number of sports participated in during this period, with descriptive results showing that they were involved in around 1–2 sports in each year. However, significant differences were observed in the type of sports engaged in for football and water polo players. Football players were involved in more team games from the ages of 6 to 12 years and in fewer CGS sports from 6 to 11 years of age (Table 3). Qualitative content analysis for team games indicated that football players were involved in futsal activities at the ages of 6–7 years, and in football activities from 7–8 years onwards. Water polo players were more likely to be involved in CGS sports from 6 to 11 years of age and in fewer team games from 6 to 9 years (Table 3). Qualitative content analysis for CGS sports indicated participants were mainly involved in swimming activities until 11 years of age.

Table 2. Number of sports practised according to age and sport.

Age	Basketball	Football	Handball	Volleyball	Water Polo	F $(p\eta^2)^2$	*p*
6 years	1.16 ± 0.80	1.20 ± 0.76	1.31 ± 0.83	1.21 ± 0.93	1.10 ± 0.89	0.86 (0.01)	0.498
7 years	1.17 ± 0.78	1.20 ± 0.70	1.25 ± 0.72	1.21 ± 0.80	1.18 ± 0.76	0.18 (0.01)	0.949
8 years	1.16 ± 0.72	1.24 ± 0.62	1.12 ± 0.69	1.24 ± 0.72	1.07 ± 0.63	1.06 (0.01)	0.375
9 years	1.17 ± 0.70	1.21 ± 0.47	1.13 ± 0.73	1.17 ± 0.75	1.12 ± 0.60	0.31 (0.01)	0.873
10 years	1.14 ± 0.62	1.19 ± 0.44	1.13 ± 0.72	1.21 ± 0.73	1.11 ± 0.61	0.40 (0.01)	0.807
11 years	1.11 ± 0.52	1.12 ± 0.36	1.09 ± 0.52	1.18 ± 0.60	1.11 ± 0.52	0.35 (0.01)	0.847
12 years	1.07 ± 0.41	1.12 ± 0.35	1.12 ± 0.58	1.05 ± 0.39	1.15 ± 0.61	0.64 (0.01)	0.635

Table 3. Chi-square statistics (% and adjusted standardised residuals) for the type of sports practised according to age.

Age	Sport	Types of Sports								χ^2	*p*	V
		Team Games		CGS sports		AC Sports		Combat Sports				
		%	adj.res.	%	adj.res.	%	adj.res.	%	adj.res.			
6	Basketball	29.7	−0.2	33.0	0.6	50.0	0.6	37.5	0.6	76.504	**<0.001**	0.187
	Football	34.5	**4.8 ***	5.0	**−4.3 ***	0.0	−0.7	18.8	−0.2			
	Handball	20.3	0.2	19.0	−0.2	0.0	−0.7	25.0	0.6			
	Volleyball	12.8	−0.6	10.0	−1.4	0.0	−0.6	18.8	0.5			
	Water Polo	2.7	**−4.9 ***	33.0	**5.6 ***	50.0	1.4	0.0	−1.7			
7	Basketball	31.5	0.4	28.0	−0.6	0.0	−0.7	38.5	0.6	86.737	**<0.001**	0.199
	Football	31.5	**4.9 ***	3.2	**−4.5 ***	0.0	−0.5	7.7	−1.2			
	Handball	18.2	−0.6	21.5	0.5	0.0	−0.5	15.4	−0.4			
	Volleyball	12.8	−0.8	8.6	−1.7	0.0	−0.4	23.1	0.9			
	Water Polo	5.9	**−4.6 ***	38.7	**7.0 ***	0.0	−0.4	15.4	0.0			
8	Basketball	30.3	−0.1	23.9	−1.5	0.0	−1.3	25.0	−0.4	80.906	**<0.001**	0.192
	Football	29.9	**4.7 ***	3.4	**−4.4 ***	0.0	−1.0	8.3	−1.1			
	Handball	17.8	−0.9	23.9	1.1	50.0	1.5	25.0	0.5			
	Volleyball	13.7	−0.4	11.4	−0.9	0.0	−0.8	16.7	0.2			
	Water Polo	8.3	**−3.9 ***	37.5	**6.4 ***	50.0	1.5	25.0	1.0			
9	Basketball	30.2	−0.1	22.8	−1.3	0.0	−1.3	18.2	−0.9	60.006	**<0.001**	0.166
	Football	27.8	**4.4 ***	3.5	**−3.4 ***	0.0	−1.0	9.1	−1.0			
	Handball	18.6	−0.7	26.3	1.4	50.0	1.5	36.4	1.4			
	Volleyball	12.0	−1.6	12.3	−0.5	0.0	−0.8	18.2	0.4			
	Water Polo	11.3	**−2.6 ***	35.1	**4.5 ***	50.0	1.2	18.2	0.3			
10	Basketball	29.9	−0.4	21.4	−1.1	20.0	−0.5	40.0	0.5	45.379	**<0.001**	0.144
	Football	25.2	**3.4 ***	3.4	**−2.8 ***	0.0	−1.1	0.0	−1.1			
	Handball	18.8	−0.6	32.1	1.7	20.0	0.0	20.0	1.3			
	Volleyball	12.8	−1.2	14.3	0.0	0.0	−0.9	0.0	−0.9			
	Water Polo	13.3	−1.5	32.1	**2.6 ***	20.0	1.2	0.0	−0.9			

Table 3. *Cont.*

Age	Sport	Types of Sports								χ^2	*p*	V
		Team Games		CGS sports		AC Sports		Combat Sports				
		%	adj.res.	%	adj.res.	%	adj.res.	%	adj.res.			
11	Basketball	31.2	0.6	7.7	−1.6	0.0	−0.9	0.0	−1.3	45.726	**<0.001**	0.145
	Football	23.7	**2.9 ***	0.0	**−1.9 ***	0.0	−0.7	0.0	−1.0			
	Handball	18.5	−1.2	38.5	1.6	50.0	1.1	10.0	1.1			
	Volleyball	12.4	−1.6	15.4	0.1	0.0	−0.6	0.0	−0.8			
	Water Polo	14.1	−1.1	38.5	**2.4 ***	50.0	1.4	0.0	−0.8			
12	Basketball	31.3	1.2	0.0	−1.2	0.0	−0.9	26.8	−0.6	23.109	0.111	0.103
	Football	21.5	**2.0 ***	0.0	−1.5	0.0	−0.7	23.2	0.5			
	Handball	18.7	−1.3	22.2	0.2	0.0	−0.7	23.2	0.7			
	Volleyball	13.9	−0.6	24.4	1.2	50.0	1.4	10.7	−0.8			
	Water Polo	14.6	−0.7	33.3	1.5	50.0	1.4	16.1	0.2			

* $p < 0.05$ and adjusted standardised residuals (adj.res.) $\geq |1.96|$.

Descriptive and inferential statistics for hours of training per week from 6 to 12 years of age are presented in Table 4. Small but significant differences were found between participants when aged 10 years ($F_{(4,544)} = 3.553$, $p = 0.007$, $\eta^2_P = 0.026$), and moderate differences were found for 11 years ($F_{(4,544)} = 10.009$, $p < 0.001$, $\eta^2_P = 0.069$) and 12 years ($F_{(4,543)} = 18.034$, $p < 0.001$, $\eta^2_P = 0.118$). Water polo players reported more hours of training compared to handball ($p = 0.01$) and football ($p = 0.01$) players when aged 10 years. Water polo players also reported more hours of training than all participants when aged 11 years ($p < 0.001$ for all) and 12 years ($p < 0.001$ for all). Football players reported fewer hours of training than basketball ($p = 0.002$) and volleyball ($p = 0.005$) players when aged 12 years.

Table 4. Number of hours of training per week according to age and sport.

Age	Basketball	Football	Handball	Volleyball	Water Polo	F (pη^2) [2]	*p*
6 years	3.41 ± 2.36	3.21 ± 2.51	3.49 ± 2.46	3.30 ± 2.62	2.84 ± 3.11	0.90 (0.01)	0.462
7 years	3.78 ± 2.38	3.44 ± 2.32	3.74 ± 2.40	3.58 ± 2.46	3.34 ± 3.05	0.62 (0.01)	0.646
8 years	4.17 ± 2.84	3.65 ± 2.05	3.67 ± 2.36	3.79 ± 2.25	3.86 ± 3.25	0.90 (0.01)	0.462
9 years	4.45 ± 2.46	3.90 ± 1.72	3.83 ± 2.34	3.92 ± 2.54	4.46 ± 3.38	1.78 (0.02)	0.131
10 years	4.61 ± 2.20	4.12 ± 1.67	4.11 ± 2.31	4.66 ± 2.58	**5.27 ± 3.60 ***	3.56 (0.03)	**0.007**
11 years	4.98 ± 2.10	4.26 ± 1.60	4.39 ± 2.19	4.86 ± 2.30	**6.25 ± 3.70 ***	10.01 (0.07)	**<0.001**
12 years	5.42 ± 1.94	**4.37 ± 1.56 ***	4.71 ± 1.90	5.53 ± 2.09	**6.98 ± 3.79 ***	18.03 (0.12)	**<0.001**

* $p < 0.05$.

4. Discussion

This study sought to provide evidence for a comparison of sport participation trajectories of male youth athletes from five different types of team sports (basketball, handball, football, volleyball, and water polo). The main aim was to provide data characterising the sport starting age in the sample (of sports in general and in the main sport), and the quantity and types of sports undertaken during the early years of development (i.e., 6 to 12 years of age). Globally, all participants started involvement in sports (in general) at the same age (around 5 years of age) and were involved in the same number of sports during their early sport development (around 1–2 sports). However, they reported different ages for initial participation in the main sport and the onset of specialisation as well as different types of sports engaged in and variations in the hours of training per week.

Initiation into sport occurred for all participants around 5–6 years of age, a finding that is in line with other data reported in existing studies on this topic [27–29]. These data showed that team sport athletes initiated their involvement in sport during the first stage of sporting development, normally situated approximately between 6 and 12 years of age [29–31]. Notwithstanding, differences between participants were observed concerning the age of initial participation in a main sport and age of specialisation. Here, large significant differences were observed for specific sports. Particularly, it was noted that football players started participating (around 5–6 years of age) and specialising (around 7–8 years of age) earlier in their main sport compared to the other youth team sport participants. While elite performance through early diversification has been observed in sports where peak performance is achieved in adulthood (e.g., in many team sports [1]), football seems to be an exception. Previous studies have shown that youth football players tend to start around 5–6 years of age in structured and intensive training in this sport [32,33].

While a relationship between quantity of specific practice and performance achievement in sport has been proposed in past research [34], early, single sport specialisation has been significantly associated with many challenges in future elite performance in team sports [1,8,12,35]. Evidence has highlighted the negative impact that early specialisation in sports may have for an athlete in a long-term perspective including insufficient sleep, increased overuse injury rates, emotional disturbances, overtraining, burnout, and eating disorders [7,36]. Empirical evidence supports these trends, with early specialisation being associated with an increased risk of overuse injuries, burnout, depression, and dropout [36,37].

On the other hand, basketball, handball, volleyball, and water polo participants reported a more diversified sport experience (involvement in 1–2 sports) before specialising in their main sport (which occurred around 10 years of age). Research suggests that diverse athletic exposure and sport sampling may enhance motor development and athletic capacity, reduce injury risk, and increase the opportunity for a child to discover the sport(s) or activities they will enjoy and possibly excel at [11,20,38]. Particularly in team sports, although there are elite players that specialised early in the target sport, evidence has also indicated that many other successful elite players participated in several sports before specialising in their main sport [27,28,39]. These ideas support theoretical suggestions about phases of talent development in young sport participants: one of the early enrichment of athletic capacities before the secondary specialisation period of dedicated practice in a target sport [13,15,40].

Despite the early diversified pathway identified in the cohort of youth team sport participants in this study, it is important to note that the specialisation age was earlier than that reported in previous studies. For example, the study of Coutinho and colleagues [30], with adult skilled and less skilled volleyball players, indicated that players, in general, specialised in their main sport around 12–15 years of age, although skilled players specialised later (14–15 years) compared to less skilled counterparts (12–13 years). Such findings are raising questions whether youth players nowadays may be specialising earlier than athletes did in the past. These findings need to be interpreted alongside concerns that children in contemporary generations are not as physically active as those in previous generations [14]. The lack of early functional movement experiences may act as a limitation and challenge for contemporary children on their trajectory developing into adult athletes.

Concerning the nature and type of sports practised, a clear pattern was identified for the football and water polo participants, but not for the other individuals (i.e., basketball, handball, and volleyball players). Football players tended to be involved in more team games (especially specialised football and futsal activities) until the age of 12 years, while water polo players were initially involved in CGS sports (swimming activities) until 11 years of age (specialisation age in water polo). Accordingly, team games and CGS sports could possibly act as complementary *donor sports*, in an early enrichment programme, since they may provide important experiences across a range of play and practice environments that support performance functionality at the moment of specialisation for football and water polo players [15,16,41]. These sports may share adjacent areas or fields of an *affordance landscape* [42] that include an extensive range of opportunities for action, which can support the transfer of functional performance behaviours to target sport participation [16]. Here, the transfer of learning could occur by using general movement behaviours, similar perceptual and contextual features, cognitive actions (i.e., problem-solving and decision-making under pressure) and physical conditioning capacities. These questions clearly raise the need for further empirical evidence and research to provide greater insights on this topic, with a particular interest in knowing if there are 'better' donor sports to enhance future abilities for specific sports or/and if there are 'global' donor sports that allow for the development of general abilities. Thus, further research could explore these issues and possibly try to understand the role of types of donor sports (for example, universal vs. specific donors).

The theoretical framework of ecological dynamics emphasises that talent development and learning in sport entails a smoothed transition between the generality and specificity of practice and transfer [40,43,44]. Richly varied play and practice experiences might potentiate exploratory and adaptive behaviours by inviting participants to continually satisfy different interacting constraints and educate their attentional focus and intentions during learning [44]. Such sporting experiences may have provided the participants in this study with the beginnings of a rich landscape of affordances that lead them to potentiate functional behavioural variability, and developing perceptual-motor exploration [13,45].

Additionally, participants in this study differed in the number of hours of training per week undertaken between 10 and 12 years of age. Water polo players reported undertaking more hours of training during this specific age period, which corresponded to the moment of specialisation (occurring around 10 years of age). This finding supports the theoretical tenets that the moment of specialisation corresponds to a period of significant investment in intensive and structured training, with an increased amount of specificity of practice [2,46]. However, caution is needed in interpreting this finding, since the specialisation of these participants is still emerging at a very young age. Huge amounts of specific practice may not be advantageous at this stage for an individual's long-term development [47–49].

Indeed, a recent meta-analysis by Güllich and colleagues [50] revealed that higher performing *youth athletes* that started playing earlier in their target sport were involved in more specific practice and showed faster initial progress than youth athletes from lower performance levels. In contrast, the results showed that *adult world-class athletes* engaged in more childhood/adolescent multisport practice, started their main sport later, accumulated less main-sport practice, and initially progressed more slowly than national-class athletes. Such observations suggest that investment in high quantities of sport-specific practice likely increases the probability of early *junior* success, but compromises the sustainability of the long-term development of international senior success [50].

Despite the important findings of this study, there are some limitations that should be addressed. Although used widely in the literature, reliable and valid retrospective methodologies only reflect the interpretation of records and the participants' reports/perceptions of their previous sport experiences. While these reflections are an important source of documented information, they do need to be triangulated with other objective data to provide a rich understanding of developmental patterns [51]. This was the same for the data science analyses of the participation rates and competitive outcomes analyses in junior and senior sports records [50]. Big data analyses need to be juxtaposed with more qualitative investigations to gain rich, perceptive analyses of expertise and talent development in sport [1]. Thus, contemporary research methods in sport science may need further evidence of *participant perception* on the nature, type, and influence of practice activities as well as the quantity of relevant units in their practice histories such as hours or the number of activities undertaken. When feasible, prospective longitudinal studies should be undertaken, although the required timescales (i.e., several years, maybe decades) make this methodology intrusive and difficult to implement.

The selected methodologies, therefore, cannot be based only on data mining since researchers have to guarantee that they are not disrupting, nor distorting the perceptions of the selected participants (whether coaches or athletes). Here, qualitative research methods (for example, in-depth interviews, focus groups, participant observation, reflective note taking, action research, ethnographic studies) may offer a deeper perspective to better understand the role of practice and play activities in athlete development and expertise achievement. Such methodologies may help researchers to better comprehend how training transfer facilitates athlete development. Further research on this topic should also explore other contexts that were not explored in this specific study. For example, the experiences of female athletes, athletes from other sports (e.g., other team sports, CGS sports, combat sports, artistic composition sports, etc.), sports from different level of popularity, and other cultural contexts (different countries and social communities, clubs from villages vs. clubs from big cities, different sport organisation such as school-model vs. club-model) need to be examined [12].

Moreover, the degree and extent of specialisation within a given sport may vary considerably and provide another highly relevant layer of analysis that should be considered in future research. Such evidence is needed to better understand the long-term athlete developmental processes and to better inform the professional work and ideology of coaches, sport systems, and organisations as well as talent development and identification programmes.

5. Conclusions

The findings of this study provided a brief characterisation of the sport participation patterns of male youth athletes from five different types of team sports (basketball, handball, football, volleyball, and water polo) in Portugal. Overall, the participants started their involvement in sports (in general) at the same age and participated in the same number of sports during their early sport development. However, they differed in the type of sports practised in their first involvement in sport, the ages for first participation in the main sport, and the onset of specialisation as well as the types of sports engaged in and variations in the hours of training per week. The results were clear in demonstrating that football players had a different sporting developmental pattern since they initiated their involvement in sport-specific formal training earlier. They might face pressures to specialise earlier in this sport by limiting their focus of experience, although they did not report more hours of training in their early years. Water polo players were also distinguished from other the participants when reporting their involvement in more CGS sports (swimming) from an early age. They reported more hours of training between 10 and 12 years compared to other participants.

Such empirical evidence provides a snapshot of how practice in youth team sports in Portugal is currently developing and allowed us to compare these practical approaches with contemporary scientific and theoretical insights. Additional research is needed to investigate the sporting developmental patterns in other types of sports and in other countries to understand how different social communities and cultures provide different sport development experiences for their children. This type of research would provide a consideration of features of best practice and process markers of athlete and talent development, leading to the emergence of robust guidelines to ensure children's health and wellbeing as well as the implementation of successful long-term developmental pathways applied in practice.

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References

1. Coutinho, P.; Mesquita, I.; Fonseca, A.M. Talent development in sport: A critical review of pathways to expert performance. *Int. J. Sport. Sci. Coach.* **2016**, *11*, 279–293. [CrossRef]
2. Côté, J.; Baker, J.; Abernethy, B. Practice and play in the development of sport expertise. In *Handbook of Sport Psychology*, 3rd ed.; Eklund, R., Tenenbaum, G., Eds.; Wiley: Hoboken, NJ, USA, 2007; pp. 184–202.
3. Brenner, J.S.; LaBotz, M.; Sugimoto, D.; Stracciolini, A. The psychosocial implications of sport specialization in pediatric athletes. *J. Athl. Train.* **2019**, *54*, 1021–1029. [CrossRef]
4. DiSanti, J.S.; Erickson, K. Youth sport specialization: A multidisciplinary scoping systematic review. *J. Sport. Sci.* **2019**, *37*, 2094–2105. [CrossRef]
5. Ericsson, K.A.; Krampe, R.; Tesch-Romër, C. The role of deliberate practice in the acquisition of expert performance. *Psychol. Rev.* **1993**, *100*, 363–406. [CrossRef]
6. Ericsson, K.A. Towards a science of the acquisition of expert performance in sports: Clarifying the differences between deliberate practice and other types of practice. *J. Sport. Sci.* **2019**, *38*, 159–176. [CrossRef]
7. Bergeron, M.; Mountjoy, M.; Armstrong, N.; Chia, M.; Côté, J.; Emery, C.A.; Faigenbaum, A.; Hall, G.; Kriemler, S.; Léglise, M.; et al. International Olympic Committee consensus statement on youth athletic development. *Br. J. Sport. Med.* **2015**, *49*, 843–851. [CrossRef]
8. Côté, J.; Lidor, R.; Hackfort, D. ISSP position stand: To sample or to specialize? Seven postulates about youth sport activities that lead to continued participation and elite performance. *Int. J. Sport Exerc. Psychol.* **2009**, *9*, 7–17. [CrossRef]
9. Côté, J.; Baker, J.; Abernethy, B. From play to practice: A developmental framework for the acquisition of expertise in team sport. In *Expert Performance in Sports: Advances in Research on Sport Expertise*; Starkes, J., Ericsson, K.A., Eds.; Humam Kinetics: Champaign, IL, USA, 2003; pp. 89–113.
10. Davids, K. Skills acquisition and the theory of deliberate practice: It ain't what you do it's the way that you do it. *Int. J. Sport Psychol.* **2000**, *31*, 461–466.
11. Côté, J.; Erickson, K. Diversification and deliberate play during the sampling years. In *Routledge Handbook of Sport Expertise*; Baker, J., Farrow, D., Eds.; Routledge: London, UK, 2015; pp. 305–316.
12. Murata, A.; Goldman, D.E.; Martin, L.J.; Turnnidge, J.; Bruner, M.W.; Côté, J. Sampling between sports and athlete development: A scoping review. *Int. J. Sport Exerc. Psychol.* **2021**, *20*, 1752–1776. [CrossRef]
13. Chow, J.Y.; Davids, K.; Button, C.; Renshaw, I. *Nonlinear Pedagogy in Skill Acquisition*; Routledge: London, UK, 2022.
14. Rudd, J.R.; Renshaw, I.; Savelsbergh, G.J.P.; Chow, J.Y.; Roberts, W.; Newcombe, D.; Davids, K. *Nonlinear Pedagogy and the Athletic Skills Model: The Importance of Play in Supporting Physical Literacy*; Routledge: London, UK, 2021.
15. Wormhoudt, R.; Teunissen, J.W.; Savelsbergh, G.; Davids, K. *The Athletic Skills Model for Talent Development—No Specialists, but Athletes with a Specialization*; Routledge | Taylor & Francis: New York, NY, USA, 2018.
16. Strafford, B.W.; van der Steen, P.; Davids, K.; Stone, J.A. Parkour as a donor sport for athletic development in youth team sports: Insights through an ecological dynamics lens. *Sport. Med. Open* **2018**, *4*, 21. [CrossRef]
17. Travassos, B.; Araújo, D.; Davids, K. Is futsal a donor sport for football?: Exploiting complementarity for early diversification in talent development. *Sci. Med. Footb.* **2017**, *2*, 66–70. [CrossRef]
18. Guimarães, E.; Baxter-Jones, A.; Williams, A.M.; Tavares, F.; Janeira, M.A.; Maia, J. The role of growth, maturation and sporting environment on the development of performance and technical and tactical skills in youth basketball players: The INEX study. *J. Sport. Sci.* **2021**, *39*, 979–991. [CrossRef] [PubMed]
19. Lawshe, C.H. A quantitative approach to content validity. *Pers. Psychol.* **1975**, *28*, 563–575. [CrossRef]
20. Güllich, A.; Emrich, E. Considering long-term sustainability in the development of world class success. *Eur. J. Sport Sci.* **2014**, *14*, S383–S397. [CrossRef] [PubMed]
21. Emrich, E.; Pitsch, W.; Papathanassiou, V. *Die Sportvereine: Ein Versuch auf Empirischer Grundlage*; The sport clubs: A trial based on empirical groundwork; Hofmann: Schorndorf, Germany, 2001.
22. Levine, T.R.; Hullett, C.R. Eta squared, partial eta squared, and misreporting of effect size in communication research. *Hum. Commun. Res.* **2022**, *28*, 612–625. [CrossRef]
23. Cramér, H. *Mathematical Methods of Statistics*; Princeton University Press: Princeton, NJ, USA, 1946.
24. McHugh, M.L. The Chi-square test of independence. *Biochem. Med.* **2013**, *23*, 143–149. [CrossRef]
25. The BMJ. Correlation and Regression. Available online: https://www.bmj.com/about-bmj/resources-readers/publications/statistics-square-one/11-correlation-and-regression (accessed on 4 April 2023).
26. Agresti, A. *Categorical Data Analysis*; Wiley: New York, NY, USA, 2002.
27. Coutinho, P.; Mesquita, I.; Davids, K.; Fonseca, A.M.; Côté, J. How structured and unstructured sport activities aid the development of expertise in volleyball players. *Psychol. Sport Exerc.* **2016**, *25*, 51–59. [CrossRef]

28. Coutinho, P.; Ramos, A.; Davids, K.; Fonseca, A.M.; Mesquita, I. The nature of formative physical activities and sports in the development of senior volleyball players. *Int. J. Sport. Sci. Coach.* **2021**, *16*, 731–740. [CrossRef]
29. Leite, N.; Baker, J.; Sampaio, J. Paths to expertise in Portuguese national team athletes. *J. Sport. Sci. Med.* **2009**, *8*, 560–566.
30. Coutinho, P.; Mesquita, I.; Fonseca, A.M.; Côté, J. Expertise development in volleyball: The role of early sport activities and players' age and height. *Kinesiology* **2015**, *47*, 215–225.
31. Haugaasen, M.; Toering, T.; Jordet, G. From childhood to senior professional football: Elite youth player's engagement in non-football activities. *J. Sport. Sci.* **2014**, *32*, 1940–1949. [CrossRef] [PubMed]
32. Haugaasen, M.; Toering, T.; Jordet, G. From childhood to senior professional football: A multi-level approach to elite youth football players' engagement in football-specific activities. *Psychol. Sport Exerc.* **2014**, *15*, 336–344. [CrossRef]
33. Sarmento, H.; Anguera, M.T.; Pereira, A.; Araújo, D. Talent identification and development in male football: A systematic review. *Sport. Med.* **2018**, *48*, 907–931. [CrossRef]
34. Baker, J.; Côté, J.; Deakin, J. Expertise in ultra-endurance triathletes early sport involvement, training structure, and the theory of deliberate practice. *J. Appl. Sport Psychol.* **2005**, *17*, 64–78. [CrossRef]
35. Law, M.; Côté, J.; Ericsson, K.A. Characteristics of expert development in rhythmic gymnastics: A retrospective study. *Int. J. Sport Exerc. Psychol.* **2007**, *5*, 82–103. [CrossRef]
36. DiFiori, J.P.; Benjamin, H.J.; Brenner, J.S.; Gregory, A.; Jayanthi, N.; Landry, G.; Luke, A. Overuse injuries and burnout in youth sports: A position statement from the American medical society for sports medicine. *Br. J. Sport. Med.* **2014**, *48*, 287–288. [CrossRef]
37. Rothwell, M.; Rumbold, J.L.; Stone, J.A. Exploring British adolescent rugby league players' experiences of professional academies and dropout. *Int. J. Sport Exerc. Psychol.* **2018**, *18*, 485–501. [CrossRef]
38. Jayanthi, N.; Pinkham, C.; Dugas, L.; Patrick, B.; LaBella, C. Sports specialization in young athletes: Evidence-based recommendations. *Sport. Health* **2013**, *5*, 251–257. [CrossRef]
39. Güllich, A. "Macro-structure" of developmental participation histories and "micro-structure" of practice of German female world-class and national-class football players. *J. Sport. Sci.* **2018**, *37*, 1347–1355. [CrossRef]
40. Button, C.; Seifert, L.; Chow, J.Y.; Araújo, D.; Davids, K. *Dynamics of Skill Acquisition: An Ecological Dynamics Rationale*, 2nd ed.; Human Kinetics: Champaign, IL, USA, 2020.
41. Savelsbergh, G.; Wormhoudt, R. Creating adaptive athletes: The athletic skills model for enhancing physical literacy as a foundation for expertise. *Mov. Sport Sci.* **2018**, *102*, 31–38. [CrossRef]
42. Rietveld, E.; Kiverstein, J. A rich landscape of affordances. *Ecol. Psychol.* **2014**, *26*, 325–352. [CrossRef]
43. Davids, K.; Araújo, D.; Hristovski, R.; Passos, P.; Chow, J. Ecological dynamics and motor learning design in sport. In *Skill Acquisition in Sport: Researcher, Theory and Practice*, 2nd ed.; Hodges, N.J., Williams, A.M., Eds.; Routledge: New York, NY, USA, 2012.
44. Seifert, L.; Papet, V.; Strafford, B.W.; Coughlan, E.; Davids, K. Skill transfer, expertise and talent development: An ecological dynamics perspective. *Mov. Sport Sci.* **2019**, *102*, 39–49. [CrossRef]
45. Bernstein, N. *The Co-Ordination and Regulation of Movements*; Pergamon Press: Oxford, UK, 1967.
46. Baker, J.; Cobley, S.; Fraser-Thomas, J. What do we know about early sport specialization? Not much! *High Abil. Stud.* **2009**, *20*, 77–89. [CrossRef]
47. García-Rubio, J.; García-Vallejo, A.; Arenas-Pareja, M.d.l.Á.; López-Sierra, P.; Ibáñez, S.J. From Junior to Elite in Soccer: Exploring the Relative Age Effect and Talent Selection in Spanish Youth National Teams. *Children* **2022**, *9*, 1543. [CrossRef] [PubMed]
48. Pérez-González, B.; León-Quismondo, J.; Bonal, J.; Burillo, P.; Fernández-Luna, Á. The New Generation of Professional Soccer Talent Is Born under the Bias of the RAE: Relative Age Effect in International Male Youth Soccer Championships. *Children* **2021**, *8*, 1117. [CrossRef]
49. Simenko, J. Youth Judokas Competing in Higher Age Groups Leads to a Short-Term Success. *Children* **2022**, *9*, 1737. [CrossRef]
50. Güllich, A.; Macnamara, B.; Hambrick, D. What makes a champion? Early multidisciplinary practice, not early specialization, predicts world-class performance. *Perspect. Psychol. Sci.* **2021**, *17*, 6–29. [CrossRef]
51. Sosniak, L.A. Retrospective Interviews in the Study of Expertise and Expert Performance. In *The Cambridge Handbook of Expertise and Expert Performance*; Ericsson, K.A., Charness, N., Feltovich, P.J., Hoffman, R., Eds.; Cambridge University Press: New York, NY, USA, 2006; pp. 287–301.

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Review

Enriching Athlete—Environment Interactions in Youth Sport: The Role of a Department of Methodology

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Abstract: The aim of this insights paper is to propose how the theory of ecological dynamics may invite re-consideration of how sport scientists could support performance, learning and development of children and youth in sports programmes. We seek to outline why learning should be *individualised* and *contextualised*, based on the specific needs of learners, such as children and youth, women and disabled athletes in sport. Case examples from individual and team sports are presented to illustrate how constraints can be designed to enrich interactions of children and youth with different performance environments, based on integrating principles of specificity and generality in learning and development. These case examples suggest how a collaborative effort by sport scientists and coaches in children and youth sport may be undertaken in a department of methodology to enrich learning and performance.

Keywords: ecological dynamics; coaching; department of methodology; transdisciplinarity; skill adaptation; ecological enrichment; affordances

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1. Introduction

Re-imagining sport science education and training to support development of individuals in specific sub-groups in sport is necessary because of a historical tendency to use data from studies of adult male athletes to plan programmes for athlete development and performance preparation for universal implementation. This re-consideration is needed in children and youth sport programmes because there has been a historical tendency to inappropriately treat them as "miniature adults". For example, in the socio-historical culture of colonial Puritan communities in North America, the needs and desires of children and youth were not recognised, nor were specific societal roles and identities specified for them [1]. According to Beales [1], this culturally entrenched view on children's place in society also impacted on common psycho-social attitudes to child-rearing practices.

More recently, Rothwell et al. [2] documented how these socio-cultural and historical constraints have continued to shape childhood and youth development experiences in formal sport programmes in more recent times. They identified the increasing professionalisation and "adultification" of junior sports programmes as a significant threat to the health and wellbeing of children and youth in sports participation programmes at different levels of skill and expertise [3].

Related to this issue, a similar argument can be made with regards to the challenge of working with other groups in sport, including women and paralympic athletes. Indeed, this insights paper posits the need for theoretically based contextualised training programmes for learning and development of individuals in specific sub-groups in sport programmes, exemplified by, but not limited to, children and youth, women and groups with disabilities. Individuals in all groups have their own specific psycho-physiological needs framed by socio-cultural and historical expectations.

1.1. Children and Youth Are Not 'Mini-Adults'

A key principle of an ecological dynamics-oriented application of sports sciences to facilitate developmental experiences in competitive sports is that children (and others) should not be treated as "honorary male adults" during training and practice for the purposes of performance preparation and athlete development. Not treating children as "mini-adults" places the individual child or young person at the centre of learning and development processes with which they are challenged throughout the early span of the life course [4].

The aim of this insights paper is to review how training designs in sport programmes can be based upon general principles to provide relevant sports science and sport pedagogical support for all groups. Here, we argue that *contextualisation* of practice is vital, based on the specific needs of different athlete populations, as well as *individualisation* of practice and training designs [3]. To support this rationale, we critically reviewed the existing literature in ecological dynamics, and papers from sports science research relevant to examining the argument that the needs of different sub-groups (e.g., children, women and disabled individuals) have been under-investigated due to the dominant tendency to conduct studies on male, adult athletes. More specifically, this critical analysis allowed us to unpack what contextualisation and individualisation means in terms of sport science support for youth and children. To achieve our aim, we conducted an overview of the existing literature, providing a critical analysis as to why an ecological dynamics rationale can explain why contextualised and individualised sport science support is vital for sub-groups of participants at all performance levels, such as children and youth. Three case examples from individual, team sports and training are provided to bring to life the theoretical ideas explored in our critical review.

1.2. An Ecological Dynamics Rationale for Development of Youth in Sport

Some calls to avoid treating children as adults in sports training have been evidence-based, for example from a health and safety perspective [5,6]. Some sport development models, with a practical application focus, such as the long-term athlete development model [7,8] and youth physical development model [9,10], consider the maturational status of the child [as opposed to simply relying on chronological age], offering a strategic approach to athletic development of children and youth. However, these models have not provided a detailed theoretical explanation for why the "adultification" of children's experiences in sport needs to be avoided, focusing on practical implications (e.g., injury repercussions) instead. Furthermore, individual development in such models is often considered in isolation, for practical purposes, separating physical, technical, tactical and psychological skills training [11]. The assumption is that the performance of a young athlete can be improved by simply addressing a single component of a larger, complex system at a time.

In contrast, the contemporary theoretical framework of ecological dynamics provides a complementary integration of concepts, ideas and tools from nonlinear dynamics and ecological psychology to contextualise and individualise each child's experiences in sport development [3,12]. Key ideas in ecological dynamics have been applied to the study of sport performance in individual athletes and teams, addressing motor learning, the acquisition of expertise and talent development throughout the past few decades [13]. The principles of ecological dynamics can help with the challenge of enriching the learning experiences of children and youth participating in sports programmes at all skill levels to facilitate implicit skill adaptation. Self-organising actions implicitly, to satisfy interacting constraints in sport, supports performers (conceptualised as nonlinear dynamical systems) to perceive surrounding information (e.g., visual, proprioceptive, haptic and acoustic) to regulate intentions and use cognition (for problem-solving to make choices and decisions) [14,15].

Nonlinearity in dynamical movement systems refers to the varied rates at which different sub-systems of each individual change over time, through growth, maturation and development. This important idea captures how children, youth and adults are continuously changing, at different timescales (e.g., learning and development), throughout the life course under the influence of various interacting constraints [16]. Nonlinearity of development and maturation is a significant challenge for sport scientists engaged in identification, prediction and assessment of "talent" at an early age [17]. For this reason, identification, selection and development of young children in early specialisation programmes in sport have been rejected as ineffective and inefficient uses of time and resources in sport science (see Coutinho et al., this special issue). Instead, sport scientists should improve their focus on *enriching the interactions* of individuals with sport environments to provide the most effective and efficient opportunities and experiences for learning and development, rather than allocate resources and efforts on identification and selection of individuals at an early age, relative to each sport's norms [18].

1.3. Newell's Constraints Model

Newell's [19] model of interacting constraints implies that a most effective way for sport scientists, coaches and teachers to guide performance, learning and development in sport is to manipulate individual, environmental and task constraints continuously guide the development of each individual in practice.

Individual constraints include characteristics and properties of movement systems at a specific phase of maturation and development in childhood and adolescence [16]. Different sub-systems of each individual change at different rates across varying timescales. This important point presents individual children with challenges during performance, learning and development. The sub-systems of each child include those which guide action, perception, cognition, emotions, hormones production and more throughout the life course [16]. Each sub-system may change at different rates in each individual, presenting a strong case for individualised sport science support of youth athletes by groups of specialist practitioners working together in developing practice and training programmes that are relatively unique. Even within the same age group (e.g., athletes aged 13–14 yrs) there will be a significant amount of variability with regards to maturation and development of each sub-system, as well as different levels of learning, education and experience. For this reason, nonlinearity of development, encompassed by inter-individual and intra-individual variability in action capabilities and performance capacities, should be considered to be typical throughout childhood [3,13]. Treating every child in the same way will not provide equality of opportunity for children and youth to achieve their potential [3,20]. Consequently, *individualisation* of development and preparation for performance should be based on the specific personal constraints of each child in the design of youth sports programmes for learning and development.

Task constraints refer to the conditions of practice design, e.g., practice area dimensions and locations, intended aims of the task, equipment and technology used to enrich interactions of children and the learning environment [13]. An ecological rationale for technology use for learning and development of children proposes that sport scientists should not seek to replace the children's direct experience with sport contexts [21]. The implication is that teachers and coaches should limit the amount of indirect experience that children and youth have (e.g., watching video films of athletes performing skills instead of engaging directly with sports performance environments to gain primary experiences). These ideas have important implications for how coaching practitioners and sport scientists use, and their attitudes towards, technologies which contribute to the secondary experiences of young people during learning. Even when educators and practitioners intend to provide primary learning experiences, technology often becomes the main contributor to designing practice landscapes. Technology-based learning contexts are less likely to provide *direct* experience of competition such as primary encounters in practice and performance. In physical education and sports, an important aim for sport scientists is to consider how technology can enrich interactions between athletes, coaches, content (e.g., areas of performance to be explored), and a learning and development context. Essentially, technology can be used to strengthen and support reciprocal interactions within the athlete–coach–environment learning system. Too often, technology gets in the way of these interactions, because it is believed to provide what practitioners consider to be "an objective truth" [e.g., statistical data] about what performance issues might need "fixing" in a team or an individual athlete. The over-use of statistical performance data in coaching youth can encourage explicit learning methods, rather than facilitate implicit skill adaptation and, of course, there is much more to sport performance that sport scientists need to consider.

A major task constraint under the remit of sport scientists includes designing *affordances* [22,23] in the practice landscape. According to Gibson [22], affordances are not causes of a movement, but rather are *possibilities or opportunities for action* which people may or may not use to achieve their intended performance outcomes. In ecological dynamics, practice is a search process for children to find and use available affordances as opportunities for action in the sport performance landscape [24]. This important ecological idea implies that the environment is a "manifold of action possibilities" [23] with which a young person needs to learn to interact in sport practice.

A sport science team's role is to guide these interactions by helping young athletes to learn to attend to available affordances in a performance environment: to seek, discover and exploit them to enhance their performance functionality during learning. According to Jacobs and Michaels [25], one can guide an athlete's intentions in negotiating a performance environment, with regards to specific aims, objectives and performance goals which may support decision making and problem solving in youth sport.

These ideas of Withagen et al. [23] suggest that task constraints for motor learning in sport cannot improve utilisation of affordances in young learners by making them more prominent (e.g., providing bigger gaps between defenders for attackers to pass through in a team games drill). Rather, affordance utilisation in youth sport can best be improved by better aligning the effectivities or action capabilities of individual children with the information and the affordances that become available in a performance environment. In ecological dynamics, a performer's effectivities refer to their personal capacities, predispositions, underlying abilities and tendencies for performance which allow them to use a range of affordances for action that emerge in play, recreation and sport. To achieve this purpose, task constraints should be designed to be more *neutral* [23] to support the improved functionality of the athlete–environment relationship. This idea aligns neatly with Bernstein's [26] conception of practice as 'repetition without repetition' [repeatedly seeking different performance solutions in practice], a key principle in ecological dynamics.

In contrast, a popular principle of design in everyday life is that many objects and locations in life can have *limited* purposes [23]. It is the same in team sports and other dynamic performance environments. In junior volleyball, for example, drills are often designed to deliberately manipulate practice task constraints for athletes to achieve a specific performance outcome. This type of prescriptive task constraint design is common in many sports where *repetition and "choreography" of a movement technique* is over-emphasised e.g., simply rehearsing an "ideal" technique for smashing a volleyball in attack, without opposition present at the net, and without consequences if the ball is hit out of court [27]. This "technique rehearsal" approach overlooks the search for solutions during practice to problems of avoiding a two- or three-person opposition block, for example. Using a "technique repetition" approach, coaches typically prescribe few opportunities for decision making or problem solving, including a lot of pre-determined movement sequences with which athletes need to comply.

Instead, by designing more *neutral* task constraints, sport scientists and coaches can facilitate adaptability, creativity and innovation in children. To exemplify, in volleyball, coaches can encourage children to explore neutral performance landscapes by adding defenders and changing attack location at the net and ensuring there are consequences if the ball is hit into the net or out of court by the attackers. Games and play activities with *Neutral* task constraints in sports coaching and teaching have many affordances, appearing and disappearing, depending on the ebb and flow in the dynamics of a well-designed "open" practice environment [11,28]. In such a sport practice landscape, the aim is to encourage children to search, discover and explore affordances which are more diverse [3]. Designing practice task constraints which are more *neutral* in terms of performance outcomes could better simulate the constraints of the competitive performance environment, encouraging children to problem solve, make decisions and learn to use different affordances during practice. With this coaching methodology learning designs in sport practice could resemble "repetition without repetition", including *solicitations* for functional actions in a specific field of promoted actions [e.g., in a transitional phase of play in basketball] to specify the learning context of an individual child or team during practice [3].

Environmental constraints include socio-cultural and historical factors that can manifest in strong traditions and attitudes towards developmental practices, such as taken-for-granted misconceptions for treating children and youth as mini-adults in society [1]. In children's sport programmes, socio-cultural-historical constraints can act as adverse *rate limiters* on children's development, but are not always tangible, and in many cases serve to hinder children's development, unbeknown to parents and practitioners. To fully embrace established principles of child development in ecological dynamics, from the perspective of working with children as a special population, we must not only consider factors within the child's immediate environment [e.g., physical, geographic and developmental experiences], but also their interactions within the wider environment [e.g., social and cultural systems and historical tendencies].

To understand the wider ecology of a child's development, the prominent ecological psychologist Urie Bronfenbrenner [29,30] proposed a bioecological theory of human development. A key feature of Bronfenbrenner's work is the process–person–context–time model [31]. Bronfenbrenner's ecological conceptualisation highlights the interrelatedness, and proximal processes between individuals and the (immediate and wider) environment within which they are situated, as important drivers of their development. In essence, development is an emergent property emanating from the synergistic and reciprocal interactions between individuals and their environments. Applying this idea to sport development in children, environments are considered to be complex and interconnected systems (i.e., macro—e.g., cultural norms, exo—e.g., the influence of sport scientists on a performance pathway, meso—e.g., school/education and micro—e.g., day-to-day practice designs), that shape (positively or negatively) an aspiring athlete's developmental experiences. Take, for example, the unacceptable culture of British Gymnastics World Class Programmes, a culture that was born out of an unhealthy obsession with competitive success (macro level), leading to performance preparation practices that normalised the physical and emotional abuse of young gymnasts during training (micro level) [32]. These issues were confounded by poor safeguarding practices and procedures within British Gymnastics clubs (exo-level), meaning that many elite level gymnasts, and parents, felt unable to raise their concerns with the relevant authorities (meso-level) [32].

1.4. Enrichment and Task Constraints with Neutral Affordances

In sports organisations, sport scientists could advise coaches and teachers on how to design task constraints and skill adaptation programmes that enrich the individual-performance environment relationship, providing greater functionality in children and youth. Enhanced functionality needed for successful interactions with a performance environment can emerge through enriching interactions: at specific and general levels [3]. Coaching frameworks such as nonlinear pedagogy and the athletic skills model (ASM) advocate that children and youth should undertake a complementary programme of less-specialised (general activities involving play and practice in multiple sports) as well as more-specialised (specific to one or two sports) movement experiences prior to advanced training. A nuanced balance is needed between *generality* and *specificity* of practice during learning in childhood and youth phases of sport development. These ideas align with those of Anatoly Bondarchuk [33], a sport scientist who proposed a complementary relationship between generality and specificity of training for young athletes on sport development pathways.

This complementarity provides the basis for developing athleticism and foundational movement capacities needed to make the most of specialised training in a single sport at a later phase of development.

Specific aspects of a play or practice environment could include the property of "*inviting potential*" [24], predisposing children to seek and explore certain performance tendencies as functional outcomes. Sport scientists could design soliciting effects in practice which invite individual athletes or teams to perform in a relational way with the affordances of a performance environment, helping them to learn to accept or resist their influence. This approach to practice provides the basis for athlete self-regulation in sport, explaining autonomy and agency at the performer–environment scale of analysis. According to Reed [34] self-regulation is predicated on the idea that "organisms make their way in the world". This is a useful way to consider how children and youth could be encouraged to negotiate the trials and tribulations of competitive performance.

For example, this idea has important implications for the design of athlete development pathways, such as the elite pathway for players in team sports such as rugby union, which comes in to play at under 14 yrs of age. "Talent" selection in rugby union is traditionally undertaken through implementing reductionist tests of anthropometric measurements, technique assessments in isolation and small-sided games, with a child's performance scored through a tick sheet composed by the elite club involved. In the UK, judgements about "talent" are made by the localised coaches working in each Developing Player Programme (DPP). An elite club works with affiliated junior clubs and this does have an impact on the volunteer coaches and how they coach. They observe these procedures as part of the coaching system that they need to affiliate with and aspire to. Although the Rugby Football Union in the UK views rugby as a late specialisation sport, selection is undertaken at age 13 and 14 yrs, which brings significant challenges for the player. This idea also ties in well with key ideas of Bronfenbrenner's model [discussed earlier], since the players go to the DPP once a week, but then play and train with other local club teams and in school, where they are faced with different socio-cultural values and traditions.

1.5. Individual Constraints Can Be Rate Limiters

Sub-systems of an individual's movement system, developing at different rates, can act as rate limiters on performance and functionality in some children at varied states of development. For example, sub-systems for regulating actions requiring dynamic power, agility, flexibility, strength and endurance may vary in development throughout adolescence in some individuals due to different rates of maturation and physical and hormonal changes. These developmental variations may result in performance decrements at critical phases of junior sport programmes [35]. This individual variation has implications for how sport scientists plan, organise and monitor performance in competition and training in youth sport programmes. The level of intra- and inter-individual variations in competition and training may vary more in youth athletes than in adult performers, which needs to be recognised in terms of planning the intensity, duration and the nature of recovery activities.

1.6. What Should Practice Look like in Youth Sport?

A key implication concerns repetition in training and practice. Endless repetition and rehearsal of skills and exercises is not recommended in performance preparation and development of youth athletes, due to potential physical and psychological impacts. Rather, Bernstein's [26] conceptualisation of practice as "*repetition without repetition*" in the search for functional movement solutions implies an emphasis on the *quality* of practice, rather than quantity, as advocated by some other approaches to expertise, such as deliberate practice [36]. Bernstein [26] emphasis on "repetition without repetition" develops dexterity in athletes, essentially allowing an individual to form an adaptive relationship with a performance environment in individual and team sports. This has been termed "skill adaptation", allowing children and youth to move in a dexterous and functional way in sport performance contexts [37]. In acquiring functional dexterity, play has been proposed as particularly important for young organisms of any species, including human children and youth. In children and youth, play is important in development of cognitive, perceptual and motor system functioning [15,16] and is important in early childhood learning experiences in schools for developing *physical literacy* [11,38].

1.7. Physical Literacy and the Athletic Skills Model: Enriching Interactions of Children in Sport Practice

Enrichment in childhood and youth phases of development facilitates skill adaptation as proposed in an ecological dynamics rationale for physical literacy [11]. These ideas, predicated on principles from the ASM, advocate the importance for sport scientists for engaging with first the child, then the mover and finally the athlete. A functional balance between generality and specificity of training and practice can enrich the interactions of an individual's *effectivities* [22] and available affordances in different sport contexts. Sports training environments can be designed to be more soliciting of affordances which are closely related to the effectivities of each individual performer, facilitated by a transdisciplinary approach to performance, learning and development [39]. A transdisciplinary approach to the development of young athletes individualises and contextualises practice and training in sport. As we outline in more detail next, teams of sport scientists could work together in a department of methodology to design individualised development programmes based on the needs of each child/youth. These early sport experiences for children and youth are essential to enrich their relationships with sport performance environments, supporting them to explore and exploit the relations between their effectivities and available affordances. The relevant enrichment of interactions of children and youth athletes starts with the formal education environment at school age where sound habits could be developed as a result of formal experiences in physical education, as well as informal, unstructured play activities with peers and parents in the playground, parks and streets [11]. Interactions in family and peer group settings at the meso-level [29,30] can support the development of child and youth athletes in adopting important habits for an active lifestyle, related to nutrition, play and physical activity, education and study and rest.

1.8. Defining Enrichment of Interactions with the Environment: A Nuanced Balance between Specificity and Generality of Practice

This balanced and more nuanced approach to enrichment and development of children and youth in sport avoids the physical, psychological and emotional pitfalls of early specialisation in childhood and adolescence. The main role of enrichment activities is to support individual–environment interactions. The emphasis should not be on enriching the child/youth or the practice environment universally and separately. Enrichment should be scaled to the specific child/youth–environment *relationship* in sport. This subtle aim can be achieved through carefully designed, developmentally-appropriate practice and training tasks which engage individuals in solving problems, facing challenges and making decisions—all with functional actions as the outcome.

Therefore, a balance between general and specific practice and play activities is important for youth athletes in interacting with performance and practice environments (as advocated in athlete development models such as the ASM). An ecological dynamics rationale links dexterity, functional variability and skill adaptation to the integration of S&C with motor learning. The implication is that individual needs in children and youth can be best understood, planned for and met by coordinated work of sport science specialists working in a collaborative partnership, for example nutritionists, educators, S&C staff, skill acquisition specialists, psychologists, movement scientists, physiotherapists and the like. It has been shown how the work of collaborating specialists can be well organised in a department of methodology [28].

1.9. The Role of a Department of Methodology to Support Integrated Practice

A key implication of an ecological dynamics rationale is that the holistic development of children (e.g., skills work, tactical development, strength and conditioning (S&C) training and cognitive skills such as problem solving and decision making) should be integrated into specially designed games and practice activities by a group of collaborating sport scientists and coaches. Typically, distinct attributes for performance are viewed as isolated components that are developed independently from one another. This type of reductionist thinking can lead to further levels of separation, evident in so-called "skills training", where specific techniques are developed in isolation (e.g., unopposed technique practice of passing, dribbling and heading in soccer). These approaches have tended to operate in a linear and rational way, where hierarchical staff structures limit integration and collaboration between other practitioners in the wider multidisciplinary team. Criticisms have been aimed at this linear and reductionist way of operating, with complexity science being proposed as a theoretical framework to update taken-for-granted methodological principles to guide integrated sport science support [40]

To move away from reductionist and siloed practices, researchers [28,41,42] have conceptualised a transdisciplinary framework for sport scientist and coach integration called a department of methodology (DoM). At the core of a DoM is a view of transdisciplinarity that (re)positions a collective of practitioners as an integrated, inquiry-based unit collaboratively solving development- and performance-based problems [41,42]. This repositioning strengthens the focus on enriching specific *child-environment interactions* in practice and training, by identifying the needs of each child, based on skill level, maturation and development, and the nature of their previous experiences. Through an inquiry-based approach, a holistic perspective encourages a stronger relationship between the inquirer [e.g., sport scientists, coaches and the children themselves] and the inquiry [what the immediate development needs of the child are] [41], so enrichment activities can be designed in full consideration of the multidimensional factors that contribute to a child's learning and development.

Adopting a DoM in this way provides a framework to encourage a vibrant ecosystem that facilitates healthy and valuable knowledge transfer between key personal [including the child]. For example, team members with relevant knowledge and experience of coaching pedagogy, skill acquisition and performance analysis could work together to evolve practice experiences that rejects universal and decontextualised learning tasks. Collaboratively designing learning and development experiences that offer *neutral* practice landscapes rich in opportunities to explore, discover and exploit new action capabilities can more effectively strengthen child–environment interactions [3]. In a similar way, a developmental paediatrician, S&C coach, and technical and tactical coach could collaborate to identify appropriate physical demands, according to maturation levels, when designing small-sided games that stress an individual's full range of skills. In summary, under the guidance of a DoM, applied scientists responsible for the growth of children can develop better interconnections to identify the dynamic properties that can enrich the child-environment system.

The concept of integrating generality and specificity of practice (linked to the ideas of Bernstein and of Bondarchuk), requires a better integration between subdiscipline specialists that can support more effective transitioning along a continuum of specificity and generality of practice, leading to refined interactions opportunities for enrichment. This leads to an important question for sport scientists: what type of practice does an individual child need/want and when? Based on these needs, manipulation of task constraints can support athlete learning and development and performance preparation by scaling performance area dimension, the numbers of athletes involved in practice designs, equipment and technologies used and rules and challenges presented to learners [43]. This analysis provides important information in responding to important questions for sport scientists working with children and youth in team games; for example: when are small-sided and conditioned games needed over full sided games? When might an individual sport athlete/child need to compete up or down an age group? What specific effects may specific small-sided and conditioned games have on children's effectivities (e.g., 2v2, 4v4 and 7v7)?

This integrated approach differs from the conventional approach to performance development of children and youth in sport, which emphasises isolated training and practice of techniques, or physical training separately [18]. Reductionism in development can lead to an exaggerated over-emphasis on generality of practice, with sports-specific skills only being integrated in training later in the development pathway. Indeed, the development of functional movement patterns is necessary to promote physical literacy and create a movement foundation during childhood and youth phases [continuing in later adulthood]. It is often also necessary to utilise generality in practice to stress and overload physiological systems, thereby achieving physical adaptations such as improved strength or speed [33].

However, ecological dynamics proposes that greater specificity in practice tasks may also be introduced *alongside* such general skills training to simultaneously develop all sub-systems underpinning performance. To achieve this aim, fundamental motor skills can be blended into various games and play activities for children. Skill can be refined by varying, dynamic and challenging environments to enable children to use perception, cognition and action to become more capable of solving various movement problems they will encounter in their sport. In a department of methodology, a transdisciplinary approach incorporating better integration between subdiscipline specialists would facilitate more effective movement along the continuum of specificity and generality of practice, leading to better enrichment of interactions. In the following section, we discuss several practical case examples of how child–environment interactions may be enriched in individual- and team-sport skills training integrated with S&C training.

2. Practical Case Examples

2.1. Enrichment in Individual Sports (Diving)

Training environments for diving are based in dry-land contexts and the pool, with many tasks being decomposed into segments to facilitate performance improvement and development [44]. It is assumed that reducing a whole movement into isolated, manageable subcomponents will lead to successful performance of the entire task when parts are re-integrated together in competitive performance [45]. Coaches often devise drills that emphasise repetitive rehearsal of *perfect* movement techniques. This approach to practice is based on the traditional (false) assumption that, once a movement technique is well learned, stable and "programmed internally", it is more resilient to the stresses of a dynamic competitive environment [20]. This traditional approach follows a historical progression in practice design of transitioning tasks from *simpler to more complex*, by deconstructing the complexities of a whole skill into parts. However, the risk is that the coach may disrupt the development of important information–movement couplings, thereby inhibiting skill adaptation [27]. Barris et al. [44] found that different coordination tendencies emerged (e.g., variations in jump height and hurdle-step length) when comparing the preparation phase of the dive in the dry land and pool. These coordination differences observed between the dry-land and pool environments were likely due to the change of task constraints encountered by the diver due to task decomposition. In contrast, a non-linear pedagogical approach advocates *task simplification*. Task simplification is a process of maintaining information–movement couplings and involves making tasks simpler without disrupting the information–movement couplings that regulate behaviour [13].

2.2. Performance Problem Exemplar: Diver Landing/Entering the Water Too Far Away or Too Close from the Board

A diver's aim is to land a safe distance away from the diving board without diving too far into the pool. Diving too close or too far from the board (see Figure 1) will have an impact on their overall scores, facing a 0.5–2-point deduction from the judges [46]. Landing too far out will not only have an impact on their overall score but will change how they interact with the diving board, their rotational speed, the shape quality, the flight and entry phases.

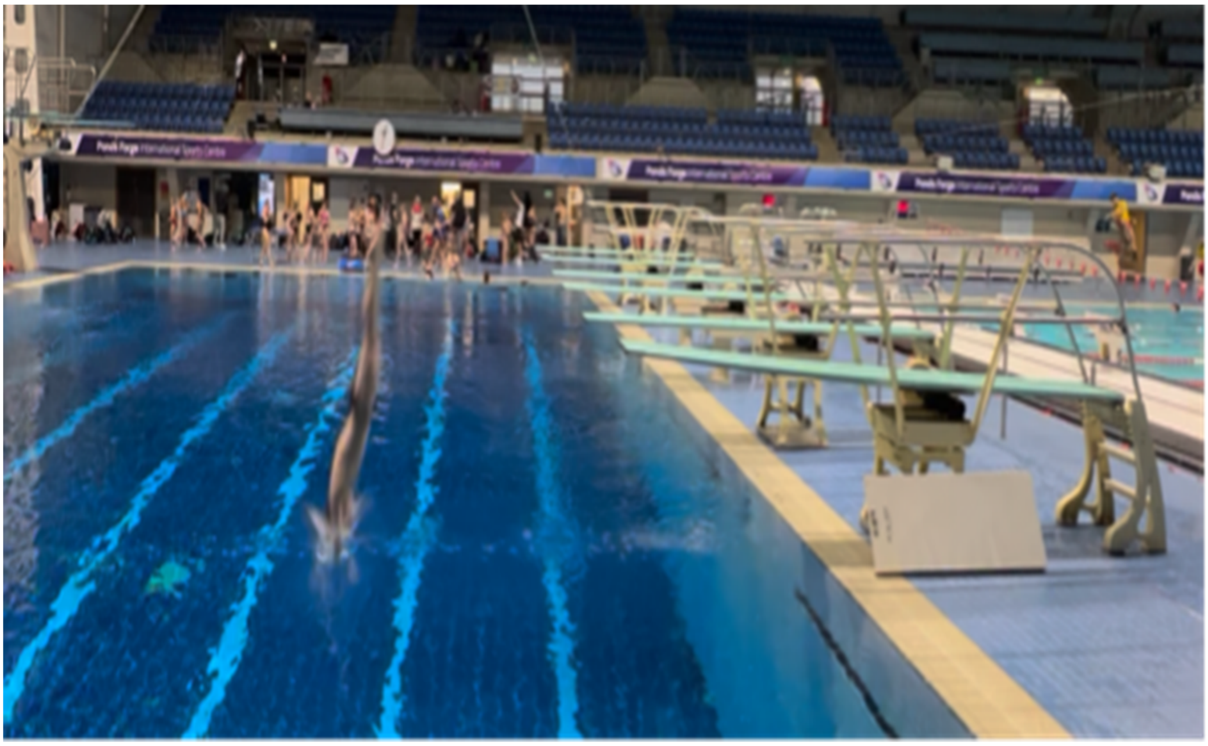

Figure 1. A snapshot of a diver landing too far away from the diving board.

A traditional approach to this performance problem would be to separate all the component parts into subcomponent parts and train them independently in both dry-land and pool training environments before "fitting" them together again in competition [44]. The practice design could include separate training sessions involving: upper body conditioning to help with shape coordination, lower body S&C work to improve the diver's strength, power and balance, gymnastic-type acrobatic and somersault work on a AirTrack or tumble track, dry-diving board and trampoline (landing on foam mats) work on the approach and take-off phase and a mixture of pool skills that include standing and hurdle-step jumps and dives.

In contrast, a transdisciplinary ecological approach to facilitate improved balance on the diving board would seek to use both generality and specificity principles to enrich the interactions of the performer with the environment. Adopting a constraints-led approach, the diver is encouraged to search for and find an individualised solution. By strategically placing an object into the pool to guide intentions and provide a performance goal of "*land on or before the chamois*" [Figure 2], the diver will be encouraged to find a relevant, individualised solution to achieve the performance goal [Figure 3]. This practice task maintains the interconnectedness of the components of the dive and affords the diver the opportunity for greater action regulation. This task design offers rich opportunities for the performer to scale the complexity of the task (the diver can choose to place the object further out or closer in), therefore co-designing the practice environment to meet their individual needs [39].

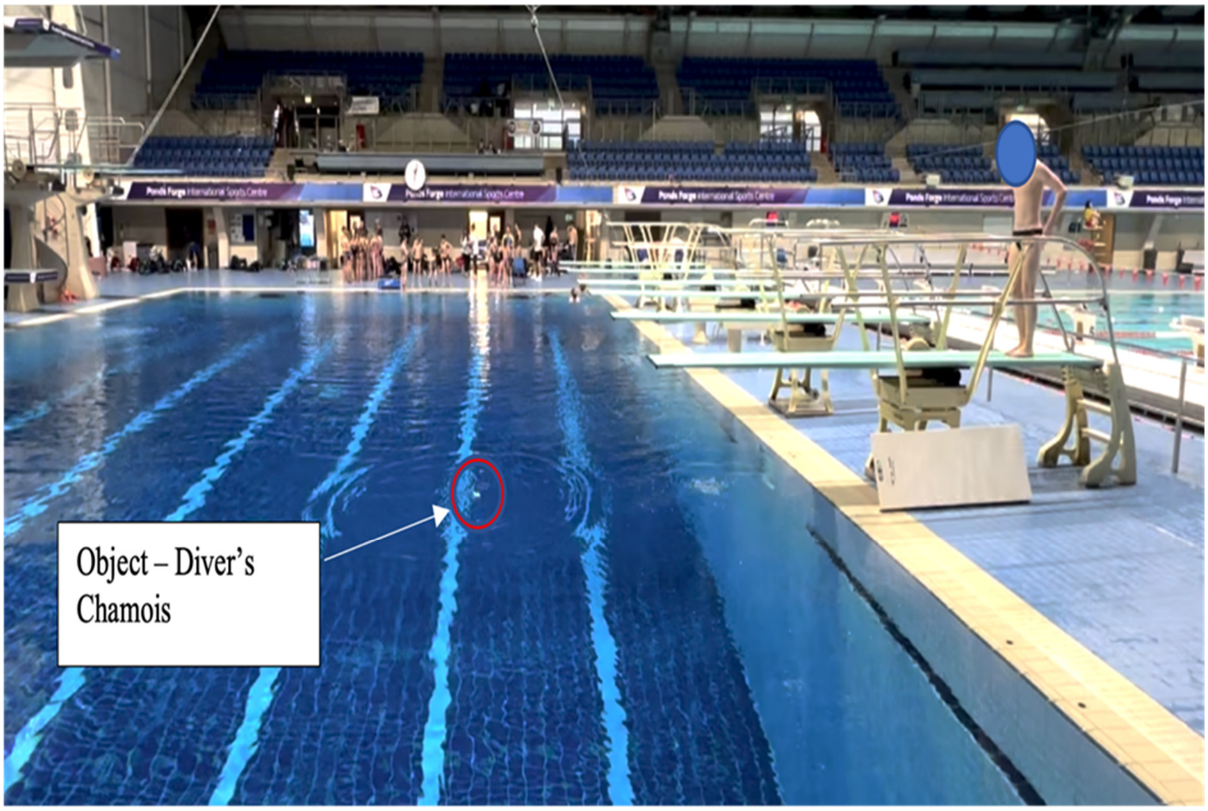

Figure 2. "Land on or before the chamois": an example of a task constraint that could be used in the pool to help regulate where the diver lands. The positioning of the chamois cloth on the water surface specifies the location of the targeted entry position for the diver.

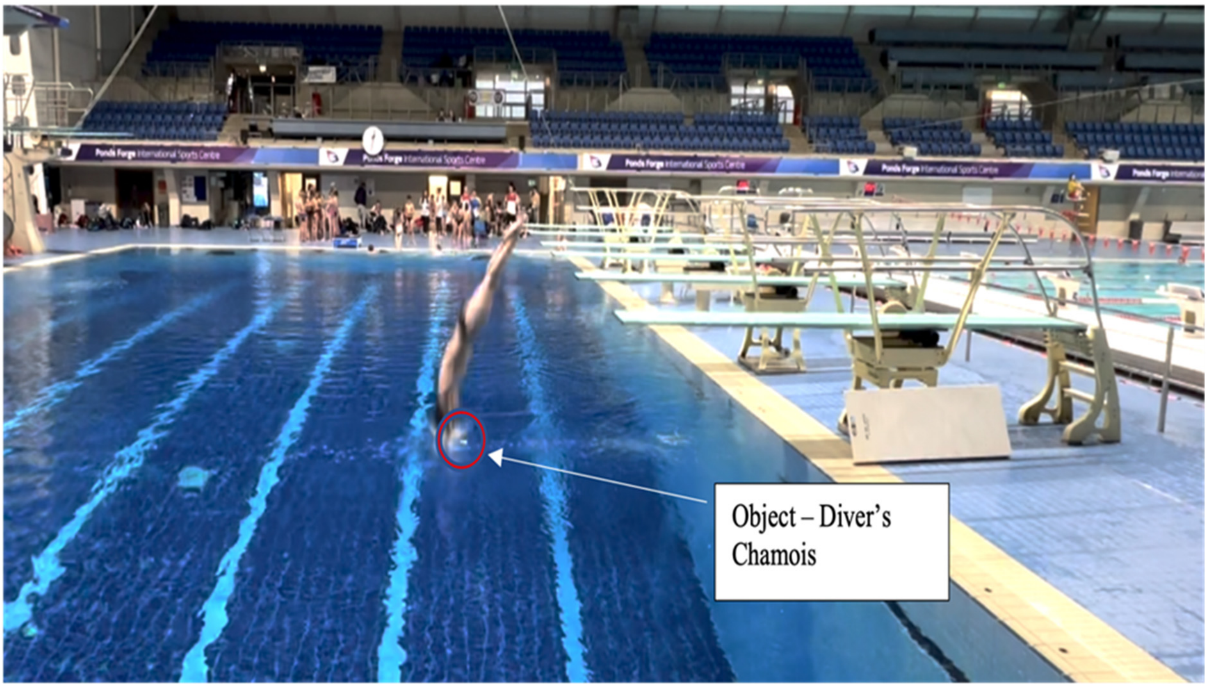

Figure 3. A snapshot of a diver's landing and entry position as a result of the "land on or before the chamois" practice design.

Dry-land equipment such as trampolines can be useful for performers in more general practice tasks. Their performance functionality can be improved by learning how they can regulate their balance, power and height in the preparation phase of the dive. For example, using the rectangles and crash mats at the end of the trampoline affords the diver with minimal space to land in, or they will bounce off the trampoline. This task requires the diver to coordinate the trampoline action in such a way that they do not rotate forward onto the crash mat, potentially hurting themselves (Figure 4). Rather, the task constraints of the trampoline action guide them to regulate their functional capacities of power, balance and rotational speed to successfully navigate the task to land accurately and safely.

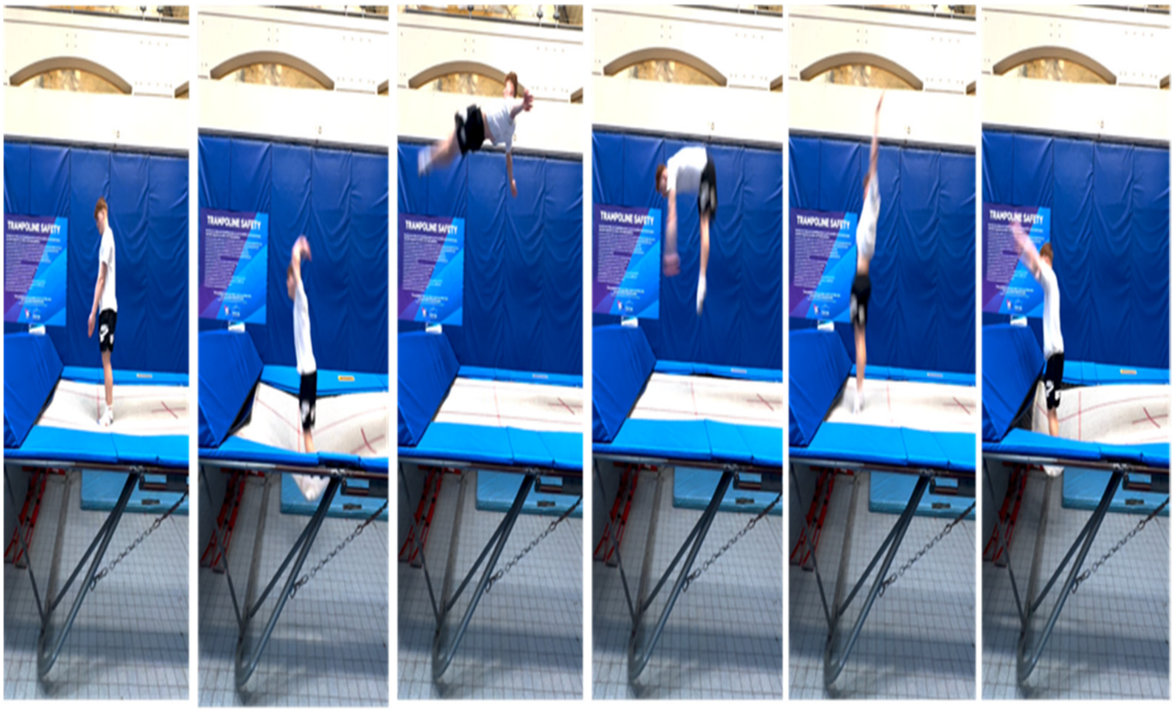

Figure 4. An example of a task constraint used on a trampoline in the dry-land practice area. The specific landing location on the trampoline that the diver is afforded guides them to regulate their functional capacities of power, balance and rotational speed to land accurately and safely.

2.3. Enrichment in Team Sports (Rugby Union)

Age Grade Rugby [AGR] was introduced by the English Rugby Football Union [RFU] in 2016 to facilitate children's (6–18 years) enjoyment in a safe environment, promoting holistic development and lifelong participation. Alongside AGR, the RFU also introduced seven Age Grade Rugby Codes of Practice (CoP) [47] as guidance for coaches in UK youth rugby union [47]. These range from minimum standards for coaches, grouping of players, individuals playing up and down age groups, out of season activities and keys to coaching children, developing the whole player and adopting a player-centred approach to playing and training [47,48]. To support coaches in building an individual-centred approach to develop the whole player, the RFU are using the *STEP Principle* as a coaching framework [49]. Coaches are encouraged to manipulate constraints based on space, task, equipment and people [STEP] within training and games to help structure sessions to promote holistic player development.

This case study outlines how a constraints-led approach can be used to meet the RFU CoP and to develop an individualised, ecological (child-centred) approach using the under 10 yrs (U10) AGR rules to enrich child-environment interactions in team sports. The U10 age grade rules allow for an eight-a-side game on a pitch size of 60 × 35 m. Games are played with a maximum of fifteen minutes per half [47], comprising tackling, a three-person uncontested scrum, and rucks and mauls which one support player from each team can join.

An example of a training game to afford children opportunities for running with the ball and finding space, as well as creating two attackers vs. one defender situations and a defensive team working together with less numbers, is *overload attack*. Under this type of task constraints, children can build physical condition to play rugby union, acquire relevant skills which can be adapted to different task constraints and learn to tactically interact with teammates and opponents in fundamental patterns. To represent the U10 game, this game should be designed on 60 × 35 m pitch with eight attackers against six defenders. If coaches have a bigger squad, they can design two games, one in each half of the pitch. If there is limited space, game design can have two defensive teams and one attacking team who attack a try line at each end against one defending team. Coaches can rotate the attacking team. Other *task constraints* in the game could challenge players to tackle, hold or touch. If there are new players involved, then a two-handed touch on the opponent's waist could simulate a tackle. For any players lacking confidence in tackling at this stage, coaches could encourage a two-handed touch on the opponent's waist to simulate a tackle. This task constraint allows those players to attune to the speed of the game, running lines of both attackers and defenders and also observe, at game speed, in-context tackling by other players, providing social affordances of others [45]. To form a ruck situation, once the ball carrier is held, tackled or touched, they must go to the floor and present the ball to their team. The tackler must also go to the ground if still standing and then get back on their feet. The closest attacking support player has 3 s to bear crawl past the tackler or their team lose possession of the ball. One defender must also bear crawl past the tackled player. These task constraints allow players to build strength and conditioning and encourage the adaptation of body height at the ruck. The next nearest attacker must then pass the ball away from the ruck area. This could be a designated player to include them in the game, or to develop passing. With two attackers and two defenders in each ruck this should leave a six vs. four overload attack. Scrums in the game, as with U10 rules, are uncontested but should involve the three nearest players from both attack and defence to form. Games should involve 5-min intervals and should be started with different scenarios, including: ball from a ruck in a specific area, a scrum in a position on the field, a pass in from the side of the field and rotating players. Using this format, coaches could take into consideration which players are competing with and against whom, which is so important to the dynamics of the game environment. Responsibility may be given to two attack and two defence team captains (to afford self-organisation and co-adaption) which can rotate after each 5-min interval. Those players may feed back their thoughts to the coach, teams and parents. Those captains could be allowed to theme their team, as superheroes, a pack of wolves or characters from films, which the children can decide.

As rugby union is an outdoor sport, environmental constraints are important to consider, for example, changing the direction of play if it is a windy day, or in bright sunshine, to offer different affordances for children. Playing times can be increased or decreased if it is very cold or hot, but play should only be 30 min in total. A key factor in building the learning environment is to involve parents, encouraging the parents for each child to hear and listen to the attack and defensive captains' feedback after each interval in the game. Parents can be solicited to count number of successful, passes, runs and tackles of their child or a team, and the intended outcomes of the training can be explained to parents to promote understanding and encourage positivity. This type of ecological design should promote innovative and adaptive tactical behaviours within the practice environment and meet the RFU CoP requirements [11].

2.4. Generally Enriching S&C Designs for Sport Performance in Children and Youth

The primary goal of the S&C specialist in working with young athletes is to obtain changes in movement and physical capacities [22] that facilitate enhanced sports performance and injury prevention. In a typical "coach-centred" approach, this is attempted through explicit instruction that strives to align the young athlete's technique with that which is considered "optimal" by the coach [50]. In contrast, an "individual-centred" approach involves less explicit instruction, having a reduced focus on a child executing each movement repetition in compliance with a putative "optimal" technique. An individual-centred approach provides opportunities for children to enhance their movement functionality by engaging in conditioning games, play activities and practice designs to explore diverse, relevant solutions to a movement problem [13].

Conditioning activities provide many opportunities to enrich youth-environment interactions. A broad range of physical attributes, such as speed, changing direction, agility and aerobic capacity may be simultaneously targeted and developed through participation in appropriately designed games to express movement skills [10]. A nuanced balance between generality and specificity of practice in children can also be used with adult athletes, who possess a higher training status and may require more specialised stimuli [i.e., focused sprinting activities] to continue to improve distinct physical qualities [51]. For example, with youth athletes, relay races involving actions with a ball, teammates and opponents and using playing area line markings, may be implemented to target acceleration, deceleration and change of direction or agility abilities, whilst handling the ball under pressure of competition, thereby maximising motivation, concentration and effort [10]. Similarly, small-sided games may be strategically designed to encourage athletes to cover greater distances (e.g., adapting their interactions with larger playing area dimensions, smaller player numbers, unequal sides, adding sudden opposition over-loads and teammate under-loads) providing more of a speed endurance stimulus [52]. The use of such interactive and dynamic games also provides an opportunity to integrate different aspects of performance development consistent with a transdisciplinary approach [i.e., psychological skills training, tactical adaptations, problem solving and decision making]. As an example, ensuring that children encounter feelings of uncertainty and lack of familiarity at different times in practice may provide them with opportunities to assert their ideas and express their autonomy, enhancing their communication and interaction skills. To illustrate, targeting specific instructions to individuals or sub-groups [e.g., attackers or defenders] not universally to all, could require children to work out what the opposition tactics are. Alternatively, deliberately providing unfair refereeing decisions may be embedded into skill games, without participant awareness, to promote the development of emotional self-regulation and coping skills [53].

Even in resistance-training activities (which involve less room for movement variability) information from external task constraints can be introduced to guide the learner towards effective and desirable movement solutions. For example, during squatting, jumping and landing movement patterns, resistance bands can be placed around the knees to encourage young athletes to perceive information from activating muscles necessary to overcome knee valgus. Similarly, during certain closed-chain kinetic exercises (i.e., push ups, inverted rows, etc.), promoting hip and trunk stiffness may help children maximise stability. This can be encouraged by placing a foam roller between the legs of the learner, who must contract the relevant hip and trunk musculature to keep the foam roller in position. As a final example, external objects (e.g., walls, agility poles, etc.) can be used to constrain dynamical movements and encourage the most biomechanically efficient and safe movement pattern for each young learner. By placing agility poles in front of a youth performing a power clean, the performer inherently learns to adopt a linear barbell path that remains close to the body [50]. Here, it is worth noting the similarities of using these external task constraints with the placement of the chamois in the case of helping divers to enhance spatial perception of diving into a specific pool location.

3. Conclusions

In this insights paper we have discussed why children and youth should not be treated as mini-adults by sport scientists in learning and development and preparation for performance. The expertise of professional specialists working in a department of methodology is important for design enrichment opportunities for children and youth in team games and individual sports. Our critical analysis showed that future research is needed for identifying in detail the needs and specific characteristics of specific sub-groups in sport, such as children and youth, women, and disabled athletes, at all levels, from recreation to high performance. Applied scientific research in various sport science sub-disciplines from the social and cultural sciences, bio-physical and pedagogical sciences, is needed to further identify and examine the needs of children and youth so that their performance trajectory and lived experiences in sport may promote enriched learning and training opportunities throughout that important part of the life course. The case examples showcased several types of designs which could fulfil this aim for children and youth in sport, framed by the contemporary ecological idea of enriching their interactions with performance and practice environments. These practice and training designs should facilitate a large amount of variability [54] providing many opportunities for play and games which facilitate implicit learning through interactions of children with sports environments. These practice designs for children and youth should emphasise a rich range of activities which integrate opportunities for skill adaptation, S&C and tactical and strategical behaviours. This important aim could be achieved by sport scientists collaborating together in a DoM to design affordances which invite functional actions for youth and children to adapt skills, perceive information to regulate actions, make decisions and solve problems, all while performing more or less dynamic movements at speed, showing endurance and using strength, flexibility and agility. Further research could be undertaken to show how professional practice, considered in this ecological way, could help collaborating sport scientists, trainers and coaches to *contextualise* learning designs and *individualise* the performance and development process in sports, based on the needs of individual children.

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References

1. Beales, R. In Search of the Historical Child: Miniature Adulthood and Youth in Colonial New England. *Am. Q.* **1975**, *27*, 379–398. [CrossRef]
2. Rothwell, M.; Davids, K.; Stone, J. Exploring forms of life in player development pathways-the case of British rugby league. *J. Mot. Learn. Dev.* **2019**, *7*, 242–260. [CrossRef]
3. Rothwell, M.; Rudd, J.; Davids, K. Integrating specificity and generality of practice to enrich children's learning in sport. In *Routledge Handbook of Coaching*; Toms, M., Jeane, R., Eds.; Routledge: London, UK, 2022; pp. 284–292.
4. Bailey, R.; Agans, J.P.; Côté, J.; Daly-Smith, A.; Tomporowski, P.D. (Eds.) *Physical Activity and Sport during the First Ten Years of Life: Multidisciplinary Perspectives*; Routledge: London, UK, 2021.
5. Faigenbaum, A.D.; Kraemer, W.J.; Blimkie, C.J.; Jeffreys, I.; Micheli, L.J.; Nitka, M.; Rowland, T.W. Youth resistance training: Updated position statement paper from the National Strength and Conditioning Association. *J. Strength Cond. Res.* **2009**, *23*, S60–S79. [CrossRef] [PubMed]
6. Plowman, S.A. Children Aren't Miniature Adults: Similarities and Differences in Physiological Responses to Exercise: Part 2. *ACSM's Health Fit. J.* **2001**, *5*, 13–18. Available online: https://journals.lww.com/acsm-healthfitness/citation/2001/05060/children_aren_t_miniature_adults__similarities_and.6.aspx (accessed on 1 October 2022).
7. Balyi, I.; Hamilton, A. *Long-Term Athlete Development: Trainability in Childhood and Adolescence—Windows of Opportunity—Optimal Trainability*; National Coaching Institute British Columbia & Advanced Training and Performance Ltd.: Victoria, BC, Canada, 2004.
8. Howard, R.; Eisenmann, J.C.; Moreno, A. Summary: The national strength and conditioning association position statement on long-term athletic development. *Strength Cond. J.* **2019**, *41*, 124–126. Available online: https://journals.lww.com/nsca-scj/FullText/2019/04000/Summary__The_National_Strength_and_Conditioning.15.aspx (accessed on 17 February 2021). [CrossRef]
9. Lloyd, R.S.; Oliver, J.L.; Meyers, R.W.; Moody, J.A.; Stone, M.H. Long-term athletic development and its application to youth weightlifting. *Strength Cond. J.* **2012**, *34*, 55–66. Available online: https://journals.lww.com/nsca-scj/Fulltext/2012/08000/Long_Term_Athletic_Development_and_Its_Application.10.aspx (accessed on 17 February 2021). [CrossRef]
10. Lloyd, R.S.; Oliver, J.L. (Eds.) *Strength and Conditioning for Young Athletes: Science and Application*; Routledge: London, UK, 2019.

11. Rudd, J.R.; Pesce, C.; Strafford, B.W.; Davids, K. Physical literacy—A journey of individual enrichment: An ecological dynamics rationale for enhancing performance and physical activity in all. *Front. Psychol.* **2020**, *11*, 1904. [CrossRef]
12. Araújo, D.; Davids, K.; Hristovski, R. The ecological dynamics of decision making in sport. *Psychol. Sport Exerc.* **2006**, *7*, 653–676. [CrossRef]
13. Button, C.; Seifert, L.; Chow, J.-Y.; Araújo, D.; Davids, K. *Dynamics of Skill Acquisition: An Ecological Dynamics Rationale*, 2nd ed.; Human Kinetics: Champaign, IL, USA, 2020.
14. Correia, V.; Araújo, D.; Duarte, R.; Travassos, B.; Passos, P.; Davids, K. Changes in practice task constraints shape decision-making behaviours of team games players. *J. Sci. Med. Sport* **2012**, *15*, 244–249. [CrossRef]
15. Thelen, E.; Smith, L.B. *A Dynamic Systems Approach to the Development of Cognition and Action*; MIT Press: Cambridge, MA, USA, 1994.
16. Smith, L.B.; Thelen, E. Development as a dynamic system. *Trends Cogn. Sci.* **2003**, *7*, 343–348. [CrossRef]
17. Phillips, E.; Davids, K.; Renshaw, I.; Portus, M. Expert Performance in Sport and the Dynamics of Talent Development. *Sport. Med.* **2010**, *40*, 271–283. [CrossRef] [PubMed]
18. Ribeiro, J.; Davids, K.; Silva, P.; Coutinho, P.; Garganta, J. Talent development in sport requires athlete enrichment: Contemporary insights from a Nonlinear Pedagogy and the Athletic Skills Model. *Sport. Med.* **2021**, *51*, 1115–1122. [CrossRef] [PubMed]
19. Newell, K.M. Constraints on the development of coordination. In *Motor Development in Children: Aspects of Coordination and Control*; Wade, M.G., Whiting, H.T.A., Eds.; Martinus Nijhoff: Dordrecht, The Netherlands, 1986; pp. 341–360.
20. Renshaw, I.; Davids, K.; O'Sullivan, M. Learning and performing: What can theory offer high performance sports practitioners? *Braz. J. Mot. Behav.* **2022**, *16*, 162–178. [CrossRef]
21. McCosker, C.; Otte, F.; Rothwell, M.; Davids, K. Principles for technology use in athlete support across the skill level continuum. *Int. J. Sport. Sci. Coach.* **2021**, *17*, 437–444. [CrossRef]
22. Gibson, J.J. *The Ecological Approach to Visual Perception*; Houghton Mifflin: Boston, MA, USA, 1979.
23. Otte, F.W.; Davids, K.; Millar, S.-K.; Klatt, S. Understanding how athletes learn: Integrating skill training concepts, theory and practice from an ecological perspective. *Appl. Coach. Res. J.* **2021**, *7*, 22–32. Available online: https://www.ukcoaching.org/resources/topics/research/applied-coaching-research-journal (accessed on 1 March 2023).
24. Withagen, R.; de Poel, H.J.; Araújo, D.; Pepping, G.P. Affordances can invite behaviour: Reconsidering the relationship between affordances and agency. *New Ideas Psychol.* **2012**, *30*, 250–258. [CrossRef]
25. Jacobs, D.; Michaels, C. Calibration and perceptual learning in event perception. *Percept. Psychophys.* **2001**, *63*, 572–574. [CrossRef]
26. Bernstein, N.A. *The Co-Ordination and Regulation of Movements*; Pergamon Press: Oxford, UK, 1967.
27. Correia, V.; Carvalho, J.; Araújo, D.; Pereira, E.; Davids, K. Principles of nonlinear pedagogy in sport practice. *Phys. Educ. Sport Pedagog.* **2019**, *24*, 117–132. [CrossRef]
28. Otte, F.; Rothwell, M.; Davids, K. Big picture transdisciplinary practice—extending key ideas of a Department of Methodology towards a wider ecological view of practitioner-scientist integration. *Sport. Coach. Rev.* **2022**, 1–24. [CrossRef]
29. Bronfenbrenner, U. *The Ecology of Human Development: Experiments by Nature and Design*; Harvard University Press: Cambridge, MA, USA, 1979.
30. Bronfenbrenner, U.; Morris, P.A. The bioecological model of human development. In *Handbook of Child Psychology: Volume 1, Theoretical Models of Human Development*, 6th ed.; Damon, W., Lerner, R.M., Eds.; John Wiley: New York, NY, USA, 2006; pp. 793–828.
31. Rosa, E.M.; Tudge, J.R.H. Urie Bronfenbrenner's theory of human development: Its evolution from ecology to bioecology. *J. Fam. Theory Rev.* **2013**, *5*, 243–258. [CrossRef]
32. The Whyte Review. An Independent Investigation Commissioned by Sport England and UK Sport following Allegations of Mistreatment within the Sport of Gymnastics. Sport England and UK Sport. 2022. Available online: https://www.sportengland.org/guidance-and-support/safeguarding/whyte-review (accessed on 12 January 2023).
33. Bondarchuk, A. *Transfer of Training in Sports;* Ultimate Athlete Concepts: Muskegon, MI, USA, 2007.
34. Reed, E.S. *Encountering the World: Towards an Ecological Psychology*; Oxford University Press: Oxford, UK, 1996.
35. Wormhoudt, R.; Teunissen, J.W.; Savelsbergh, G.; Davids, K. *The Athletic Skills Model for Talent Development—No Specialists, but Athletes with a Specialization*; Routledge | Taylor & Francis: New York, NY, USA, 2018.
36. Ericsson, K.A.; Krampe, R.; Tesch-Romër, C. The role of deliberate practice in the acquisition of expert performance. *Psychol. Rev.* **1993**, *100*, 363–406. [CrossRef]
37. Araújo, D.; Davids, K. What exactly is *acquired* during skill acquisition? *J. Conscious. Stud.* **2011**, *18*, 7–23.
38. Chow, J.Y.; Davids, K.; Button, C.; Renshaw, I. *Nonlinear Pedagogy in Skill Acquisition*; Routledge: London, UK, 2022.
39. Woods, C.T.; Rothwell, M.; Rudd, J.; Robertson, S.; Davids, K. Representative co-design: Utilising a source of experiential knowledge for athlete development and performance preparation. *Psychol. Sport Exerc.* **2021**, *52*, 101804. [CrossRef]
40. Pol, R.; Balagué, N.; Ric, A.; Torrents, C.; Kiely, J.; Hristovski, R. Training or synergizing? Complex systems principles change the understanding of sport processes. *Sport. Med.-Open* **2020**, *6*, 28–41. [CrossRef]
41. Woods, C.; Rudd, J.; Araújo, D.; Vaughan, J.; Davids, K. Weaving lines of inquiry: Promoting transdisciplinarity as a distinctive way of undertaking sport science research. *Sport. Med.-Open* **2021**, *7*, 55. [CrossRef]
42. Rothwell, M.; Davids, K.; Stone, J.; O'Sullivan, M.; Vaughan, J.; Newcombe, D.; Shuttleworth, R. A Department of Methodology Can Coordinate Transdisciplinary Sport Science Support. *J. Expert.* **2020**, *3*, 55–65.

43. Davids, K.; Araújo, D.; Correia, V.; Vilar, L. How small-sided and conditioned games enhance acquisition of movement and decision making skills. *Exerc. Sport Sci. Rev.* **2013**, *41*, 154–161. [CrossRef]
44. Barris, S.; Davids, K.; Farrow, D. Representative learning design in springboard diving: Is dry-land training representative of a pool dive? *Eur. J. Sport Sci.* **2013**, *13*, 638–645. [CrossRef]
45. Renshaw, I.; Chow, J. A constraint-led approach to sport and physical education pedagogy. *Phys. Educ. Sport Pedagog.* **2019**, *24*, 103–116. [CrossRef]
46. Fina. Fina Diving Rules 2022–2025. 2023. Available online: https://resources.fina.org/fina/document/2022/11/30/3f3df9e6c41a4853-b62e-6d57ff750150/1_Diving-Technical-Rules.03.12.2022_clean.pdf (accessed on 11 January 2023).
47. Rugby Football Union. Age Grade Rugby, Codes of Practice. 2022. Available online: https://www.englandrugby.com//dxdam/fa/fa24cdeb-274f-4f94-a5af-26c1227ce068/Age-Grade-Rugby-Codes-of-Practice.pdf (accessed on 11 January 2023).
48. Côté, J.; Vierimaa, M. The developmental model of sport participation: 15 years after its first conceptualization. *Sci. Sport.* **2014**, *29*, S63–S69. [CrossRef]
49. Kiuppis, F. Inclusion in sport: Disability and participation. *Sport Soc.* **2018**, *21*, 4–21. [CrossRef]
50. Verhoeff, W.J.; Millar, S.K.; Oldham, A.R.; Cronin, J. Coaching the power clean: A constraints-led approach. *Strength Cond. J.* **2020**, *42*, 16–25. [CrossRef]
51. Haugen, T.; Seiler, S.; Sandbakk, Ø.; Tønnessen, E. The training and development of elite sprint performance: An integration of scientific and best practice literature. *Sport. Med.-Open* **2019**, *5*, 44. [CrossRef] [PubMed]
52. Köklü, Y.; Asçi, A.; Koçak, F.Ü.; Alemdaroglu, U.; Dündar, U. Comparison of the physiological responses to different small-sided games in elite young soccer players. *J. Strength Cond. Res.* **2011**, *25*, 1522–1528. [CrossRef]
53. Tee, J.C.; Ashford, M.; Piggott, D. A tactical periodization approach for rugby union. *Strength Cond. J.* **2018**, *40*, 1–13. [CrossRef]
54. Davids, K.; Glazier, P.; Araújo, D.; Bartlett, R.M. Movement systems as dynamical systems: The role of functional variability and its implications for sports medicine. *Sport. Med.* **2003**, *33*, 245–260. [CrossRef]

children

Article

Influence of Rule Manipulation on Technical–Tactical Actions in Young Basketball Players: A Scoping Review

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Abstract: The purpose of this scoping review was to analyse the effect of rules modification on technical and tactical action in young basketball. The publications search period ranged from January 2007 to December 2021. The search covered the following electronic databases: SCOPUS, SportDiscus, and the Web of Science core collection. Following this search process, 18 articles were included in the review. The following variables were analysed: characteristics of the sample, the constraints manipulated, the duration of the intervention, and the effect on technical–tactical actions. The studies reviewed modified the following constraints: (a) number of players (66.7%), (b) court dimensions (27.8%), (c) ball/player interactions (11.1%), and (d) ball/player interactions, basket height, game time and number of baskets (5.6%, respectively). The findings show that rule manipulation can increase players' participation and promote the variability of players' actions. The current evidence about rule modification in youth basketball presents areas in which more studies are needed to have a complete perspective of their impact in practice and competition through the different stages of players' development. Taking into account individual needs and developmental stages, further studies should consider different age groups (e.g., from U-10 to zU-14) and female players. Expanding scientific knowledge in this area would help coaches make short- and long-term plans in accordance with players' developmental stages.

Keywords: sport; children; training; competition; scaling equipment

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1. Introduction

Sports rules establish how the game is played. It is common for coaches and federations to realize adaptations of the official rules to get different goals, such as facilitating learning, promoting different actions, scaling the game to children, or developing specifical physical capacities (e.g., the inclusion of the three-point line in basketball). However, although these adaptations are common, most of the research done about these adaptations has been done in adult sports [1–5]. There is reduced evidence of the impact of rule manipulations on children and the developmental stages of the players. This involves the absence of strong evidence about the impact of manipulating the task and the practice environment constraints in youth sports. The present review attempted to provide information about the current state of rule modification in basketball and provide recommendations about possible research lines to follow.

Sports rules establish the task and environment constraints (e.g., the number of players or court size). A manipulation of constraints that establish the official rules has the goal of creating more optimal learning landscapes and enhancing players' teaching-learning processes [6–12]. Rule manipulation is done by coaches and sports stakeholders to adapt practice and competition to players' characteristics. This manipulation can help to facilitate the holistic development of players in competition and training [13–18]. For example, the use of small-sided games in which there is a manipulation of the court size, and the number of players is common in practice. This approach is an effective strategy for training technical and tactical skills in different ages and skill levels [19–22]. These manipulations affect the participation and actions of players and teams (e.g., increase of the 1 vs. 1 situations). With their use, coaches are promoting the realization of different actions and behaviours by players in training. However, the impact depends on the type of modification, the age of players, and their skills (among others).

Most of the current research is focused on adults and the study of the impact of rule manipulation on physical actions (e.g., external workload). There is less evidence on the impact of common manipulations of the task and environment constraints implemented by coaches and other stakeholders, such as the number of players, court size, basket height, dribbling rules, or type of defence. These limitations show that is not clear how the rule changes in practice and competition affect technical and tactical actions, their efficacy, and the decision-making of basketball players of different ages and levels [4,15,23–30]. Besides, each study shows the effect of different rule manipulations on players of specific ages and levels. It is necessary to have a broad perspective of the effect of these rule modifications in practice and competition through the different stages of player development to provide evidence-based information that can be referred to in the process of their implementation. This information can also help sports scientists to establish future research according to the deficits found in the literature. The purpose of this scoping review was to analyse the effect of rule modification on technical and tactical action in young basketball players.

2. Materials and Methods

This scoping review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement [31,32].

2.1. Search Strategy

The search conducted for this study covered the following electronic databases: SCOPUS, SportDiscus, and the Web of Science core collection (e.g., the Social Citation Index Expanded, the Social Sciences Citation Index, and the Emerging Sources Citation Index). The following keyword combinations were used: TS = (BASKET*) AND TS = "Small-sided games" OR "large-sided games" OR "large-sided games" OR "Short small-sided games" OR "small-sided basketball games" OR "small-sided and conditioned games" OR "Equipment scaling" OR "Scaling sporting equipment" OR "Scaling basketball equipment" OR "Scaling constraints" OR "modified basketball games" OR "Modifying equipment" OR "Modified games" OR "Changing rules" OR " Reducing pitch size".

2.2. Article Screening and Data Extract Process

The publication search period ranged from January 2007 to December 2021. In total, 111 papers were identified in the original database search. Two independent reviewers selected the abstracts and full texts of the studies that met the inclusion criteria. With regards to papers where there was doubt on whether they met the inclusion criteria, a third expert reviewer made the decision instead. Reliability was calculated in the registry using Cohen's Kappa coefficient, whereby minimum values of 0.99 were obtained. With regards to the selection and extraction studies process, the following hierarchical order was utilized: excluded by title; excluded by abstract; and excluded by full text that did not meet the eligibility criteria. Figure 1 details the data extraction process.

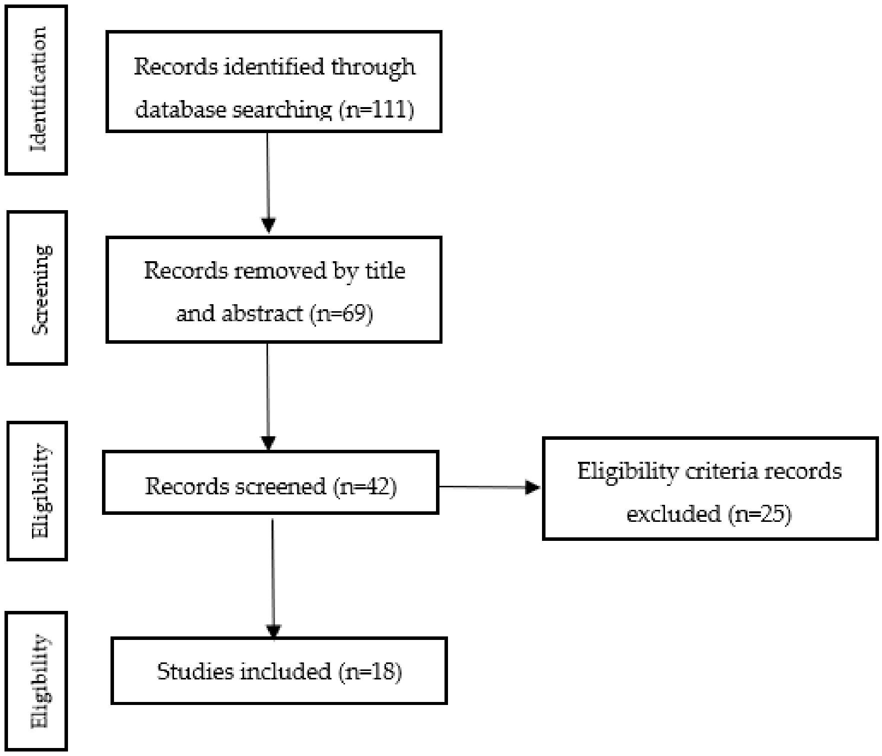

Figure 1. The PRISMA flowchart illustrating each stage of the literature search.

2.3. Eligibility Criteria

The following eligibility criteria were used, where the papers included: (a) small-sided games in basketball; (b) modified and changing rules; and (c) was written in English, Portuguese, or Spanish. The exclusion criteria utilized were studies that included: (a) other sports as the subject of study; (b) wheelchair basketball; (c) adult players; (d) did not analyse technical–tactical variables; (e) congress papers; (f) systematic reviews; (g) nonexperimental studies; and (h) a sample of coaches and/or teachers.

2.4. Variables Analysed

The following variables for each paper were analysed: (a) publication year; (b) sex (women, men, and both sexes participated); (c) age of the sample (under 10, under 12, under 14, under 16, and under 18); (d) duration of the study (short-term: less than four weeks, medium-term: between 1 and 4 months, and long-term: more than 4 months); (e) constraints modification (basket height, court dimensions, game time, number of baskets, number of players, ball/player interactions), (f) technical–tactical variables studied (dribbles, passes, shots, rebounds, ball screens, decision-making, steals, turnovers, offensive possessions, fakes, assists, fast breaks, and defensive actions), and (g) effect of constraint manipulation on the technical and tactical variables.

3. Results

3.1. Studies Characteristics

Only a total of 18 articles matched the inclusion criteria. Most of the studies were done in the last years of the period analysed (61.1% in the last four years) and most were done by researchers from Portugal, Brazil, and Italy. Most of the studies included older categories (72.2% for U-16 and U-18). Twenty-two per cent of the studies included female players, 53% male players, and 25% involved players of both sexes. Regarding the duration of the study, no studies were found with an intervention duration of longer than four months. Fifty-six per cent had a short duration (less than four weeks) and 44% had a duration between one month and four months.

The studies reviewed modified the following constraints: (a) number of players (66.7%), (b) court dimensions (27.8%), (c) ball/player interactions (11.1%), and (d) ball player interactions, basket height, game time and number of baskets (5.6%, respectively). These studies analysed the effect of manipulating these constraints on 15 technical–tactical variables. Three were used in more than 50% of the studies, which were: pass and shot (58.8%) and rebound (52.3%). Another group of variables was used in more than 20% of the studies, which were: dribble and offensive possessions (35.3%), turnovers (29.4%), and steals (23.5%). The least studied variables with a presence of less than 20% in the studies were: defensive actions (17.6%), assists (11.8%), as well as ball screens, decision-making, fakes, and fast-break (5.8%). Specific information on the results (authors, sample, independent variables, dependent variables, and the effect of the intervention for each study) can be found in Appendix A (Table A1).

3.2. Constraints Modification: Number of Players

Four studies analysed the differences between playing 3 vs. 3 and 5 vs. 5 [33–36]. The games with fewer players showed more situations with potential for learning and improving decision-making and motor skills, due to the higher number of 2-point shots, possessions, and passes. Two studies compared the difference between playing 2 vs. 2 and 4 vs. 4 [21,37]. The 2 vs. 2 situation showed a higher number of ball screens, dribbles, passes, rebounds, and shots. In addition, in the study done with younger players, there were a higher number of dribbles, rebounds, passes, and shots [21]. A similar study compared the 3 vs. 3, 4 vs. 4, and 5 vs. 5 situations [22]. They found a higher number of assists, passes, rebounds, steals, shots, and turnovers in 3 vs. 3 games than in the 4 vs. 4 and 5 vs. 5 games.

Two studies compared the different options of player number manipulation: 1 vs. 1, 2 vs. 2, 3 vs. 3, 4 vs. 4, and 5 vs. 5. These studies also manipulated the court dimensions in each situation [38,39]. In male players and female players [38,39] situations with fewer players (and court size) had higher numbers of technical–tactical actions per player per minute. However, both studies found that each situation involved an increase of different actions (e.g., a higher number of rebounds on 2 vs. 2, a higher number of shots on 4 vs. 4, or a higher number of turnovers on 1 vs. 1).

One study focused on the analysis of how players improved playing 2 vs. 2 after six weeks of training [40]. The results showed a higher number of shots and more passing efficacy at the end than on the first day of the intervention. Two studies focused on the effect of having more players on one team [23,41]. One study compared the situations 3 vs. 2, 3 vs. 3, and 3 vs. 2+1 [41]. Its results showed that playing 3 vs. 2 involved more effective dribbles and rebounds when compared with 3 vs. 3 and 3 vs. 2+1. Another study analysed the differences between the situations 3 vs. 3, 4 vs. 3, and 3 vs. 3+1 (non-scorer floater) [23]. Its results showed a higher number of dribbles, passes, fast-breaks, offence possessions, and space creations without the ball, compared to the 4 vs. 3 and 3 vs. 3+1 situations.

3.3. Constraints Modification: Court Dimensions

Five studies modified the court dimensions [37,38,42–44]. In four of these, researchers compared the difference between playing in half and full courts [37,42–44]. In the other study, researchers manipulated the court dimensions simultaneously with the number of players per team (15 × 6 m, 22 × 8 m, 24 × 11 m, 26.13 m, and 28.15 m) [38]. These studies showed an increase in the number of actions of dribble, pass, rebound, shot, and turnover, and an increase in the number of fakes.

3.4. Constraints Modification: Ball/Player Interactions, Basket Height, Game Time and Number of Baskets

Regarding the manipulation of the basket, two studies focused on this aspect. One study focused on the effect of basket height and the other study on the number of available baskets. The study that focused on basket height assessed the differences between playing 5 vs. 5 with a basket of a height of 3.05 m and a height of 2.80 m [45]. The study showed that with a lower basket height, there were a higher number of fast breaks and longer positional attack phases. The researchers found an increase in the number of defensive and offensive rebounds, dribbles, and shots in the four baskets games. However, there was a decrease in the number of passes, number of steals, and number of possessions in the four baskets games.

One study focused on the effect of game time (4 × 2.5 min and 2 × 5 min) on individual and team offence and defence actions [37]. The study found that playing for shorter periods increased the realization of dribbles, passes, shots, rebounds, and ball screens. Regarding the manipulation of the interaction of the players with other players and the interaction with the ball, two studies were found. One focused on defensive pressure [46]. This study found that changing the type of defence pressure during the game promoted different collective offence behaviours, which affected the creative and perception actions done by players. The second study assessed the difference between playing with dribbling and without dribbling [22]. In this study, the results showed an increase in the number of assists, passes, rebounds, steals, and turnovers in the no-dribbling games, and a decrease in the number of shots in no-dribbling games.

4. Discussion

4.1. Studies Characteristics

The low number of studies found with younger athletes demonstrates the need for increasing our knowledge about the effect of rule manipulation in the foundational stages of basketball players' development. Most of the studies in the review used a sample of under-16 and under-18 players. There is a paucity of studies at the under-10, under-12, and under-14 levels. Similar issues occur with the study of rule modification in young female basketball players. We should obtain information on all the different stages of the developmental process to guide the training and competition decisions (e.g., what rules we can change to promote players' learning). The analysis of this sample of studies showed important differences in the ways that different researchers report the characteristics of the players. It is recommended that standard criteria regarding their maturation, skills, level of competition, and hours of practice are included in future studies to allow other researchers to contextualize the studies. An adaptation to youth athletes as proposed by Alannah et al. could be a starting point [47]. We know that practice and competition at young levels should be in line with the evolutionary process of each player at each stage of development [2,35,48]. However, it is not possible to achieve this if we do not have information on the maturational development, skills, experiences, etc. of the players [49–51]. Regarding the duration of the studies, there is a paucity of longitudinal studies. This limits our knowledge about the effectiveness of the changes in the long term. If it is not possible to implement longitudinal studies, another possibility is to study the effect of the changes in different age groups, sexes, or skill levels at the transversal level.

4.2. Constraints modification: Number of Players

A reduction in the number of players involves an increase in the actions done by players [21,33–37]. These results can be considered normal; fewer players per team involves more ball contact by players (dribble, rounds, passes, and shots). If the practice infrastructure allows it (e.g., multiple baskets available), this manipulation can increase the players' participation in offence and defence. However, if several baskets are not available, this approach may involve not all players participating. The manipulation of player numbers can be done simultaneously with the court size reduction. Unfortunately, this aspect has been studied in only two studies [38,39]. They found that 1 vs. 1 and 2 vs. 2 situations increased turnovers and rebounds. The reduction of players and space could cause players to assume more risk in their actions to solve the game situations. This issue was not found for the 3 vs. 3 situations. In summary, our current evidence shows that the manipulation of the number of players can involve an increase in player participation in training and competition.

Another possibility evaluated in several studies was the effect of having different numbers of players in a team or having a non-scorer floater player [23,41]. This type of manipulation means that the team with more players has a higher number and more effective offensive actions, as well as defensive actions. This manipulation also involves the realization of more fake situations by players. These results can be considered normal. The creation of an unbalance situation for one team facilitates the realization of their individual and team actions, as well as introduces more variability. This allows players to have a higher number of positive actions, which can increase their acquisition. For players in the team with fewer players, this type of approach is a challenge to overcome. Although the number of studies in this research was limited [23,41], our current evidence shows that these manipulations can be used by coaches to promote positive and variable individual and team actions, as well as challenge players in defence.

4.3. Constraints Modification: Court Dimensions

A reduction of the court dimensions involves an increase in individual and team actions [37,38,42–44]. The consequence of this could be that with more space available, players do more collective actions, which provokes a higher number of individual skills, which results in the higher participation of players. The reduction of space involves the realization of more fake movements by players in order to overcome opponents. As we mentioned in the previous point, more studies are needed to determine the relationship of court dimension manipulation with other variables, such as the number of players, the type of defence, or no-dribbling. The implementation of the court dimension changes is easier when the standard court dimensions are used (half-court or full-court), so most of the studies focused on this approach [37,42–44]. Only one study focused on other sizes and combined them with manipulation of the number of players. Smaller court dimensions (and numbers of players) involved more shots and rebounds [38]. The reduction of court dimensions could provoke a high number of 1 vs. 1 situations, which involve the possibility of greater variability of movements [45]. Our current evidence shows that more studies are needed to increase our knowledge about different possibilities that involve the manipulation of court dimensions according to the number of players, and the creation of different zones or the alteration of the current ones (e.g., three-point line and paint-zone).

4.4. Constraints Modification: Ball/Player Interactions, Basket Height, Game Time and Number of Baskets

There was a reduced number of studies that manipulated baskets available, game time, and players' actions in defence and with the ball [22,37,46,52]. All these studies showed an increase in individual and team offence skill actions. Manipulations, like playing for numerous short periods of time, using the pressure defence, or not allowing dribbling, are interesting tools that coaches can use in practice to generate variability, challenge decision-making and promote different behaviours in players (e.g., the realization of more passes when no dribbling is allowed). However, more studies are needed to confirm these findings because only one study was found for each of these manipulations.

Only one study out of 18 focused on the manipulation of basket height. The rest of the studies used the same basket height used for adults, independently of the characteristics and age of the youth players studied. Most of the studies focused on the manipulation of actions that were easy to implement or transfer to practice and competition. Manipulations that involved changing the court lines or manipulating the basket height were fewer. However, the study that evaluated the effect of playing with a lower basket (2.80 m) found changes in the offensive game style. There were more fast breaks and longer positional attacks, which involve higher numbers of 1 vs. 1 situations and more player participation. It is critical to increase our evidence about which basket height is more appropriate for each age group, sex, and skill. At this level, no studies were found regarding the manipulation of ball size. This information about equipment scaling could help to establish if it should be introduced in competitions and the benefits of using different basket heights (or ball sizes) in practice.

4.5. Future Research and Practical Applications

The analysis of the studies reviewed shows that there are areas in which more research is needed, such as for U10, U12, and U14 age groups, female basketball, and long-term studies (more than four months). Our current evidence does not allow us to have a complete perspective of the effect of different constraining manipulations throughout the whole process of basketball players' development. At this level, it is important that researchers better contextualize the characteristics of their sample (e.g., skills/level, hours of practice). Regarding the different constraints that coaches can manipulate, most of the studies focused on the manipulation of the number of players (e.g., 3 vs. 3) and official court dimensions (full-court versus half-court). More research is needed regarding other less common manipulations. For example, how the basket height should be adapted through the change of player height during their maturation. Another aspect to consider in future studies is that most of the studies analysed individual actions done by players. It is recommended that we gain a better perspective of the impact of the changes, and the impact on collective defence and offence actions (e.g., fast-break, offence possession, spacing with and without the ball, type of defence, defence team movements).

From a practical perspective, the studies showed how each manipulation involves specific changes in technical and tactical actions. This information can provide coaches with a better understanding of the impact of reducing the number of players or playing half-court versus full-court. It is necessary to emphasize that there is a reduced number of studies in some age groups and female basketball, and the information about the sample used in some studies limits the generalization of the findings. However, the trends that these studies provide can serve as a reference to guide coaches in the design of task and practice situations that can increase players learning. The reduced evidence-based information about youth basketball limits the analysis and discussion of whether the current competition rules used in developmental stages need to be reconsidered or not.

5. Conclusions

The current evidence about rule modification in youth basketball presents areas in which more studies are needed to have a complete perspective of their impact in practice and competition through the different stages of players' development. Taking into account individual needs and developmental stages, further studies should consider different age groups (e.g., from U-10 to U-14) and female players. Expanding scientific knowledge in this area would help coaches make short- and long-term plans in accordance with players' developmental stages. It is also necessary to include in the studies that analyse technical–tactical actions, variables related to defence actions, team actions, and decision-making. The findings show that rule manipulation can increase players' participation and promote the variability of players' actions. The authors of this study believe that the scientific community, sports federations, and sports clubs should promote and conduct more studies in this line of research for all age groups and sex.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Comisión de Ética de la Universidad de Murcia (2820/2020, 28/04/2020).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Article analysed.

Citation	Sample	Duration Intervention	Independent Variable	Technical Tactical Variables	Mean Findings
Leite, Leser, Gonçalves, Baca & Sampaio (2014) [46]	20 male basketball players (under 16.05 ± 2.09 years)	Short-term (1 day)	Type of defence pressure on 5 vs. 5	Defence and offence possessions.	Changing the level of defensive pressure promotes different collective behaviours.
Tallir, Pihilippaert, Valckle, Musch & Lenoir (2012) [36]	23 male and 7 female basketball players (11.08 ± 0.55 years old).	Short-term (2 days)	3 vs. 3 and 5 vs. 5	Decision-making.	3 vs. 3 involved more potential situations for learning (and improving) decision-making and motor skill execution.
Mateus, Gonçalves, Exel, Esteves & Sampaio (2019) [52]	14 male basketball players (14 ± 0.9 years old)	Short-term (2 days)	2 and 4 baskets	Dribble, passes, offence positions, rebounds, & steals.	Short-term effects found in changing the number of baskets provoke offence technical variables (dribble, pass, and rebound), defence technical variables (rebound and steal), and team offence variables (offence possessions).
Ortega, Garcia-Angulo, Gimenez & Palao (2021) [45]	51 male basketball players (13.32 ± 0.41 years old).	Short-term (2 days)	Basket Height: 3.05 m vs. 2.80 m	Fast breaks, passes, possessions, & shots.	The use of an adapted basket height in the competition promoted a game style that increased the occurrence of fast breaks and the execution of long positional attack phases.
Bredt, Camago, Mortoza, Andrade, Paopuci, Rosso, Praça & Chagas (2021) [23]	45 male basketball players (14.2 ± 0.3 years old).	Short-term (3 days)	3 vs. 3, 4 vs. 3 and 3 vs. 3+1	Dribbles, fast breaks, offence possessions (no shots), space creations wo ball, possessions, & passes.	The small-sided games with additional players or those games played on a half-court enhance group tactical–technical behaviour.
Sanchez, Carretero, Valiente, Gonzalo, Sampaio & Casamichana (2018) [44]	6 young female basketball players (14.3 ± 0.5 years old).	Short-term (4 days)	Half-court and-full court	Passes, possessions, rebounds, & shots.	Half court games involved a higher number of passes, possessions, rebounds, shots
Alti, Koklu, Alemdaroglu & Kocak (2013) [42]	12 young female basketball players (age 15.5 ± 0.5 years old).	Short-term (1 week)	Half-court and full-court	Assists, passes, rebounds, shots, steals, passes, & turnovers.	Half-court 3-a-side games involved a higher number of technical actions compared to full-court 3-a-side games.
Erculj, Vidic & Leskosek (2020) [33]	72 teams (≈500 male and female U18 basketball players)	Short-term (1 week)	3 vs. 3 and 5 vs. 5.	Shots.	3 vs. 3 basketball created more shooting situations and provoke a higher number of shots.
López & Arias (2019) [34]	18 mini-basket players (9.89 ± 0.8 years old).	Short-term (4 weeks)	3 vs. 3 and 5 vs.5.	Offence possessions & passes.	The 3 vs. 3 game form should be used to favour players' game implications (passes and offence possessions), successful participation, positive emotions, as well as satisfying preferences.

Table A1. *Cont.*

Citation	Sample	Duration Intervention	Independent Variable	Technical Tactical Variables	Mean Findings
Diniz, Bredt & Praça (2021) [41]	45 schoolchildren (11.55 ± 0.49 years old) from both sexes.	Short-term (4 weeks)	3 vs. 3, 3 vs.2 and 3 vs. 3+1.	Dribbles, passes, rebounds, & shots.	3 vs. 2 small-sided games involved higher participation than 3 vs. 3 and 3 vs. 3+1 small-sided games. The constant presence of a free player in these types of small-sided games may variability for shooting and rebounding.
McCormick, Hannon, Newton, Shultz, Miller & Young (2012) [35]	12 young male basketball players (15 years old).	Medium-term (6 weeks)	3 vs. 3 and 5 vs. 5	Possessions.	The results suggest that 3 vs. 3 leagues may be an appropriate sport for initial exposure to young basketball players.
Klusemann, Pyne, Foster & Drinkwater (2012) [37]	16 elite junior basketball players. 8 male (18.2 ± 0.3 years old) and 8 female (17.4 ± 0.7 years old).	Medium-term (6 weeks)	2 vs.2 and 4 vs.4. Half court and full court 4 × 2.5 min vs. 2 × 5 min	Ball screens, dribbles, passes, shots, rebounds, and ball screens.	The number of players on the court, court size, and work-to-rest ratios involved changes in the realization of technical actions and their Frequency.
Delextrat & Martinez (2014) [40]	24 male basketball players (U17)	Medium-term (6 weeks)	2 vs. 2	Defensive actions, pass, & shot.	The use of 2 vs. 2 increased basketball-specific skills performance.
Conte, Favero, Nierderhausen, Capranica & Tessitore (2016) [21]	21 young male basketball players (15.4 ± 0.9 years).	Medium-term (6 weeks)	2 vs. 2 and 4 vs.4.	Dribbles, passes, rebounds, shots, steals & turnovers.	The number of players influenced the technical actions done in the drills. The 2 vs. 2 situation increased ball screens, dribbles, passes, rebounds, and shots.
Clemente, Conte, Sanches, Moleiro, Gomez & Lima (2018) [39]	20 young male basketball players (U12 & U14)	Medium-term (5 weeks)	1 vs. 1, 2 vs. 2, 3 vs. 3, 4 vs. 4 and 5 vs. 5	Rebounds, shots, & turnovers.	The number of players influence the physical effort of players which was associated with tehcnical actions (received & attacking balls and shots).
Bredt, Torres, Diniz, Praça, Andrade, Morales, Rosso & Chagas (2020) [43]	12 junior male basketball players (17.01 ± 0.24 years old).	Medium-term (5 weeks)	Half court and full court.	Defensive actions, dribbles, & fakes.	3 vs. 3 full court increased the number of fakes.
Ferioli, Rucco, Rampinini, La Torre, Mnafredi & Conte (2020) [22]	10 male basketball players (average 18.3 years old).	Medium-term (16 weeks)	3 vs. 3, 4 vs. 4 and 5 vs. 5 Regular dribble and No dribble.	Assists, passes, rebounds, shots, steals & turn-overs.	Reducing the number of players increased the game-based drills and technical elements, while the No Dribble format promoted a greater number of turnovers and passes.
Clemente, Bredt, Praça, Andrade, Sanchez, Moleiro & Lima (2021) [38]	10 female basketball players (14.3 ± 1.3 years old).	Medium-term (15 weeks)	1 vs. 1, 2 vs. 2, 3 vs. 3, 4 vs. 4 and 5 vs. 5. 15 × 6 m, 22 × 8 m, 24 × 11 m, 26 × 13 m and 28 × 15 m (respectively).	Rebounds & shots.	The smaller basketball small-sided games format induced higher numbers of technical–tactical actions per player per minute. Furthermore, they induced adjustments in the relative playing area. Regarding the effect of successive small-sided games bouts, two successive bouts only do not seem to impact either the numbers of technical–tactical actions or RPE.

References

1. Broadbent, N.; Buszard, T.; Farrow, D.; Reid, M. Scaling junior sport competition: A body-scaling approach? *J. Sport. Sci.* **2021**, *39*, 1–9. [CrossRef] [PubMed]
2. Buszard, T.; Farrow, D.; Reid, M. Designing Junior Sport to Maximize Potential: The Knowns, Unknowns, and Paradoxes of Scaling Sport. *Front. Psychol.* **2020**, *10*, 2878. [CrossRef] [PubMed]

3. Marín, A.A.; Estévez-López, F.; Cárdenas, D.; Piñar, M.I. Modificación reglamentaria en baloncesto: Descripción del juego colectivo de ataque en categoría infantil. *Rev. Euroam. De Cienc. Del Deporte* **2013**, *2*, 67–75.
4. Nunes, A.; Gonçalves, B.; Davids, K.; Esteves, P.; Travassos, B. How manipulation of playing area dimensions in ball possession games constrains physical effort and technical actions in under-11, under-15 and under-23 soccer players. *Res. Sport Med.* **2020**, *29*, 170–184. [CrossRef] [PubMed]
5. Ortega, E.; García-Angulo, A.; Gimenez, J.M.; García-Angulo, F.J.; Palao, J.M. Effect of manipulations in rules in competition on participation of male youth goalkeepers in soccer. *Int. J. Sport. Sci. Coach.* **2018**, *13*, 1040–1047. [CrossRef]
6. Araujo, D.; Davids, K.W.; Hristovski, R. Ecological Dynamics of Decision-Making. *Psychol. Sport Exerc.* **2006**, *7*, 653–676. [CrossRef]
7. Baker, J.; Coté, J.; Abernethy, B. Sport-Specific Practice and the Development of Expert Decision-Making in Team Ball Sports. *J. Appl. Sport Psychol.* **2003**, *15*, 12–25. [CrossRef]
8. Button, C.; Seifert, L.; Chow, J.; Davids, K. *Dynamics of Skill Acquisition: A Ecological Dynamics Approach*; Human Kinetics: Harrogate, UK, 2020.
9. Chow, J.; Davids, K.; Button, C.; Renshaw, I. *Nonlinear Pedagogy in Skill Acquisition: An Introduction*; Routledge: New York, NY, USA, 2015.
10. Davids, K.; Araújo, D.; Correia, V.; Vilar, L. How small sided and conditioned games enhance acquisition of movement and decision making skills. *Exerc. Sport Sci. Rev.* **2013**, *41*, 154–161. [CrossRef]
11. Davids, K.; Button, C.; Bennet, S. *Dynamics of Skill Acquisition: A Constraints-Led Approach*; Human Kinetics: Champaign, IL, USA, 2008.
12. Fernández-Espínola, C.; Abad, M.; Giménez, F.J. Small-sided games as a methodological resource of team sports teaching: A systematic review. *Int. J. Environ. Res. Public Health* **2020**, *17*, 1884. [CrossRef]
13. Araújo, D.; Hristovski, R.; Seifert, L.; Carvalho, J.; Keith, D. Ecological Cognition: Expert decision-making behaviour in sport. *Int. Rev. Sport Exerc. Psychol.* **2019**, *12*, 1–25. [CrossRef]
14. Gimenez, J.M.; Ortega, E.; Palao, J.M.; Torres, G. Effect of Scalling equipment on U-10 players tennis serve during match-play: A nonlinear pedagogical approach. *Chaos Solitons Fractals* **2020**, *139*, 1–10.
15. Light, R.; Harvey, S.; Mouchet, A. Improving 'at-action' decision-making in team sports through a holistic coaching approach. *Sport Educ. Soc.* **2014**, *19*, 258–275. [CrossRef]
16. Low, B.; Coutinho, D.; Gonçalves, B.; Rein, R.; Memmert, D.; Sampaio, J. A Systematic Review of Collective Tactical Behaviours in Football Using Positional Data. *Sport. Med.* **2019**, *50*, 343–385. [CrossRef]
17. Wood, M.; Mellalieu, S.; Araújo, D.; Woods, C.; Davids, K. Learning to coach; an ecological dynamics perspective. *Sport. Sci. Coach.* **2022**, *22*, 1–12. [CrossRef]
18. Woods, C.; McKewon, I.; Rothwell, M.; Araújo, D.; Robertson, S.; Davids, K. Sport practitioners as sport ecology designers: How ecological dynamics has progressively changed perceptions of skill "acquisition" un the sporting habitat. *J. Psychol.* **2020**, *11*, 654. [CrossRef]
19. Bucheit, M.; Laursen, P.B.; Kuhnle, J.; Ruch, D.; Renaud, C.; Ahmaidi, S. Small game-based training in young elite handball players. *Int. J. Sport. Med.* **2009**, *30*, 251–258. [CrossRef]
20. Clemente, F.; González-Víllora, S.; Delextrat, A.; Martins, F.M.L.; Vicedo, J.C.P. Effects of the Sports Level, format and Game and Task Condition on Heart Rate Responses, Rechnical and Tactical Perfomance of Youth Basketball Players. *J. Hum. Kinet.* **2017**, *58*, 141–155. [CrossRef]
21. Conte, D.; Favero, T.; Niederhausen, M.; Capranica, L.; Tessitore, A. Effect of different number of players and training regimes on physiological and technical demands of ball-drills in basketball. *J. Sport Sci.* **2016**, *34*, 780–786. [CrossRef]
22. Ferioli, D.; Rucco, D.; Rampinini, E.; La Torre, A.; Manfredi, M.; Conte, D. Combined Effect of Number of Players and Dribbling on Game-Based-Drill Demands in Basketball. *Int. J. Sport. Physiol. Perform.* **2020**, *15*, 825–832. [CrossRef]
23. Bredt, S.; Camargo, D.; Mortoza, B.; Andrade, A.; Paolucci, L.; Rosso, T.; Praça, G.; Chagas, M. Additional players and half-court areas enhance group tactical-technical behavior and decrease physical and physiological responses in basketball small-sided games. *Int. J. Sport Sci. Coach.* **2021**, *17*, 1079–1088. [CrossRef]
24. Bredt, S.; Morales, J.; Andrade, A.; Torres, J.; Peixoto, G.; Greco, P.J.; Chagas, M. Space Creation Dynamics in Basketball Small-Sided Games. *Percept. Mot. Ski.* **2017**, *125*, 162–176. [CrossRef]
25. Clemente, F.; Sarmento, H.; Csota, I.; Enes, A.R.; Lima, R. Variability of Technical actions during small-sided games in young soccer players. *J. Hum. Kinet.* **2019**, *69*, 201–212. [CrossRef]
26. Coutinho, D.; Gonçalves, B.; Santos, S.; Travassos, B.; Schöllhorn, W.; Sampaio, J. The effects of individual and collective variability on youth players' movement behaviours during football small-sided games. *Res. Sport. Med.* **2022**, *24*, 1–16. [CrossRef]
27. Gorman, A.D.; Headrick, J.; Renshaw, I.; McComarck, C.J.; Topp, K.M. A principled approach to equipment scaling for children's sport: A case of study in basketball. *Int. J. Sport. Sci. Coach.* **2020**, *16*, 158–165. [CrossRef]
28. Poureghbali, S.; Arede, J.; Rehfeld, K.; Schollhorn, W.; Leite, N. Want to impact physical, technical and tactical performance during basketball small-sided games in youth athletes? Try Differential Learning Beforehand. *Int. J. Environ. Res. Public Health* **2020**, *11*, 9279. [CrossRef]
29. Ortega, E.; Giménez, J.M.; Verdú, I.; Palao, J.M. Effect of basket height adaptation on technical-tactical skills, self-efficacy, cooperation, and students' perception in a basketball unit. *Sustainability* **2020**, *12*, 10180. [CrossRef]

30. Sangnier, S.; Cotte, T.; Brachet, O.; Coquart, J.; Tourny, C. Planning training workload infootball using small-sided games' density. *J. Strength Cond. Res.* **2019**, *33*, 2801–2811. [CrossRef]
31. Sarmento, H.; Clemente, F.M.; Araújo, D.; Davids, K.; McRobert, A.; Figueiredo, A. What performance analysis need to know about research trends in association football (2012–2016): A systematic review. *Sport. Med.* **2018**, *48*, 799–836. [CrossRef]
32. Sarmento, H.; Clemente, F.M.; Harper, L.D.; Costa, I.T.D.; Owen, A.; Figueiredo, A.J. Small sided games in soccer–a systematic review. *Int. J. Perform. Anal. Sport* **2018**, *18*, 693–749. [CrossRef]
33. Erculj, F.; Vidic, M.; Leskosek, B. Shooting efficiency and structure of shooting in 3 × 3 basketball compared to 5 vs. 5 basketball. *Int. J. Sport. Sci. Coach.* **2020**, *15*, 91–98. [CrossRef]
34. López, F.; Arias, J. Effect of game form (5 vs. 5 and 3 vs. 3) on motor and psychological behaviours in under-11 basketball. *Retos–Nuevas Tend. En Educ. Física Deporte Y Recreación* **2019**, *36*, 354–361.
35. McCormick, B.; Hannon, J.; Newton, M.; Shultz, B.; Miller, N.; Young, W. Comparison of Physical Activity in Small-Sided Basketball Games Versus Full-Sided Games. *Int. J. Sport. Sci. Coach.* **2012**, *7*, 689–697. [CrossRef]
36. Tallir, I.; Philippaerts, R.; Valcke, M.; Musch, E.; Lenoir, M. Learning opportunities in 3 on 3 versus 5 on 5 basketball game play: An application of nonlinear pedagogy. *Int. J. Sport Psychol.* **2012**, *43*, 420–437.
37. Klusemann, M.; Pyne, D.; Foster, C.; Drinkwater, E. Optimising technical skills and physical loading in small-sided basketball games. *J. Sport. Sci.* **2012**, *30*, 1463–1471. [CrossRef]
38. Clemente, F.; Bredt, S.; Praça, G.; Andrade, A.; Sanchez, R.; Moleiro, C.; Lima, R. Basketball small-sided games: Effects of varying formats and using successive bouts. *Kinesiology* **2021**, *53*, 28–36. [CrossRef]
39. Clemente, F.; Conte, D.; Sanches, R.; Moleiro, C.; Gomes, M.; Lima, R. Anthropometry and fitness profile, and their relationships with technical performance and perceived effort during small-sided basketball games. *Res. Sport Med.* **2018**, *27*, 452–466. [CrossRef]
40. Delextrat, A.; Martinez, A. Small-Sided Game Training Improves Aerobic Capacity and Technical Skills in Basketball Players. *Int. J. Sport. Med.* **2014**, *34*, 385–391. [CrossRef]
41. Diniz, L.; Bredet, S.; Praça, G. Influence of non-scorer floater and numerical superiority on novices' tactical behaviour and skill efficacy during basketball small sided games. *Int. J. Sport. Sci. Coach.* **2021**, *17*, 37–45. [CrossRef]
42. Atli, H.; Koklu, Y.; Alemdaroglu, U.; Kocak, F.U. A comparison of heart rate response and frequencies of technical actions between half-court and full-court 3 a side games in high school female. *J. Strength Cond. Res.* **2013**, *27*, 352–356. [CrossRef]
43. Bredt, S.; Torres, J.; Diniz, L.; Praca, G.; Andrade, A.; Morales, J.; Rosso, T.; Chagas, M.H. Physical and physiological demands of basketball small-sided games: The influence of defensive and time pressures. *Biol. Sport* **2020**, *37*, 131–138. [CrossRef]
44. Sanchez, J.; Carretero, M.; Valiente, J.; Gonzalo, O.; Sampaio, J.; Casamichana, D. Heart rate response and technical demands of different small-sided game formats in young female basketballers. *RICYDE–Rev. Int. De Cienc. Del Deporte* **2018**, *14*, 55–70. [CrossRef]
45. Ortega, E.; García-Angulo, F.J.; Giménez, J.M.; Palao, J.M. Effect of scaling basket height for young basketball players during the competition: Seeking out positive sport experiences. *J. Sport. Sci.* **2021**, *39*, 2763–2771. [CrossRef] [PubMed]
46. Leite, N.; Leser, R.; Gonçalves, B.; Calleja, J.; Baca, A.; Sampaio, A. Effect of defensive pressure on movement behaviour during an under-18 basketball game. *Int. J. Sport. Med.* **2014**, *35*, 743–748. [CrossRef]
47. McKay, A.K.; Stellingwerff, T.; Smith, E.; Martin, D.T.; Mujika, I.; Goosey-Tolfrey, V.L.; Sheppard, J.; Burke, L.M. Defining training and performance caliber: A participant classification framework. *Int. J. Sport. Physiol. Perform.* **2022**, *17*, 317–331. [CrossRef]
48. Moher, D.; Liberati, A.; Tetzlaff, J.; Altman, D.G.; Prisma Group. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *Ann. Intern. Med.* **2009**, *151*, 264–269. [CrossRef]
49. Arede, J.; Esteves, P.; Ferreira, A.P.; Sampaio, J.; Leite, N. Jump higher, run faster: Effects of diversed sport participation talent identification and selection in youth basketball. *J. Sport. Sci.* **2019**, *37*, 2220–2227. [CrossRef]
50. Cañadas, M.; Gómez, M.A.; García-Rubio, J.; Ibáñez, S. Analysis of Training Plans in Basketball: Gender and Formation Stage Differences. *J. Hum. Kinet.* **2018**, *62*, 123–134. [CrossRef]
51. Jayanthi, N.; Kliethermes, S.A.; Coté, J. Youth sport specialization: The need for an evidence-based definition. *Br. J. Sport Med.* **2019**, *54*, 196–197. [CrossRef]
52. Mateus, N.; Gonçalves, B.; Exel, J.; Esteves, P.; Sampaio, J. Short-term effects of adding 1-m wide to each side the basketball court on youth baskrtball players' performance. *Cuad. De Psicol. Del Deporte* **2019**, *20*, 82–94. [CrossRef]

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Article

Effectiveness of Video Modeling in Improving Technical Skills in Young Novice Basketball Players: A Quasi-Experimental Study

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Abstract: (1) Objective: This is a quasi-experimental study that investigated the effect of four weeks of training sessions using video modeling (VM) on individual and collective technical skills in young novice basketball players. (2) Method: 20 players were equally assigned to either a control group (CG, $n = 10$; 12 ± 0.7 years) or a video modeling group (VMG, $n = 10$; 12.5 ± 0.5 years; visualizing videos before each session) were assessed before and after the four-week training period using the Basketball Skill Test of the American Alliance for Health, Physical Education, Recreation and Dance for individual techniques and three vs. three small-sided games for collective aspects. (3) Results: For the passing test, VMG induced higher performance than CG ($p = 0.021$; $d = 0.87$). For offensive balls post-intervention, higher values were recorded for VMG compared to CG ($p = 0.003$; $d = 1.81$). In addition, the number of attack balls index post-intervention was higher for VMG compared to CG ($p = 0.001$; $d = 0.28$). For losing the ball, VMG induced lower values than CG after the training intervention ($p < 0.001$; $d = -3.23$). The efficiency index was higher post-training compared to pre-training for VMG ($p = 0.013$; $d = 1.24$). (4) Conclusion: The study highlighted the importance of using video modeling as an effective strategy to improve technical skills and collective performance in novice young basketball players.

Keywords: training; skill acquisition; performance improvement; motor learning

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1. Introduction

Technology has rapidly evolved and is being incorporated into various fields of investigation including sports [1,2]. Amongst the different areas of technology, digital video modeling, which mainly focuses on social and observational learning theory [3,4] is increasingly attracting interest in varieties of sports studies [5–7]. As a way of frequent manipulation [8], video modeling (VM) including demonstration, video feedback, and athletes' movement allows self-examination and self-learning to improve athletes' motor skills [9–11]. Moreover, it has been revealed that most of the information that reaches the brain is acquired through the eyes/visualization [12,13]. From this perspective, various studies have suggested that VM is an effective strategy that induces learning improvements and enhances athletic movements such as gymnastics skills [9,14,15], snatch movement in weightlifting [16], tennis service [17], basketball shooting form [18–20], and basketball tactical skills [20–23]. This is particularly true, as digital environments allow coaches to use videos to analyze athletic movements, evaluate their team performance, and adjust their collective strategies and individual technical skills to enhance their performance [5,24].

VM allows players to see and analyze the correct techniques of a skill, which can be difficult to learn through only verbal instruction. Additionally, VM allows players to observe and learn from the mistakes of others [25] and this can be especially beneficial for beginners who may not be aware of common mistakes or misconceptions about a skill [26,27]. Further, by watching expert athletes' performances on video, young beginning players can identify areas of improvement and focus their training on specific skills. Furthermore, VM can enhance collective performance through team coordination, dynamics, and communication improvements which allow players to recognize how their actions affect the performance of their teammates [28,29].

Basketball is one of the most popular team sports worldwide, requiring complex technical and tactical skills for success [30,31]. Previous studies have recommended VM as a powerful strategy that attracts both players and coaches through its effectiveness to reinforce the performance of basketball players [20,22,32] individually, and as a team [5,26,33]. This technique can be applied to basketball players at all levels, from youth and novice leagues to the professional level [20,34,35]. Because young athletes often devote more attention to video demonstrations and are easily attracted by images in motion, VM has been recommended in the literature [36]. By watching footage of themselves, players can see how they move and react on the court and adjust their technique and positioning [37] whilst watching the footage of other players, and this practice can help them to learn from the best and pick up new moves and strategies [38].

Despite the numerous benefits reported by previous studies on the use of VM in the teaching of basketball skills, using this technology has been limited to a few basketball techniques such as the free throw [39] or shooting [40], with a focus only on students' performance [18,22,39]. However, most of these previous studies have been conducted with experienced adult athletes, leaving a gap in the literature regarding the effectiveness of video modeling for young, novice athletes. Furthermore, previous studies have primarily focused on the immediate effects of video modeling, with limited research on its long- and medium-term effects on skill improvement and transfer [41]. Therefore, the current study expands on previous studies by exploring the effectiveness of video modeling as a teaching tool for novice young basketball players and providing insight into the potential long-term benefits of this approach. Despite the growing usage of video modeling in teaching physical education practical lessons, research on how this medium of instruction can appropriately be integrated to improve technical–tactical elements during physical education is limited [42].

To date, and to the best of our knowledge, no study has investigated the effect of VM on the individual and collective performance of young basketball players. Thus, the general purpose of the present study was to examine the effects of adding video modeling during four weeks of a basketball training program for young novice players, with the specific objectives of assessing the effects on individual technical skills, assessing the impact on collective game performance measures, and comparing the performance of the video modeling group to the control group. It was hypothesized that adding VM to a habitual basketball training program would improve the individual's technical skills and the volume of play of young novice basketball players.

2. Materials and Methods

2.1. Participants

This is a quasi-experimental study design that examined the effect of adding VM to a habitual training program for four weeks on individual and collective basketball performance. An a priori power analysis was performed using the G*Power software (Version 3.1.9.4, University of Kiel, Kiel, Germany) and the F-test family (ANOVA: repeated measures, between–within interaction). The analysis revealed that a minimum sample size of 16 participants would be adequate to detect differences (effect size f = 0.40, α = 0.05) with an actual power of 85.08%. Twenty (20) young players volunteered to participate in the present study. They were equally and randomly assigned to either control group (CG, n = 10; Mean $\pm$ SD: age: 12 $\pm$ 0.7 years; body mass: 47 $\pm$ 11 kg; height: 153 $\pm$ 10.5 cm) and a video modeling experimental group (VMG, n = 10; Mean $\pm$ SD: age: 12.5 $\pm$ 0.5 years; body mass: 51 $\pm$ 16 kg; height: 158 $\pm$ 9.5 cm) using the function of Microsoft Excel software (Table 1). The subjects were recruited from a basketball regional team, with one year of experience. The players were regularly training four sessions per week, with each session lasting 90 min. The inclusion criteria for this study were: (1) athletes should be novice basketball players from the same club and participating in the same basketball training program, (2) aged from 11 to 14 years, (3) no more than one year of basketball experience, (4) they had no injuries or medical restrictions. The exclusion criteria were: (1) players with a good previous basketball training experience or participating in school or another club team for more than one year, (2) players who are not currently participating in a training program that might interfere with the study, (3) any significant medical problems or injuries that would affect their ability to participate in a basketball training program.

Table 1. Anthropometric measurements of the CG and VMG groups (n = 10 each): Age, body mass, and height.

	CG (n = 10)	**VMG (n = 10)**
Age (year)	12 $\pm$ 0.7	12.5 $\pm$ 0.5
Body mass (kg)	47 $\pm$ 11	51 $\pm$ 16
Height (cm)	153 $\pm$ 10.5	158 $\pm$ 9.5

2.2. Measures

2.2.1. The Basketball Skill Test-American Alliance for Health, Physical Education, Recreation and Dance (AAHPERD)

One of the most widely adopted basketball skills test batteries was developed by the American Alliance for Health, Physical Education, Recreation and Dance (AAPHERD, American Alliance for Health, 1984). The AAPHERD test battery consists of four separate tests assessing the most common basketball skills: Passing and recovering the basketball accurately while moving, Speed Shot Shooting Test, Handling and Dribbling the ball while moving Test, and Defensive movement Skill Test [43]. In summary, these tests record successful passes while moving to different targets in 30 s on two trials (Passing Test); successful shots from different spots in 60 s $\times$ two trials (Shooting Test); elapsed time to cover a specific circuit while dribbling in two trials (left hand and right hand, Dribbling Test); and defensive movement with sliding steps without crossing the feet (Defensive Movement Test).

The scoring system for AAHPERD is as follows:

- For the passing test: two points were recorded for each chest pass that hit the center of the target, one point for a ball that touched between the targets, and 0 points for a ball that contacted below or above the targets.
- For the Speed Shot Shooting Test: two points were awarded for each basket scored, one point for each ball hitting the ring, and zero points for each air ball.

- For the dribbling test: the player established two trials in a zigzag dribble circuit placed in the restricted area. The experimenter should record the time elapsed in each trial (left hand and right hand).
- For the defensive movement test: The player was instructed to move from side to side in a circuit of eight cones in the restricted area that are placed in a zigzag form. The time elapsed during the two trials was recorded.

The intra-class correlation coefficient (ICC) for the test–retest trial for the present study was 0.91, 0.83, 0.79, and 0.79 for passing, shooting, dribbling, and defending, respectively.

2.2.2. Using 3 vs. 3 Small-Sided Games

A 3 vs. 3 small-sided game in a half-court with only one hoop, excluding the lateral lanes (14×9 m) in order to guarantee a better interaction between players (42 m^2) and the width per player near the basket (1.5 m^2) was performed [44]. The game consisted of three blocks of 4 min with at least 2 min of passive rest in between [44,45]. All International Basketball Federation (FIBA) rules were respected, except for time-outs and free throws. Any personal foul committed in a team resulted in losing the ball possession, and the other team regained possession by throwing the ball from the sideline. After each basket scored, the team that conceded the points puts the ball back into play from the sideline too. Coaches verbally encouraged players in a similar way to maintain a high effort level and replaced any ball that was thrown out of play if necessary. A total of 18 bouts were video recorded and subsequently analyzed by the same investigator. Additionally, to guarantee the transparency of our results, the videos were evaluated twice by the same investigator within 7 days of interval.

A Team Sport Assessment Procedure (TSAP) has been previously reported to provide teachers and coaches with an objective tool that allows them to assess the offensive performance of students and players in different games and team sports [46]. In the present study, specific player behaviors, i.e., conquering the ball (CB), receiving the ball (RB), losing the ball (LB), offensive ball (OB), successful shot (SS), attack balls (AB), the volume of play (PB), and the efficiency index) were observed and recorded during the 3 vs. 3 small, sided game for further analysis. Additionally, the sum of different skills scores was calculated to determine different offensive indices [(i.e., number of attacking balls and volume of play (the number of times the player has gained possession)], and then the efficiency index [46] that are all calculated as follows:

- The number of attacking balls (AB): AB = OB + SS
- The volume of play (PB): CB + RB
- The efficiency index = (CB + AB)/ (10 + LB) or (CB + OB + SS)/(10 + LB)

ICC for test–retest trial for the present study was 0.98 for CB, RB, and LB, 0.92 for OB, 1 for SS, 0.96 for AB, 0.97 for PB, and 0.95 for efficiency index.

2.3. Procedures

Following adherence to the last Declaration of Helsinki, the protocol was fully approved by a local research ethics committee of the Higher Institute of Sport and Physical Education of Kef, University of Jendouba, Kef, Tunisia, with reference number (n° 050/2022) dated 14 December 2022. Afterwards, permission was sought from the management and coaches of the basketball regional team to allow their players to be selected to participate in the study. After obtaining a complete overview of the aims, advantages, and potential risks associated with the investigation, players and their parents signed a written informed consent/assent form.

Pre- and post-test were conducted to measure the technical performance changes across the four weeks of intervention within young novice basketball players. The assessments were conducted inside a basketball court with each assessment session lasting approximately 90 min.

This experiment was conducted in an indoor basketball court respecting the FIBA regulatory dimensions using an official size 6 ball, the dimensions of the court were

28 × 15 m, the basket was placed at a height of 3.05 m from the ground and the ring had a circumference of 0.46 m.

The pre-intervention testing session was conducted one week before the start of the training program, whereas the post-intervention assessment was conducted 48 h after the end of the program.

The assessments were administered by two trained research assistants, who were not informed of the group assignment. Athletes were assigned to VMG or a CG that performed its habitual training without any intervention. For the VMG, the intervention consisted of watching a short pre-training video sequence for four weeks (4 sessions/week) lasting approximately 3 min 30s. Ten (10) minutes before the start of each training session, the entire VMG joined a meeting room to watch video footage of a professional basketball player practicing one of the basic basketball skills according to the planned training session schedule by the team's technical director. There are several potential benefits to choosing a professional player as a role model for new athletes. In fact, professional athletes are typically highly skilled in their sport and have a wealth of experience that can be valuable for new athletes to develop their skills in a more realistic and understandable way [47–49].

The experimenter did not influence the team's practice schedule that was set in advance, and it was conducted using a Lenovo laptop computer (PC0MFE53) placed 30 cm away from the participants. The viewing angle of the screen was approximately 45° and the video was played via the VLC media player. Throughout the video session, the player could ask the coach to stop the sequence, reverse it, or ask for an explanation. After watching the video, the VMG joined the rest of the team to begin the training session. All training sessions during the intervention period were the same for both the experimental and control groups. The video sequences and exercises used in the training sessions were not similar to the exercise modality used in the tests to avoid any possible learning effects that could influence the results at the end of the intervention period. Before and after the four-week intervention phase, both VMG and CG were assessed for individual and collective basketball technical skills. Specifically, for individual technical skills (i.e., passing, shooting, dribbling, and defending) using AAHPERD [43]. For collective basketball skills, athletes were subjected to 3 vs. 3 basketball small-sided games (SSG) [45,50], video recorded, and subsequently analyzed to determine various technical–tactical aspects (i.e., conquering the ball, receiving the ball, losing the ball, offensive ball, shooting success, attacking balls, the volume of play, and the efficiency index) [46]. Before each training session, 15 min of standardized warm-up session was performed consisting of regular runs, sprints, jumps, stops and technical circuits using balls.

2.4. Statistical Analysis

Statistical analyses were performed using SPSS version 20.0 statistical software (IBM Corps., Armonk, NY, USA). Data has been presented as means and standard deviations. The Shapiro–Wilk test was used to confirm normality, and the Levene test was used to verify the homogeneity of variances. A two-way repeated measures ANOVA (2 groups × 2 times) was used to compare results on the passing, speed shooting, dribbling, and defensive movement tests. Conquering the ball, receiving the ball, losing the ball, successful shorts, the volume of play, and efficiency indexes were compared using a multivariate analysis of variance (MANOVA). For the variables (Offensive and the number of attack balls), an analysis of covariance (ANCOVA) was performed with a pre-test as the covariate. When a significant difference was reported, a Bonferroni post hoc test was used to detect differences in means. Partial eta squared (η_p^2) effect size values were reported and classified as 0.01 = small, 0.06 = medium, 0.14 = large [51]. Moreover, standardized effect size analysis (Cohen's *d*) was used to interpret the magnitude of differences between variables and considered as: trivial ($\leq$0.20); small ($0.20 < d \leq 0.60$); moderate ($0.60 < d \leq 1.20$); large ($1.20 < d \leq 2.0$); very large ($2.0 < d \leq 4.0$); and extremely large (>4.0) [52]. In addition, the upper and lower 95% confidence intervals of the difference ($95\%CI_{dif}$) were calculated for the corresponding variation. The level of statistical significance was set at $p \leq 0.05$.

3. Results

Table 2 reported results for normality from Shapiro–Wilk test and homogeneity of variance assessed by Levene's test for dependent variables assessed by the basketball skill test (AAHPERD).

Table 2. Normality and homogeneity of variance values for dependent variables assessed by the basketball skill test.

		Shapiro–Wilk Test		Levene's Test	
		W	**p**	**F**	**p**
Passing	Pre	0.956	0.460	1.468	0.351
	Post	0.950	0.367	0.003	0.959
Shooting	Pre	0.958	0.510	0.001	0.985
	Post	0.979	0.926	1.292	0.271
Defense	Pre	0.949	0.348	0.116	0.737
	Post	0.956	0.464	0.103	0.752
Dribbling	Pre	0.966	0.674	0.042	0.840
	Post	0.964	0.630	0.060	0.809

W: Shapiro–Wilk statistic, F: Levene's test statistic.

Table 3 reported results for normality from Shapiro–Wilk test and homogeneity of variance assessed by Levene's test for dependent variables assessed by the three vs. three small-sided games.

Table 3. Normality and homogeneity of variance values for dependent variables assessed by the 3 vs. 3 small-sided games.

	Shapiro–Wilk Test		Levene's Test	
	W	**p**	**F**	**p**
CB	0.965	0.251	0.913	0.444
RB	0.973	0.451	1.170	0.334
LB	0.942	0.338	3.082	0.032
SS	0.964	0.640	0.403	0.752
PB	0.949	0.072	0.593	0.624
OB	0.983	0.814	0.006	0.940
AB	0.971	0.378	0.993	0.332
Efficiency	0.969	0.341	0.393	0.759

W: Shapiro–Wilk statistic, F: Levene's test statistic; CB: conquering the ball; RB: receiving the ball; LB: loosed ball; OB: offensive ball; SS: successful shot; AB: attacking ball; PB: volume of play.

Table 4 presents the performances recorded in both the experimental and control groups before and after the intervention period for the Basketball Skill Test.

For the passing test, there was a main effect of time ($F_{1,18}$ = 55.27; p < 0.001; η_p^2 = 0.754) with values higher after the intervention period compared to before the intervention (95%CI_{dif} = 8.9 to 15.8; d = 1.27; p < 0.001). There was a main effect of group ($F_{1,18}$ = 6.38; p = 0.021; η_p^2 = 0.262) with values higher for VMG compared to CG (95%CI_{dif} = 1.5 to 16.7; d = 0.87; p = 0.021). For the speed shooting test, there was a main effect of time ($F_{1,18}$ = 20.25; p < 0.001; η_p^2 = 0.529) with values higher after the intervention compared to before intervention (95%CI_{dif} = 3.9 to 10.9; d = 1.03; p < 0.001). For the dribbling test, there was a main effect of time ($F_{1,18}$ = 16.10; p = 0.001; η_p^2 = 0.472) with lower values recorded after the intervention period compared to before the intervention period (95%CI_{dif} = −4.0 to −1.3; d = −1.04; p = 0.001). For the defensive movement test, there was a main effect of time ($F_{1,18}$ = 117.9; p < 0.001; η_p^2 = 0.868) with lower values recorded after the intervention period compared to before (95%CI_{dif} = −5.5 to −3.7.7; d = −2.36; p < 0.001).

Table 4. Technical performances recorded in the basketball skill test for both video modeling (VMG) and control groups (CG) before and after the intervention period (Values are mean ± SD; $n = 20$).

	CG ($n = 10$)		VMG ($n = 10$)	
	Pre-Test	**Post-Test**	**Pre-Test**	**Post-Test**
Passing (point)	42.20 ± 12.73	51.80 ± 6.46 *	48.60 ± 8.06+	63.70 ± 6.63 *+
Shooting (point)	22.9 ± 7.32	31.70 ± 6.46 *	21.64 ± 6.64	27.70 ± 8.68 *
Defense (s)	27.40 ± 2.40	23.47 ± 1.60	28.82 ± 2.05	23.51 ± 1.74
Dribbling (s)	26.35 ± 3.66	23.74 ± 1.84 *	27.13 ± 3.07	24.43 ± 1.35 *

* Indicates significant difference from pre-test ($p < 0.05$); + indicates significant difference from CG ($p < 0.05$).

Table 5 presents the performances recorded on both the experimental and control groups before and after the intervention period during the small, sided game. For offensive balls post-intervention, there was a main effect of group ($F_{1,17} = 11.73$; $p = 0.003$; $\eta_p^2 = 0.408$), with performance values being higher for VMG compared to CG (95%CI_{dif} = 1.6 to 6.8; $d = 1.81$; $p = 0.003$). For the number of attack balls index post-intervention, there was a main effect of group ($F_{1,17} = 16.66$; $p = 0.001$; $\eta_p^2 = 0.495$), with performance values recording higher for VMG compared to CG (95%CI_{dif} = 3.1 to 9.8; $d = 0.28$; $p = 0.001$).

Table 5. Technical performances recorded in the small, sided games for both the video modeling group (VMG) and control group (CG) before and after the intervention period (Values are mean ± SD; $n = 20$).

	CG ($n = 10$)		VMG ($n = 10$)	
	Pre-Test	**Post-Test**	**Pre-Test**	**Post-Test**
CB	7 ± 3	7 ± 3	6 ± 3	6 ± 2
RB	10 ± 2	8 ± 2	8 ± 3	9 ± 2
LB	6 ± 2	8 ± 2 †	6 ± 3 *	4 ± 1 *+
OB	14 ± 5	12 ± 3	7 ± 3	12 ± 4 *
SS	1 ± 2	1 ± 2	1 ± 1	3 ± 2
AB	15 ± 6	14 ± 4	8 ± 4	15 ± 6 *
PB	16 ± 4	15 ± 4	14 ± 5	16 ± 2
Efficiency Index	1.3 ± 0.6	1.1 ± 0.4	0.97 ± 0.4	1.5 ± 0.5 ¶

* Indicates a significant difference from CG ($p < 0.05$); + indicates lower values after the intervention compared to CG ($p < 0.05$); † indicates higher values for CG post-intervention compared to before ($p < 0.05$); ¶ indicates higher values for VMG post-intervention compared to pre ($p < 0.05$). CB: conquering the ball; RB: receiving the ball; LB: loosed ball; OB: offensive ball; SS: successful shot; AB: attacking ball; PB: volume of play.

4. Discussion

The aim of the present study was to investigate the effects of adding video modeling during four weeks of a basketball training program on individual technical performances assessed by the Basketball Skill Test-American Alliance for Health, Physical Education, Recreation and Dance (i.e., passing, shooting, dribbling, and defense) and collective aspects assessed by the three vs. three small-sided games (i.e., conquering the ball, receiving the ball, losing the ball, successful shorts, the volume of play, the number of attacking balls, volume of play, and the efficiency index) among young novice basketball players.

The results revealed that the VMG reported a significant improvement over the control group on the passing test. Nevertheless, the dribbling and the defensive movement test showed lower values after the intervention, indicating a potentially negative effect on these skills. Additionally, regarding collective game performance, results showed that VMG resulted in higher offensive balls, number of attack balls index, and lower ball loss compared to the control group and that the efficiency index was higher for VMG after the intervention compared to before. These results partially confirm our hypothesis.

The results recorded in the present study confirm those reported in several previous studies that confirmed that incorporating VM was a good strategy to induce beneficial improvements in terms of specific skills in both individuals (e.g., gymnastics, weightlifting) [15,16,53], and team sports such as soccer and basketball [54–56]. Specifically, in basketball, passing skills were found to be higher in VMG compared to CG. While these results cannot absolutely confirm the effectiveness of VMG compared to CG in improving this technique (i.e., no interaction effect between the groups and the time of measurement), it can open a window to focus more on this strategy as a way to improve basketball skills within young players. In this consideration, results from previous studies supported the efficacy of using video modeling in improving passing skills in school settings [20,22]. The improvement in the VMG can be explained by the state of motivation within these young players when watching skilled athletes executing this technique in addition to the importance of this technique which is one of the most important technical aspects of basketball performance [57–59]. This perspective conforms to social learning theory, which suggests that individuals may learn by observing others' behaviors and the consequences of that behavior [3,60]. However, it should be noted that the dribbling and defensive movement tests showed lower values after the intervention, indicating a potentially negative effect on these skills; this finding is not consistent with previous research which showed that video modeling was effective in improving basketball players' performance in dribbling and defensive skills (e.g., [61]). One possible explanation for this finding is that the video modeling intervention may have overemphasized passing skills at the expense of other important technical skills. It is also possible that the relatively short duration of the intervention (4 weeks) was not sufficient to produce significant improvements in all technical skills.

More interestingly, in terms of collective performance, the results showed that VMG increased the number of offensive balls and the index of the number of attacking balls, and reduced ball losses compared to the control group. In addition, the efficiency index was higher for VMG after the intervention than before. These results suggest that video modeling can be an effective tool for improving collective game performance in young novice basketball players. This is consistent with previous research that has shown the benefits of video modeling to improve team cohesion, communication, and decision-making [62,63]. Contrary to our results, Panchuk et al. [19] showed that following an immersive video intervention, individual technical performances (i.e., number of successful passes, assists, hockey assists, contested shots, deflected passes, passing turnovers, and dribbling turnovers) recorded during small-sided games did not improve compared to the control group [19]. This inconsistent result may be attributed to the difference in the competition level of participants (elite vs. novice players in the current study), type of the video modeling used, and the duration of the training intervention. Nevertheless, the results of the present study underline how much is important to assist young novice basketball players during their technical-tactical training processes using technology such as video modeling. The decrease in lost balls during small-sided games may be attributed to passing skill improvement which was assessed using AAHPERD [43].

Strengths and Limitations

The main strengths of the study were that we used objective measures of performance (e.g., passing test, offensive balls, loss of the ball) rather than relying on subjective assessments. In addition, the study used a training program designed in an ecologically valid environment with real-field-based learning experiences that could easily be replicated by coaches and trainers. However, we acknowledge some limitations of this study. First, the participants were novice players, which may restrict the generalization of the results. Again, the study sample was mainly males, and this calls for further comparative investigations across gender to ascertain motor skill learning variations. Moreover, the duration of the study was only four weeks, which may not have been long enough to induce significant improvements in other individual techniques that may require more training periods to be improved. Further, a retention test was also not included as part of the experimental protocol which restricts the long-term motor learning effects of an intervention. Usually, a standardized motor learning process has three distinct phases: acquisition, retention, and a transfer phase, where teachers are encouraged to intensify the complexity of preceding motor tasks and/ or situations (i.e., simple to complex) [64,65].

Future studies could incorporate these measures using longitudinal designs to investigate patterns across gender.

5. Conclusions

The results of the present study showed that a training program based on video modeling improved performance on the passing test, as well as offensive balls. Additionally, the number of post-intervention offensive ball indices was higher for VMG than for CG. For ball loss, VMG induced lower values than CG post-intervention. The efficiency index was higher after training than before training for VMG. The results of the study may be a useful tool for coaches in designing effective training programs that seeks to develop the individual and collective technical skills of their players which are keys to success in basketball. As well, four weeks of video modeling with a frequency of four sessions per week was effective to improve some technical skills, while others were not improved. Further studies are required to evaluate the progression of young players following a training program using video modeling for an extended period.

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Institutional Review Board Statement: Following adherence to the last Declaration of Helsinki (2013), the protocol was fully approved by a local research ethics committee of the Higher Institute of Sport and Physical Education of Kef, University of Jendouba, kef, Tunisia, with reference number (n° 050/2022) dated 14 December 2022. Afterwards, permission was sought from the management and coaches of the basketball regional team to allow their players to be selected to participate in the study.

Informed Consent Statement: After obtaining a complete overview of the aims, advantages, and potential risks associated with the investigation, players and their parents signed a written informed consent/assent form.

Data Availability Statement: The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

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References

1. Pino-Ortega, J.; Oliva-Lozano, J.M.; Gantois, P.; Nakamura, F.Y.; Rico-Gonzalez, M. Comparison of the validity and reliability of local positioning systems against other tracking technologies in team sport: A systematic review. *Proc. Inst. Mech. Eng. Part P J. Sport. Eng. Technol.* **2022**, *236*, 73–82. [CrossRef]
2. Putranto, J.S.; Heriyanto, J.; Achmad, S.; Kurniawan, A. Implementation of virtual reality technology for sports education and training: Systematic literature review. *Procedia Comput. Sci.* **2023**, *216*, 293–300. [CrossRef]
3. Bandura, A. Self-regulation of motivation through anticipatory and self-reactive mechanisms. In *Nebraska Symposium on Motivation, 1990: Perspectives on Motivation*; University of Nebraska Press: Lincoln, NE, USA, 1991.
4. Bandura, A.; Huston, A.C. Identification as a process of incidental learning. *J. Abnorm. Soc. Psychol.* **1961**, *63*, 311. [CrossRef] [PubMed]
5. Ives, J.C.; Straub, W.F.; Shelley, G.A. Enhancing athletic performance using digital video in consulting. *J. Appl. Sport Psychol.* **2002**, *14*, 237–245. [CrossRef]
6. Mödinger, M.; Woll, A.; Wagner, I. Video-based visual feedback to enhance motor learning in physical education—A systematic review. *Ger. J. Exerc. Sport Res.* **2022**, *52*, 447–460. [CrossRef]
7. Vignais, N.; Kulpa, R.; Brault, S.; Presse, D.; Bideau, B. Which technology to investigate visual perception in sport: Video vs. virtual reality. *Hum. Mov. Sci.* **2015**, *39*, 12–26. [CrossRef]

8. Maslovat, D.; Hayes, S.; Horn, R.; Hodges, N.J. Motor learning through observation. In *Vision and Goal-Directed Movement: Neurobehavioral Perspectives*; Human Kinetics: Champaign, IL, USA, 2010; pp. 315–340.
9. Boyer, E.; Miltenberger, R.G.; Batsche, C.; Fogel, V.; LeBlanc, L. Video modeling by experts with video feedback to enhance gymnastics skills. *J. Appl. Behav. Anal.* **2009**, *42*, 855–860. [CrossRef]
10. Darden, G.F. Videotape feedback for student learning and performance: A learning-stages approach. *J. Phys. Educ. Recreat. Danc.* **1999**, *70*, 40–45. [CrossRef]
11. Leight, J.; Banville, D.; Polifko, M.F. Using digital video recorders in physical education. *J. Phys. Educ. Recreat. Danc.* **2009**, *80*, 17–21. [CrossRef]
12. Born, P.; Ger, T.V. Video analysis and video feedback in tennis: Using mobile devices to benefit digital teaching and learning. *Coach. Sport Sci. Rev.* **2018**, *75*, 29–30.
13. Rizzo, J.-R.; Hosseini, M.; Wong, E.A.; Mackey, W.E.; Fung, J.K.; Ahdoot, E.; Rucker, J.C.; Raghavan, P.; Landy, M.S.; Hudson, T.E. The intersection between ocular and manual motor control: Eye–hand coordination in acquired brain injury. *Front. Neurol.* **2017**, *8*, 227. [CrossRef] [PubMed]
14. Bouazizi, M.; Azaiez, F.; Boudhiba, D. Effects of learning by video modeling on gymnastic performances among Tunisian students in the second year of secondary level. *IOSR J. Sport. Phys. Educ.* **2014**, *1*, 05–08. [CrossRef]
15. Trabelsi, O.; Gharbi, A.; Souissi, M.A.; Mezghanni, N.; Bouchiba, M.; Mrayeh, M. Video modeling examples are effective tools for self-regulated learning in physical education: Students learn through repeated viewing, self-talk, and mental rehearsal. *Eur. Phys. Educ. Rev.* **2022**, *28*, 341–360. [CrossRef]
16. Souissi, M.A.; Souissi, H.; Elghoul, Y.; Masmoudi, L.; Trabelsi, O.; Ammar, A.; Chtourou, H.; Souissi, N. Information Processing and Technical Knowledge Contribute to Self-Controlled Video Feedback for Children Learning the Snatch Movement in Weightlifting. *Percept. Mot. Ski.* **2021**, *128*, 1785–1805. [CrossRef] [PubMed]
17. Atienza, F.L.; Balaguer, I.; García-Merita, M.L. Video modeling and imaging training on performance of tennis service of 9-to 12-year-old children. *Percept. Mot. Ski.* **1998**, *87*, 519–529. [CrossRef]
18. Aiken, C.; Fairbrother, J.; Post, P. The Effects of Self-Controlled Video Feedback on the Learning of the Basketball Set Shot. *Front. Psychol.* **2012**, *3*, 338. Available online: https://www.frontiersin.org/articles/10.3389/fpsyg.2012.00338 (accessed on 13 November 2022). [CrossRef]
19. Panchuk, D.; Klusemann, M.J.; Hadlow, S.M. Exploring the effectiveness of immersive video for training decision-making capability in elite, youth basketball players. *Front. Psychol.* **2018**, *9*, 2315. [CrossRef]
20. Rekik, G.; Belkhir, Y.; Mezghanni, N.; Jarraya, M.; Chen, Y.S.; Kuo, C.D. Learning Basketball Tactical Actions from Video Modeling and Static Pictures: When Gender Matters. *Children* **2021**, *8*, 1060. [CrossRef]
21. Rekik, G.; Khacharem, A.; Belkhir, Y.; Bali, N.; Jarraya, M. The effect of visualization format and content complexity on acquisition of tactical actions in basketball. *Learn. Motiv.* **2019**, *65*, 10–19. [CrossRef]
22. Jarraya, M.; Rekik, G.; Belkhir, Y.; Chtourou, H.; Nikolaidis, P.T.; Rosemann, T.; Knechtle, B. Which Presentation Speed Is Better for Learning Basketball Tactical Actions Through Video Modeling Examples? The Influence of Content Complexity. *Front. Psychol.* **2019**, *10*, 2356. Available online: https://www.frontiersin.org/articles/10.3389/fpsyg.2019.02356 (accessed on 12 November 2022). [CrossRef]
23. Koekoek, J.; van der Kamp, J.; Walinga, W.; van Hilvoorde, I. Exploring students' perceptions of video-guided debates in a game-based basketball setting. *Phys. Educ. Sport Pedagog.* **2019**, *24*, 519–533. [CrossRef]
24. BenitezSantiago, A.; Miltenberger, R.G. Using video feedback to improve martial arts performance. *Behav. Interv.* **2016**, *31*, 12–27. [CrossRef]
25. Middlemas, S.; Harwood, C. No place to hide: Football players' and coaches' perceptions of the psychological factors influencing video feedback. *J. Appl. Sport Psychol.* **2018**, *30*, 23–44. [CrossRef]
26. Capalbo, A.; Miltenberger, R.G.; Cook, J.L. Training soccer goalkeeping skills: Is video modeling enough? *J. Appl. Behav. Anal.* **2022**, *55*, 958–970. [CrossRef] [PubMed]
27. Xu, C.; Fu, Y.; Zhang, B.; Chen, Z.; Jiang, Y.G.; Xue, X. Learning to score figure skating sport videos. *IEEE Trans. Circuits Syst. Video Technol.* **2019**, *30*, 4578–4590. [CrossRef]
28. Bruton, A.M.; Mellalieu, S.D.; Shearer, D.A. Observation as a method to enhance collective efficacy: An integrative review. *Psychol. Sport Exerc.* **2016**, *24*, 1–8. [CrossRef]
29. Shearer, D.A.; Leeworthy, S.; Jones, S.; Rickards, E.; Blake, M.; Heirene, R.M.; Gross, M.J.; Bruton, A.M. There is an "eye" in team: Exploring the interplay between emotion, gaze behavior, and collective efficacy in team sport settings. *Front. Sport. Act. Living* **2020**, *2*, 18. [CrossRef]
30. Roman, I.R.; Molinuevo, J.S.; Quintana, M.S. The relationship between exercise intensity and performance in drills aimed at improving the proficiency, technical and tactical skills of basketball players. *RICYDE Rev. Int. Cienc. Deporte* **2009**, *14*, 1–10.
31. Sansone, P.; Tessitore, A.; Lukonaitiene, I.; Paulauskas, H.; Tschan, H.; Conte, D. Technical-tactical profile, perceived exertion, mental demands and enjoyment of different tactical tasks and training regimes in basketball small-sided games. *Biol. Sport* **2020**, *37*, 15–23. [CrossRef]
32. Cheng, S.; Kosidou, K.; Burström, B.; Björkenstam, C.; Pebley, A.R.; Björkenstam, E. Precarious childhoods: Childhood family income volatility and mental health in early adulthood. *Soc. Forces* **2020**, *99*, 672–699. [CrossRef]

33. Buck, D.J.; Hutchinson, J.C.; Winter, C.R.; Thompson, B.A. The effects of mental imagery with video-modeling on self-efficacy and maximal front squat ability. *Sports* **2016**, *4*, 23. [CrossRef]
34. O'Loughlin, J.; Chróinín, D.N.; O'Grady, D. Digital video: The impact on children's learning experiences in primary physical education. *Eur. Phys. Educ. Rev.* **2013**, *19*, 165–182. [CrossRef]
35. Wulf, G.; Raupach, M.; Pfeiffer, F. Self-Controlled Observational Practice Enhances Learning. *Res. Q. Exerc. Sport* **2005**, *76*, 107–111. [CrossRef]
36. Ranker, J.; Mills, K. New directions for digital video creation in the classroom: Spatiality, embodiment, and creativity. *J. Adolesc. Adult Lit.* **2014**, *57*, 440–443. [CrossRef]
37. Huang, C.; Zhang, Y.; Zhu, C.; Zhang, C.; Meng, H. Chinese sports basketball teaching tactics training system combined with multimedia interactive model and virtual reality technology. *Multimed. Tools Appl.* **2019**, 1–15. [CrossRef]
38. Kardas, M.; O'Brien, E. Easier seen than done: Merely watching others perform can foster an illusion of skill acquisition. *Psychol. Sci.* **2018**, *29*, 521–536. [CrossRef]
39. Asadi, A.; Daneshfar, A.; Maleki, B.; Aiken, C. Effects of attentional focus and gaze instruction during observational learning of a basketball free-throw. *Hum. Mov. Sci.* **2023**, *87*, 103038. [CrossRef]
40. Erčulj, F.; Štrumbelj, E. Basketball shot types and shot success in different levels of competitive basketball. *PLoS ONE* **2015**, *10*, e0128885. [CrossRef]
41. McCullagh, P.; Weiss, M.R. Modeling: Considerations for motor skill performance and psychological responses. In *Handbook of Sport Psychology*; Wiley: New York, NY, USA, 2001; pp. 205–238.
42. Barzouka, K.; Sotiropoulos, K.; Kioumourtzoglou, E. The effect of feedback through an expert model observation on performance and learning the pass skill in volleyball and motivation. *J. Phys. Educ. Sport* **2015**, *15*, 407–416.
43. Hopkins, D.; Shick, J.; Plack, J. *Aahperd Skills Test Manual: Basketball for Boys and Girls*; AAHPERD: Reston, VA, USA, 1984; pp. 5–17.
44. Diniz, L.B.F.; da Glória Teles Bredt, S.; Praça, G.M. Influence of non-scorer floater and numerical superiority on novices' tactical behaviour and skill efficacy during basketball small-sided games. *Int. J. Sport. Sci. Coach.* **2022**, *17*, 37–45. [CrossRef]
45. McCormick, B.T.; Hannon, J.C.; Newton, M.; Shultz, B.; Miller, N.; Young, W. Comparison of physical activity in small-sided basketball games versus full-sided games. *Int. J. Sport. Sci. Coach.* **2012**, *7*, 689–697. [CrossRef]
46. Grehaigne, J.F.; Godbout, P.; Bouthier, D. Performance assessment in team sports. *J. Teach. Phys. Educ.* **1997**, *16*, 500–516. [CrossRef]
47. Bredt, S.G.T.; Morales, J.C.P.; Andrade, A.G.P.; Torres, J.O.; Peixoto, G.H.; Greco, P.J.; Praça, G.M.; Chagas, M.H. Space creation dynamics in basketball small-sided games. *Percept. Mot. Ski.* **2018**, *125*, 162–176. [CrossRef] [PubMed]
48. Ziv, G.; Lidor, R. Physical characteristics, physiological attributes, and on-court performances of handball players: A review. *Eur. J. Sport Sci.* **2009**, *9*, 375–386. [CrossRef]
49. Magill, R.; Anderson, D.I. *Motor Learning and Control*; McGraw-Hill Publishing: New York, NY, USA, 2010.
50. Ong, N.T.; Hodges, N.J. Mixing it up a little: How to schedule observational practice. In *Skill Acquisition in Sport*; Routledge: London, UK, 2012; pp. 48–65.
51. Cohen, J. Set correlation and multivariate methods. In *Statistical Power Analysis for the Behavioral Sciences*, 2nd ed.; Lawrence Erlbaum Associates, Inc.: Hillsdale, NJ, USA, 1988; pp. 467–530.
52. Hopkins, W. Probabilities of Clinical or Practical Significance', Sportscience, 6, p. Available online: https://www.Sportsciorg/jour/0201/wghprobhtm (accessed on 29 October 2022).
53. Lawrence, G.; Callow, N.; Roberts, R. Watch me if you can: Imagery ability moderates observational learning effectiveness. *Front. Hum. Neurosci.* **2013**, *7*, 522. [CrossRef]
54. Bray, K.; Kerwin, D. Modelling the flight of a soccer ball in a direct free kick. *J. Sport. Sci.* **2003**, *21*, 75–85. [CrossRef]
55. Figueira, B.; Mateus, N.; Esteves, P.; Dadelienė, R.; Paulauskas, R. Physiological responses and technical-tactical performance of youth basketball players: A brief comparison between 3x3 and 5x5 basketball. *J. Sport. Sci. Med.* **2022**, *21*, 332. [CrossRef]
56. Janelle, C.M.; Champenoy, J.D.; Coombes, S.A.; Mousseau, M.B. Mechanisms of attentional cueing during observational learning to facilitate motor skill acquisition. *J. Sport. Sci.* **2003**, *21*, 825–838. [CrossRef]
57. Howe, B.; Poole, R. Goal proximity and achievement motivation of high school boys in a basketball shooting task. *J. Teach. Phys. Educ.* **1992**, *11*, 248–255. [CrossRef]
58. Mulvenna, M.; Adie, J.W.; Sage, L.D.; Wilson, N.E.; Howat, D. Approach-achievement goals and motivational context on psycho-physiological functioning and performance among novice basketball players. *Psychol. Sport Exerc.* **2020**, *51*, 101714. [CrossRef]
59. Willer, R.; Sharkey, A.; Frey, S. Reciprocity on the hardwood: Passing patterns among professional basketball players. *PLoS ONE* **2012**, *7*, e49807. [CrossRef]
60. Rumjaun, A.; Narod, F. Social Learning Theory—Albert Bandura. In *Science Education in Theory and Practice: An Introductory Guide to Learning Theory*; Springer Nature: Berlin, Germany, 2020; pp. 85–99.
61. Hodges, N.J.; Williams, A.M.; Hayes, S.J.; Breslin, G. What is modelled during observational learning? *J. Sport. Sci.* **2007**, *25*, 531–545. [CrossRef]
62. Memmert, D.; Roth, K. The effects of non-specific and specific concepts on tactical creativity in team ball sports. *J. Sport. Sci.* **2007**, *25*, 1423–1432. [CrossRef]

63. Stanton, N.A.; Ashleigh, M.J.; Roberts, A.D.; Xu, F. Testing Hollnagel's contextual control model: Assessing team behaviour in a human supervisory control task. *J. Cogn. Ergon.* **2001**, *5*, 21–33. [CrossRef]
64. Bissonnette, S.; Richard, M. *Les Trois Phases du Processus d'Apprentissage*; Morin, G., Ed.; Chenelière Éducation: Montreal, QC, Canada, 2005.
65. Srem-Sai, M.; Hagan, J.E.; Jatong, A.B.; Schack, T. Assessment of Random and Blocked Practice Schedules on Motor Skills' Acquisition, Retention and Transfer Among Selected Senior High School Students. *Am. J. Sport. Sci.* **2019**, *7*, 26–33.

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Article

Exploring the Effects of Tasks with Different Decision-Making Levels on Ball Control, Passing Performance, and External Load in Youth Football

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Abstract: This study aimed to understand how the design of decision-making tasks affects youth football players' ball control, passing performance, and external load. A total of 16 male youth football players (age: 12.94 ± 0.25 years) competed in various tasks based on the following levels of decision-making: (i) low decision-making (Low DM), which consisted of a predefined ball control and passing sequence; (ii) moderate decision-making (Mod DM), which consisted of maintaining possession in a square with four players and two balls while maintaining the same position; and (iii) high decision-making (High DM), which consisted of a 3 vs. 3 + 2 neutral players ball possession game. The study design consisted of a pre–post design (a 6 min pre-test game, a 6 min intervention, and a 6 min post-test game). The players' ball control and passing performance were measured using the game performance evaluation tool and notational analysis, while GPS data were used to determine their physical performance. The pre–post test analysis revealed decrements in players' ability to identify more offensive players after the Mod DM task (W = 9.50, p = 0.016), while there was an increase in their ability to receive the ball towards the space following the High DM task (t = −2.40, p = 0.016). Analysis between groups showed lower values in most ball control variables for the Low DM task compared to the Mod DM task (ball control execution, p = 0.030; appropriateness, p = 0.031; motor space, p = 0.025), while there were also lower values in the distance covered while sprinting (p = 0.042). Overall, prescriptive tasks (Low DM) that are repetitive in nature may affect players' perceptual attunement, whereas static tasks (e.g., Mod DM) may limit their ability to locate players in more offensive positions. Moreover, game-based situations (High DM) seem to acutely enhance players' performance, possibly due to contextual dependency. Overall, coaches should carefully consider the type of practice structure when designing tasks that aim to improve players' technical skills in youth football.

Keywords: perception–action; training tasks; technical performance; ball control; passing behaviour; team sports

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1. Introduction

Association football is a sport where two teams compete dynamically in space and time to unfold goal-direction behaviours [1,2]. To this end, players adjust their positioning and behaviour according to the spatiotemporal information that they perceive, such as the distance and angle between teammates and opponents [2,3]. In this view, opportunities for action (i.e., *affordances*) constantly change according to variations in the context of play or in the player's exploration of the environment [4,5]. Thus, successful performance in team sports appears to depend on players' positioning to perceive and act. This emphasises the importance of decision-making (DM) processes in order to succeed within specific competitive environments.

To improve players' skills, a wide body of research has explored how different training approaches impact players' development. Traditionally, training approaches in team sports have adopted analytical tasks by prescribing specific movement patterns that reduce DM, as players' actions are often predetermined [6,7]. For example, from a technical perspective, players are often exposed to repetitive blocked practices (e.g., groups of two players passing the ball to one another in a static position), which decrease attentional demands [8,9]. These activities are usually performed during earlier phases of the training session and/or learning phase [8,10–12], following which the players are exposed to game-based scenarios where it is expected that such skills are transferred [13–15]. However, this approach has received criticism because it decouples perception from action [8], preventing individuals from perceiving when or how to use such skills [6,13].

More recently, small-sided games have been suggested as an appropriate and relevant training tool, as they allow for concomitant development of players' technical, physical, and tactical aspects of play [16,17]. In addition, coaches can vary the boundary conditions during these game-based scenarios to emphasise specific behaviours [18]. For example, coaches may reduce the size of the pitch to increase the frequency of ball control [19] and passing actions [20], or they may even limit the number of touches to encourage passing behaviour [21]. However, most studies that have explored game-based situations focus on the frequency of actions, without considering DM [22,23]. Developing a better understanding of the effects that different tasks may have on such skills may help coaches to tailor more appropriate training interventions.

When considering a player's development, mainly at younger ages (i.e., under-7 (U7) to U14), one major focus is on developing their technical capabilities [24,25]. Based on these technical skills, the ability to control [26,27] and pass the ball [28,29] are among the most relevant to be successful and attain higher performance levels [26,30–32]. Previous results exploring the DM and execution of passing behaviour showed that older players (U12/14) revealed higher values when compared to their younger counterparts (U8/U10) [33]. First, these findings suggest that players within the U12/14 category have a higher tactical awareness that allows them to locate relevant solutions within a competitive environment; second, coaches should design training practices that require such skills. In this respect, several studies have explored different training strategies to develop players' DM and execution of ball control or passing skills [34–37]. For example, Práxedes, Moreno, Gil-Arias, Claver, and Del Villar [36] displayed how the DM and pass execution of U12 football players improved after the practice of a numerical superiority exercise.

Despite the growing contribution of research to understanding how different training interventions affect youth players' ball control and passing performance [34–36,38], less scientific information is available in relation to the acute effects that different types of training tasks (i.e., more prescriptive or game-based) may have. For instance, despite game-based situations having been suggested as practices that may be more relevant to prepare players to act during competitive performances, coaches of youth players still spend a vast amount of time using prescriptive and repetitive tasks [39]. Therefore, it is important to explore the role of such training tasks to better understand players' motor execution and DM [40]. Thus, this study aimed to examine how the manipulation of contextual dependency and DM affects players' positioning and subsequent ball control, passing performance, and external load during SSGs. It was hypothesised that tasks with low-to-moderate DM would ensure low ball control and passing performance transfer to subsequent competitive tasks, due to the lower contextual dependency and DM. Additionally, it was expected that training tasks that required lower DM would lead to higher decrements in players' performance compared to tasks that required higher levels of DM. Lastly, it was expected that the type of training task adopted would lead to different effects on the players' ability to control or pass the ball, as well as on their physical performance.

2. Materials and Methods

2.1. Participants

A total of 20 youth male football players (age = 12.94 ± 0.25 years; height = 155.75 ± 6.24 cm; weight = 45.13 ± 9.62 kg; football experience = 5.56 ± 1.9 years) from a Portuguese club competing at the regional level volunteered to participate in this study. All players belonged to the same club, engaged in three training sessions per week (~90 min per training session), and played an official 11-a-side match during the weekend. Four goalkeepers participated in the study; however, considering their specific positioning on the pitch (i.e., a more regular and static positioning), their data were excluded from the data analysis. The participants included additional players who were subsequently excluded as a result of (i) injury or illness prior to the data collection (n = 1) and (ii) reporting an intention to not be present at one of the data collection sessions (n = 3). Informed and written consent was provided by the club, the head coach, the players, and their legal guardians before the start of the data collection. The study protocol adhered to the guidelines of the ethics committee of the local university and the recommendations of the Declaration of Helsinki.

2.2. Procedures

This study explored the acute effects of exposing the players to different positioning and passing tasks. For this purpose, players were exposed to a pre–post test design. Accordingly, the players performed one SSG bout followed by one of three possible experimental intervention tasks: (i) low DM (Low DM), (ii) moderate DM (Mod DM), and (iii) high DM (High DM). The players then performed one additional SSG bout under the same conditions to understand how these training tasks acutely modified the players' ball control, passing performance, and external load. The players were tested in a total of seven sessions on non-consecutive days (i.e., across four weeks on their 18:30–20:00 h Monday and Thursday sessions) during the competitive period (mid-season; November–December from the 2022–2023 season). The first session was developed for familiarisation purposes.

On all days, the sessions began with a standardised 15 min warm-up consisting of mobility-based movements and a possession game (4 vs. 4 without goals). Following the warm-up, the players were allocated to one of the pitches (Pitch 1, Team A vs. Team B; Pitch 2, Team C vs. Team D) to perform a Gk + 4 vs. 4 + Gk SSG using official 7-a-side goals on a 40 × 30 m artificial turf pitch (length × width ratio = 1.33). The game lasted for 4 min and was used to assess the players' performance prior to the training intervention (pre-test). Several official-sized footballs were placed near the pitch's external lines to guarantee the ball's fast replacement, decreasing the time spent out of play. No coach feedback or encouragement was allowed during the pre- and post-test SSGs (i.e., during the game situations used to measure the players' performance, so as not to affect the players' performance). The SSG was performed according to the official FIFA rules on an outdoor artificial turf pitch, with the following exceptions: (i) the game restarted by the corresponding goalkeeper when a goal was scored or when the ball left the pitch by the end line, allowing a faster restart; and (ii) no offside rule was applied. After the pre-test, the players had a 2 min rest period, in which they were encouraged to drink water, followed by the 6 min intervention tasks (Low, Mod, and High DM) in a random order set using random.org. Lastly, the SSG was repeated 2 min after the intervention to inspect how the intervention acutely impacted the players' performance (post-test) (Figure 1a).

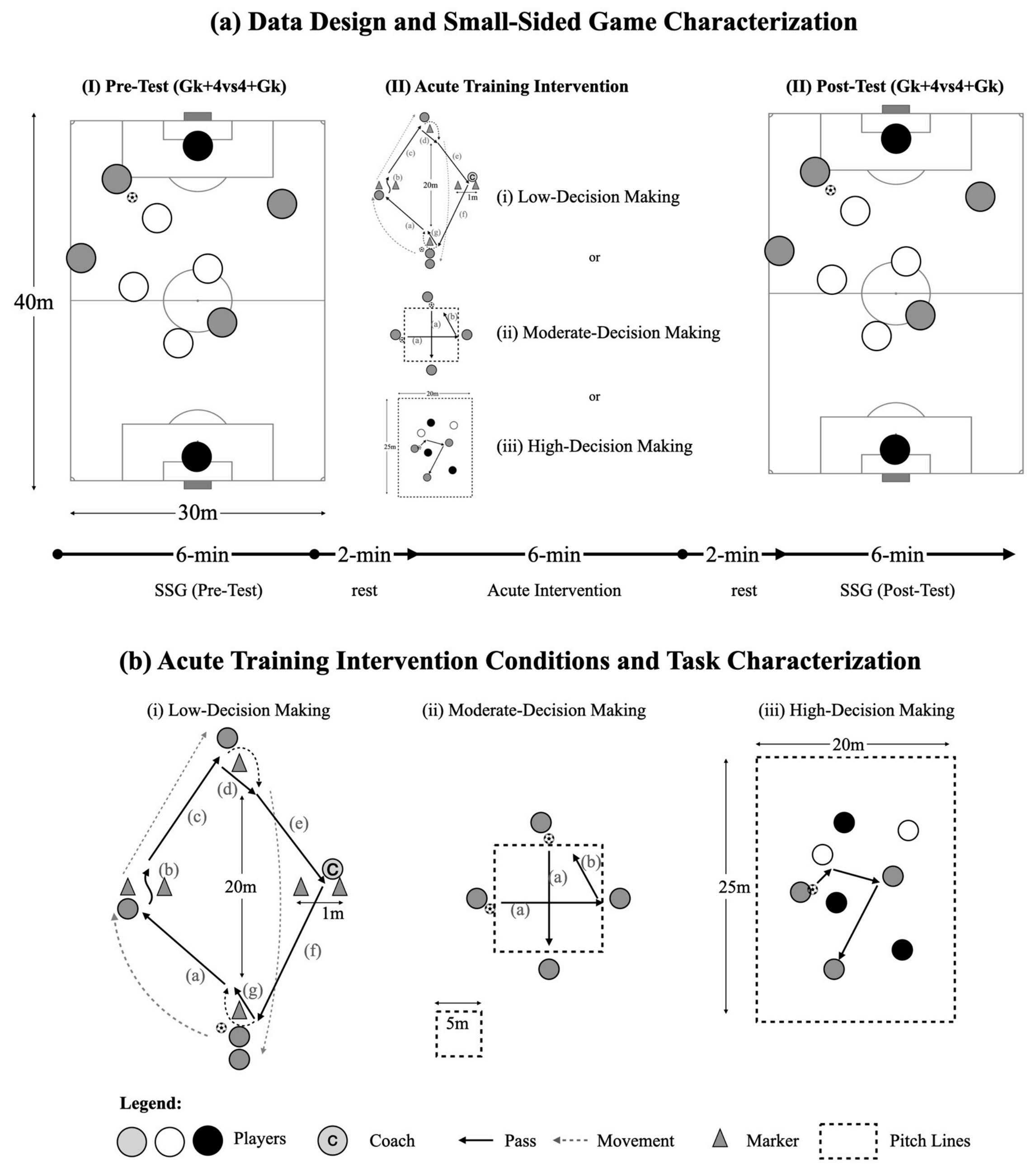

Figure 1. Representation of data design and acute training interventions.

2.3. Training Intervention

For the purpose of the study, the players were exposed to three experimental conditions (see Figure 1). First, during the Low DM conditions, the players performed a prescribed drill focused on positioning, the orientation of ball reception that is, oriented ball reception at first touch between the markers and then pass the ball towards the following teammate.. Players were constantly instructed to maintain the passing rhythm and correctly perform a high number of passes using the foot to open space to progress between the markers (Figure 1b, left panel). Second, during the Mod DM conditions, each player was required to adjust their positioning, the orientation of ball reception, and their passing to maintain the possession of two balls simultaneously [41] in a square of 5 × 5 m. Players were constantly encouraged by the head researcher (i.e., UEFA A holder with more than 15 years of training experience) to orient their bodies according to the ball's location, to receive the ball oriented, and to always pass according to the other ball's location, avoiding one player having two balls (Figure 1b, middle panel). Lastly, during the High DM conditions, the players performed a ball possession game consisting of a 3 vs. 3 + 2 neutral players on a 25 × 20 m pitch [20], while also playing two mandatory touches to stress body orientation, ball control, and passing ability [21]. The players were constantly encouraged to orient their bodies to view all teammates, to receive the ball oriented to open space, and to pass the ball to the free teammate and ensure ball possession (Figure 1b, right panel).

Before these tasks, the lead researcher (first author) provided feedback to the players regarding orientation, ball control, and passing action. In this respect, for the body orientation, the players were always encouraged to see all of their teammates and to receive the ball with their body oriented to the following passing direction and the opponent's target. For the ball control, players were encouraged in terms of (i) the ability to receive the ball with the body surface in such a way as to guarantee better conditions in terms of space and time to decide (e.g., using the right foot while playing in the right wide channel, rather than the left foot, which may limit passing opportunities), and (ii) having the ball in the motor space, which relates to the ability to retain possession by controlling the body's stiffness (e.g., being able to cushion the ball when receiving a hard ball, or to push the ball forward if it comes soft). In contrast, for the passing behaviour, the players were encouraged in terms of (i) the importance of considering how far forward the free teammate is from the closest defender (e.g., exploring passes to the wide channel to move the defenders so as to further explore the centre channel); (ii) offensive solutions, including being able to identify a player that may allow progress towards the opposing target, or to destabilise the opposing team's defensive behaviour and compactness (e.g., passing the ball to the centre channel to attract opposition to further perform a pass towards a free teammate); and (iii) rhythm and tempo, which relates to being able to adjust the passing length, speed, and direction according to the teammates' and opponents' movements, mainly by reinforcing the pass towards the front of the free teammate.

2.4. Data Collection

2.4.1. Ball Control, Passing Execution, and Decision-Making (GPET)

The SSGs were recorded using two digital video cameras (Panasonic NV-GS230) positioned at a height of 2 m and aligned with the central section of the pitch. The LongoMatch software, version 1.3.7 (LongoMatch, Fluendo, Barcelona, Spain), was used for the notational analysis of the players' ball control and passing performance.

The players' execution and decision-making ability were measured using the game performance evaluation tool (GPET) [42]. This tool has been used to measure players' DM and execution during youth soccer SSGs [36,42,43]. The execution of ball control was coded as 0 if the player was not able to properly control the ball within their motor space (e.g., ball bouncing to another teammate or opposing player), while it was coded as 1 if they were able to control it to play further (i.e., pass, travel with the ball, dribble, or shoot) [42]. Regarding the pass, the decision-making was coded as 0 if the pass was performed to a teammate closely marked by an opponent or executed to an area of a pitch without any teammate (see Figure 2f), while a value of 1 was awarded if the pass was performed to a free teammate (see Figure 2e,g). The motor execution of the pass was coded as 0 if the pass did not reach the target player (see Figure 2i), while it was coded as 1 if the pass reached the target teammate (see Figure 2d,e for reference). Both the DM (of the passing) and motor execution (from ball control and passing behaviour) were then presented as the percentage of successful related decisions over the total number of actions performed (e.g., the motor execution for the pass was coded as: successful passes/(successful passes + unsuccessful passes)) [44]. A total of 918 actions were recorded (ball control motor execution n = 450; passing behaviour motor n = 468). All videos were coded by the same expert analyst, with more than 10 years of experience in training and match analysis. The intra-observer correlation was developed considering 10% of the sample. The values ranged from 0.83 to 0.94 for the different categories, which were deemed high and within the thresholds presented in previous reports [42].

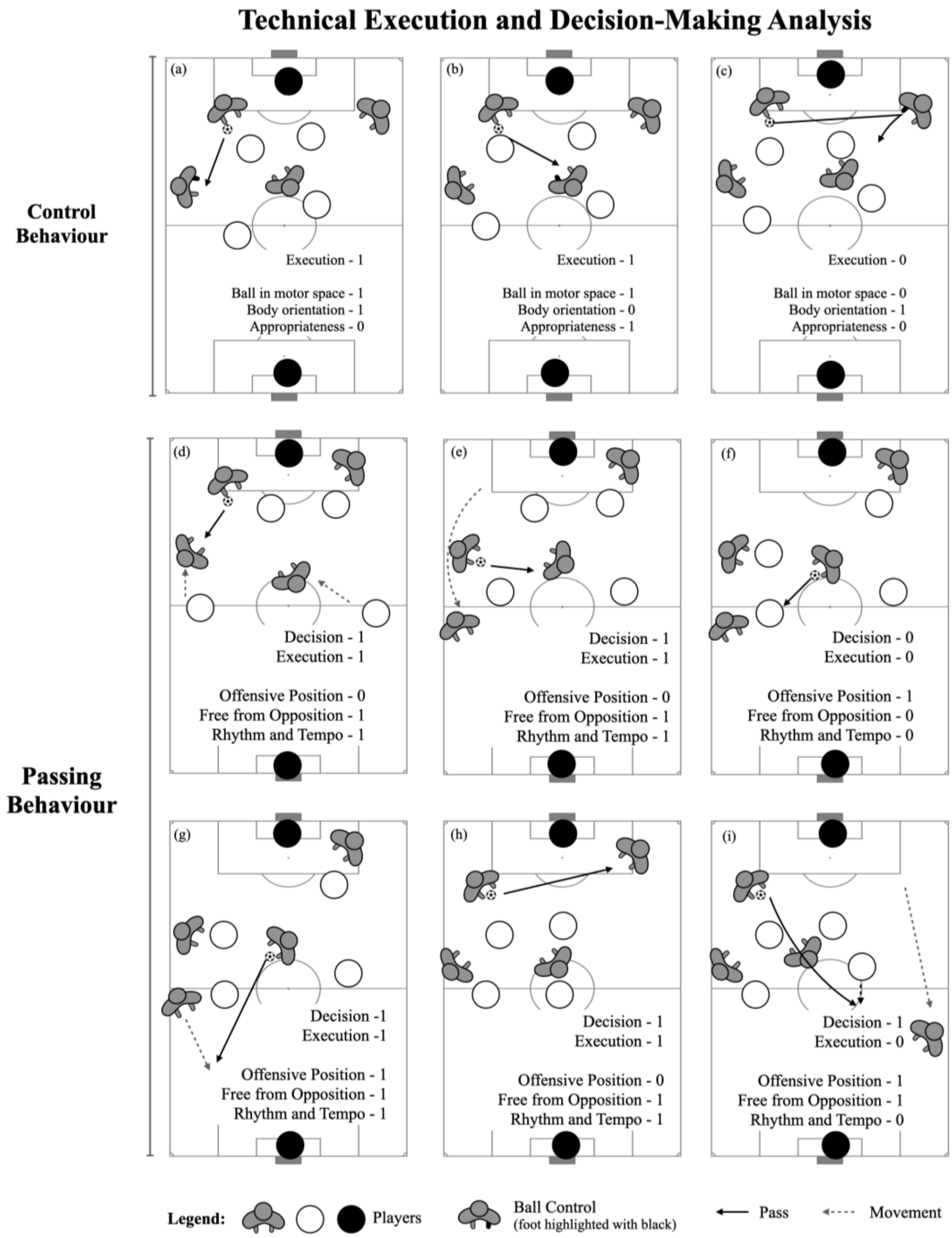

Figure 2. Representation of technical criteria of ball control and passing patterns. (**a**–**c**) analyses players' ball control according to GPET instrument and the additional technical criteria to highlight how each criteria should be coded according to the specific context. (**d**–**i**) have also GPET and technical criteria analysis however, regarding the players' passing behaviour. Note: dashed line represents players' movement, while continuous line refers to ball trajectory.

2.4.2. Technical Criteria of Ball Control and Passing

The same procedures were used to code the technical criteria of the players' ball control and passing actions. The following criteria were used to code the players' ball control (see Figure 2): (i) players' ability to receive the ball with the relevant body part to control the ball (see Figure 2a); (ii) players' ability to maintain the ball in the motor space (see Figure 2b); and (iii) players' body orientation and ability to receive the ball with the intention to progress towards the opponents' goal (see Figure 2c).

From the passing behaviour, the following technical criteria were used: (i) free from opposition, which is the player's ability to pass the ball to a teammate who is not closely marked by the opposition (e.g., see Figure 2g for a proper passing situation, and Figure 2f for a pass to a marked teammate); (ii) offensive position, which is the players' ability to perform passes that allow progress on the field (for example, Figure 2h reflects a situation in which there were more offensive solutions than the selected pass); and (iii) rhythm and tempo, which reflect the players' ability to pass the ball with proper speed and direction (see Figure 2i,h for examples). These criteria were created to complement the information from the GPET measures, which decompose the skills into more specific and contextual information. Following the data collection and one week later, 10% of the sample was retested, and the values varied from 0.89 to 0.84 for both the ball control and passing behaviours (i.e., high intraclass correlation) [45].

2.4.3. Physical Performance

Physical data during the SSGs were gathered using 10 Hz Global Positioning System (GPS) units (10 Hz, Accelerometer 1 kHz, FieldWiz, Paudex, Switzerland). These devices were placed in a specific vest on the upper backs of the players, who always used the same GPS device to reduce error. The FieldWiz GPS trackers have been shown to have a good level of accuracy for measuring movements and displacements in team sports [46]. In this respect, the total distance covered and the distance covered by the players in different speed zones were in accordance with the following thresholds adopted by previous studies analysing SSGs with youth players [21,47]: (i) total distance covered; (ii) distance covered while walking (0.0–3.5 km/h); (iii) distance covered while jogging (3.6–14.3 km/h); (iv) distance covered while running (14.4−19.8 km/h); and (v) distance covered while sprinting (>19.9 km/h). In addition, the players' average speed (m/s) was considered to understand the game's pace.

2.5. Statistical Analysis

Descriptive data were presented as the mean (M) and standard deviation (SD) for data following a normal distribution, and as the median (Me) and interquartile range (IQR) for data showing non-normal distribution. Evaluation for outliers and assumptions of normality were tested using the Shapiro–Wilk test. The differences between the pre- and post-test measures of each condition (i.e., within comparisons for Low DM, Mod DM, and High DM) were analysed using Student's *t*-test for variables with a normal distribution, while the Wilcoxon test was used for variables with non-normal distribution. Statistical significance was set at $p < 0.05$, and calculations were performed using the Jamovi Project (Computer Software Version 1.2. 2020). To examine the differences in means, 95% confidence limits (raw data) and Cohen's d effect sizes were applied to the pairwise comparisons. The thresholds for effect size statistics were as follows: 0.0–0.19 (trivial); 0.20–0.49 (small); 0.6–1.19 (moderate); 1.2–1.9 (large); $\geq$ 2.0 (very large) [48].

As a result of the inequality in the pre-test values for the technical variables, analysis of covariance (ANCOVA) was used to compare the different training tasks in the intervention, with post-test values as the dependent variable and pre-test values as the covariate. For each ANCOVA, the differences between training tasks were measured using the partial eta-squared (η^2), which was calculated using the following thresholds: 0.01 (small), 0.06 (medium), and 0.14 (large) [49].

3. Results

3.1. Ball Control and Passing Actions during the Intervention Tasks

Descriptive results from the frequency of ball control and passing behaviour (i.e., successful and unsuccessful motor executions) are outlined in Table 1. These variables are expressed as the frequency per minute for purposes of better comparison. The comparison between the intervention tasks shows higher numbers of ball control and passing actions in Mod DM compared with the Low and High DM tasks (Table 1).

Table 1. Descriptive (M ± DP) statistics from the intervention tasks (Low DM, Mod DM, and High DM).

Task Performance	Low Decision	Moderate Decision	High Decision	Difference in Means (% ± 95% CI)		
	(Mean ± SD)	(Mean ± SD)	(Mean ± SD)	Low DM vs. Mod DM	Low DM vs. High DM	Mod DM vs. High DM
Ball Control						
Unsuccessful Ball Control (n/6 min)	0.13 ± 0.16	0.21 ± 0.16	0.06 ± 0.09	0.0 ± 0.0	−0.33 ± 1.43	−0.3 ± 1.43
Successful Ball Control (n/6 min) (n/6 min)	3.54 ± 0.28	15.58 ± 2.17	1.92 ± 1.07	72.25 ± 10.71	−9.75 ± 6.56	−82.0 ± 8.00
Pass Behaviour						
Unsuccessful Pass (n/6 min)	0.25 ± 0.22	0.79 ± 0.63	0.46 ± 0.29	3.25 ± 2.56	1.25 ± 1.40	−2.00 ± 3.46
Successful Pass (n/6 min)	3.63 ± 0.25	16.92 ± 1.97	1.90 ± 0.93	79.75 ± 10.04	−10.38 ± 5.47	−90.13 ± 0.87

Note: N = number; CI = confidence interval.

3.2. *Effects of the Intervention Tasks on Players' Ball Control and Passing Actions (Within-Group Analysis)*

The acute effects of each task on the players' subsequent performance (i.e., comparing the pre-test and post-test results for each condition) are presented in Table 2 (identified by the # signal) and Figures 3 and 4. The High DM task contributed to acute improvements in body orientation (t = −2.40, p = 0.016; ES with 95% CI: ES = 0.67 [0.07; 1.27]). In contrast, there were decrements in identifying teammates in more offensive positions after the Mod DM intervention (−0.04; ±0.10 lower; W = 9.50, p = 0.016; ES = −0.22 [−0.80; 0.37]).

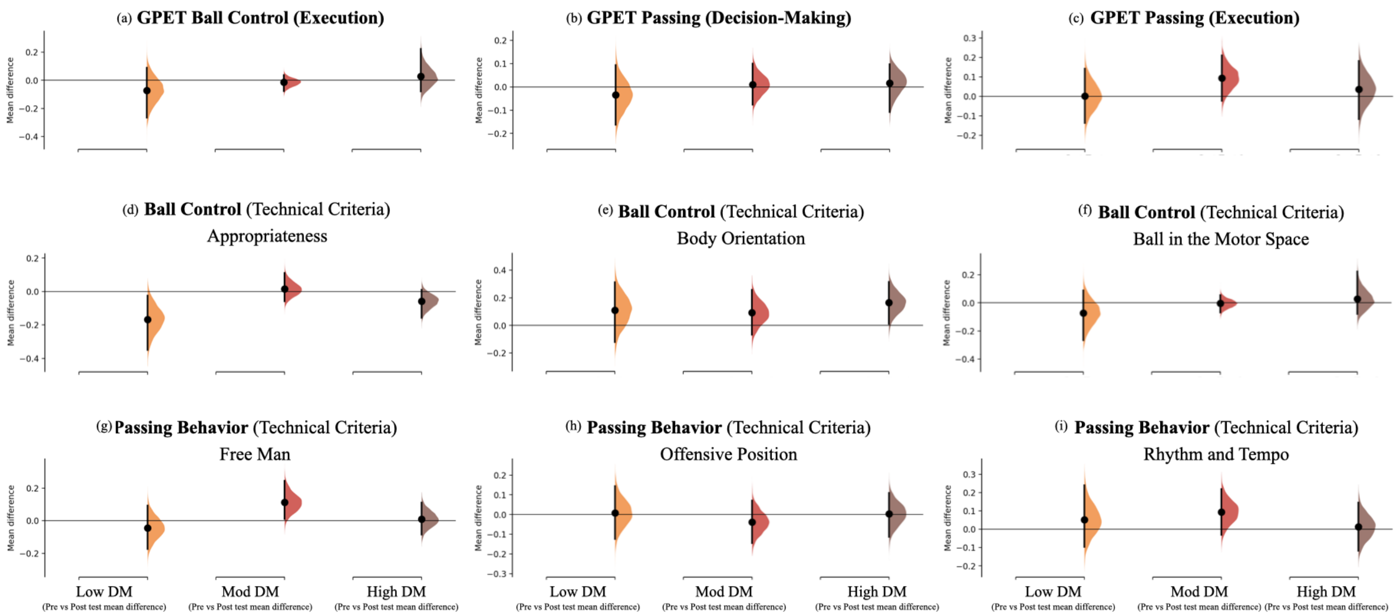

Figure 3. The mean difference (each mean difference is plotted as a bootstrap sampling distribution) for three comparisons pre- and post-measurements according to (i) GPET ball control, (ii) GPET passing execution, and (iii) GPET DM for the Low DM, Mod DM, and High DM tasks, as shown in the Cumming estimation plots above. The raw data are plotted on the upper axes. Mean differences are depicted as dots; 95% CIs are indicated by the ends of the vertical error bars [50].

Table 2. Descriptive (M ± DP; Me ± IQR; Raw ± 95% CI) and inferential statistics from the passing intervention according to the conditions (Low DM, Mod DM, and High DM).

Motor Execution and DM	Low DM		Moderate DM		High DM		Difference in Means (Raw ± 95% CI)			p
	Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test				
	(Mean ± SD) [Median ± IQR]	(Mean ± SD) [Median ± IQR]	(Mean ± SD) [Median ± IQR]	(Mean ± SD) [Median ± IQR]	(Mean ± SD) [Median ± IQR]	(Mean ± SD) [Median ± IQR]	Low DM vs. Mod DM	Low DM vs. High DM	Mod DM vs. High DM	
Ball Control (GPET) and Criteria										
Execution	[0.81 ± 0.37]	[0.78 ± 0.37]	[1.00 ± 0.00]	[1.00 ± 0.00]	[0.89 ± 0.25]	[0.86 ± 0.20]	0.06 ± 0.18	0.10 ± 0.21	0.04 ± 0.15	**0.032** [a]
Appropriateness	[1.00 ± 0.00]	[1.00 ± 0.00]	[1.00 ± 0.00]	[1.00 ± 0.00]	[1.00 ± 0.00]	[1.00 ± 0.00]	0.18 ± 0.23	0.11 ± 0.22	−0.07 ± 0.13	**0.017** [a,b]
Body Orientation	(0.38 ± 0.25)	[0.50 ± 0.57]	(0.55 ± 0.28)	(0.64 ± 0.18)	(0.50 ± 0.26)	(0.66 ± 0.19) #	−0.02 ± 0.30	0.05 ± 0.30	0.07 ± 0.20	0.167
Motor Space	[0.50 ± 0.57]	[0.50 ± 0.57]	[0.50 ± 0.57]	[0.50 ± 0.57]	[0.50 ± 0.57]	[0.50 ± 0.57]	0.07 ± 0.18	0.1 ± 0.21	0.03 ± 0.16	**0.028** [a]
Pass (GPET) and Criteria										
Execution	(0.88 ± 0.13)	[0.91 ± 0.34]	(0.86 ± 0.19)	[0.96 ± 0.20]	(0.87 ± 0.12)	[0.96 ± 0.20]	−0.04 ± 0.16	0.01 ± 0.12	0.01 ± 0.12	0.523
Decision-Making	[0.79 ± 0.35]	[0.80 ± 0.37]	[0.77 ± 0.29]	[0.85 ± 0.28]	(0.83 ± 0.31)	[0.84 ± 0.31]	0.09 ± 0.18	0.03 ± 0.22	−0.06 ± 0.19	0.512
Freedom from Opposition	[1.00 ± 0.21]	[0.91 ± 0.23]	[0.89 ± 0.22]	[1.00 ± 0.11]	(0.88 ± 0.14)	[1.00 ± 0.19]	0.16 ± 0.19	0.00 ± 0.20	−0.10 ± 0.12	0.291
Offensive Position	(0.79 ± 0.19)	[0.86 ± 0.38]	[0.82 ± 0.34]	[0.75 ± 0.14] #	(0.83 ± 0.14)	[0.87 ± 0.30]	−0.05 ± 0.21	−0.05 ± 0.19	0.04 ± 0.14	0.589
Rhythm and Tempo	[0.87 ± 0.30]	[0.87 ± 0.30]	(0.75 ± 0.20)	[0.85 ± 0.31]	(0.75 ± 0.20)	(0.77 ± 0.19)	0.04 ± 0.20	−0.04 ± 0.21	−0.08 ± 0.17	0.416
Physical Performance										
Total Distance Covered (m)	(599.09 ± 62.63)	(591.17 ± 44.46)	(587.11 ± 75.41)	(572.67 ± 63.56)	(571.29 ± 55.67)	(561.59 ± 78.6)	−6.53 ± 38.93	−1.79 ± 40.77	4.74 ± 45.16	0.741
Distance Covered While Walking (m)	(68.16 ± 15.61)	(68.81 ± 8.12)	(76.81 ± 19.36)	(80.65 ± 15.67)	(74.97 ± 11.80)	(79.58 ± 22.89)	3.18 ± 11.66	3.95 ± 12.33	0.77 ± 13.80	0.270
Distance Covered While Jogging (m)	(490.38 ± 61.88)	(475.31 ± 51.09)	(471.27 ± 72.09)	(447.32 ± 60.16)	(464.1 ± 51.89)	(457.23 ± 83.79)	−8.88 ± 45.18	8.20 ± 43.56	17.08 ± 51.99	0.658
Distance Covered While Running (m)	[29.8 ± 26.6]	(45.26 ± 24.05)	(36.33 ± 26.35)	(38.22 ± 23.02)	(31.47 ± 19.14)	(24.44 ± 22.08)	−5.58 ± 18.63	−14.50 ± 20.69	−8.92 ± 18.83	0.078
Distance Covered While Sprinting (m)	[29.8 ± 26.6]	[29.8 ± 26.6]	[29.8 ± 26.6]	[29.8 ± 26.6]	[29.8 ± 26.6]	[29.8 ± 26.6]	4.75 ± 4.71	0.56 ± 2.86	−4.20 ± 4.30	**0.042** [a]
Average Speed (m/s)	(21.40 ± 2.24)	(21.11 ± 1.57)	(20.99 ± 2.63)	(20.63 ± 2.23)	(17.99 ± 7.22)	(17.54 ± 7.37)	−0.07 ± 1.38	−0.22 ± 1.58	−0.08 ± 1.54	0.715

Note: m = metres; m/ s = metres per second; DM = decision-making; CI = confidence interval. Due to the presence of normal and non-normal data, descriptive data are presented as the mean ± standard deviation (SD) and expressed using (), while the non-normal data are presented as the median ± interquartile range (IQR) and expressed using []. For example, motor execution of ball control for the Low DM task [0.81 ± 0.37] consisted of non-normal data, while body orientation (0.38 ± 0.25) consisted of normal data. Differences between the pre- and post-test design measurements (within analysis) are identified with the # symbol in the descriptive data columns (i.e., # in body orientation for the High DM means statistically significant differences from the pre-test to the post-test). Additionally, differences between the pre-and post-tests of the different interventions are identified by bold values, while letters represent statically significant differences between groups (between-group comparison) based on the differences in the pre- and post-test measurements: (i) Low DM vs. Mod DM, (ii) Low DM vs. High DM, and (iii) Mod DM vs. High DM.

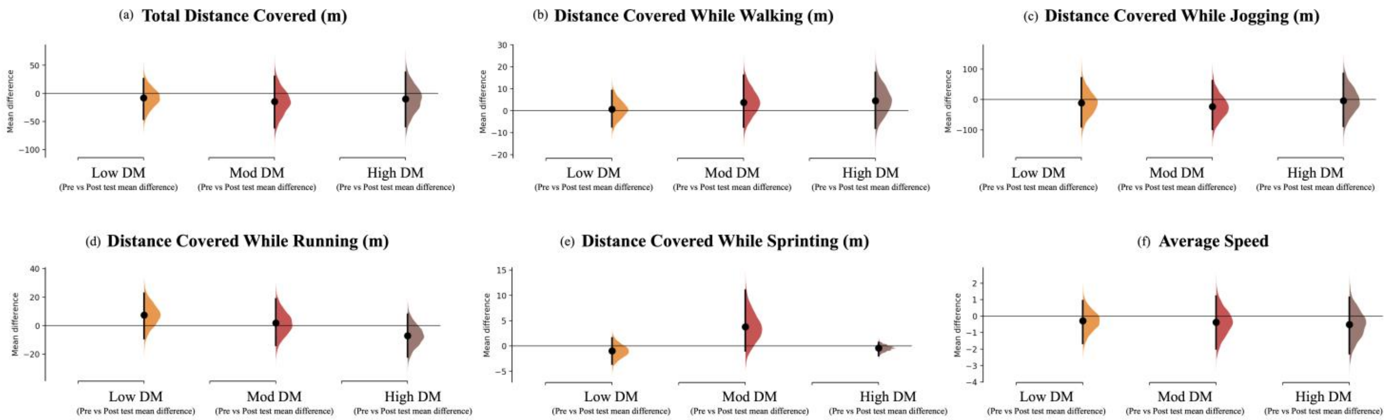

Figure 4. The mean difference (each mean difference is plotted as a bootstrap sampling distribution) for three comparisons pre- and post-measurements according to (i) total distance covered, (ii) distance covered while walking, (iii) distance covered while jogging, (iv) distance covered while running, (v) distance covered while sprinting, and (vi) average speed for the Low DM, Mod DM, and High DM tasks, as shown in the Cumming estimation plots above. Mean differences are depicted as dots; 95% CIs are indicated by the ends of the vertical error bars [50].

Mean changes are depicted in Figures 3 and 4. For example, from the GPET perspective (Figure 3a–c), the High DM task revealed improvements in the mean values for all variables, while the Mod DM task only showed improvements for passing behaviour, and the Low DM task revealed decrements for ball control and passing decision-making.

3.3. Comparing the Interventions' Acute Effects between Groups (Between-Group Analysis)

The general comparison between groups (i.e., Low DM, Mod DM, and High DM) showed effects for the ball control execution (F = 3.71, p = 0.032), appropriateness (F= 4.49, p = 0.017), motor space (F = 3.89, p = 0.028), and distance covered while sprinting (F = 3.42, p = 0.042). Accordingly, lower values of ball control execution (p = 0.030, −0.99 [−1.79; −0.21]), appropriateness (p = 0.031, −0.93 [−1.69; −0.19]), motor space (p = 0.025, −0.93 [−1.81; −0.23]), and distance covered while sprinting (p = 0.05, −0.84 [−1.58; −0.11]) were found after the Low DM task compared to the Mod DM task. Furthermore, the Low DM task revealed a general decrease in performance in ball control appropriateness (p = 0.037, 0.92 [0.17; 1.66]) compared to the High DM task.

4. Discussion

This study aimed to understand how the design of contextual dependency and DM of training tasks affect players' positioning and, consequently, their ball control, passing performance, and external load during a subsequent performance in SSGs. Overall, the results identified several possible acute effects on the players' subsequent game performance due to varying the tasks' DM levels. More prescriptive tasks (i.e., Low DM and Mod DM) contributed to a higher frequency of actions but, as expected, to a lower transfer to the subsequent game performance because of the lower contextual dependency. In turn, adopting tasks such as the game (i.e., High DM task) appeared to emphasise the coupling between perception and action, thereby enhancing the players' acute response. This evidence may support the improvements in receiving with the ball oriented following the High DM task, as well as the general improvements in DM and execution of both ball control and passing behaviour. In addition, following the Mod DM task, there was a reduction in the players' ability to find more offensive solutions, in agreement with our hypothesis, which suggests that the configuration of each training task will impact the players' performance in the subsequent task. Decrements in ball-control-related variables were also identified after the Low DM task, mainly when compared to the Mod DM task, which may have resulted from the lower perceptual demands of this type of practice.

4.1. Effects of the Intervention Tasks on Players' Ball Control and Passing Actions (Within-Group Analysis)

During training sessions, coaches often plan tasks under one or two specific topics (e.g., changing the point of attack, developing finishing behaviours), in which there is a progressive structure in terms of contextual dependency and decision-making process [6,51]. For example, before a task intended to develop the offensive process (e.g., 7 vs. 4 + Gk), coaches usually perform more repetitive tasks (e.g., specific set of players in 11 vs. 0 + Gk) that highlight the individual/collective possibilities for actions that need to be performed to be successful in the context of performance. It is considered that the low difficulty, complexity, and variability of such tasks will contribute to a high frequency of actions, subsequently promoting a better transfer to competitive scenarios [13–15]. However, one major difficulty when designing training tasks is in adjusting the level of difficulty/complexity [40] and promoting the effective transfer to the competitive context. In this study, training tasks with lower DM (i.e., Low and Mod DM) led to a higher frequency of actions compared to more complex and representative tasks (i.e., High DM). In contrast, the High DM tasks were the only ones that promoted more clear improvements in the players' performance. Therefore, while some tasks seem to stress the frequency of actions under contexts of lower contextual information (e.g., Low DM), neglecting the positioning on the field to ensure the perception and action cycle, in turn, more representative tasks with higher complexity and DM requirements may decrease the number of actions but guide and stress the emergence of such actions according to the requirements of a competitive environment [13,52]. However, such an idea cannot be generalised, and coaches need to understand the impact of each manipulation on the different factors that sustain players' performance. Accordingly, the results of the Mod DM tasks showed a decrease in the players' ability to identify teammates in a more offensive position. Considering the task design, this finding may be expected; that is, the Mod DM task consisted of a task where the players were static in the square and, when in possession, would have to pass the ball towards one teammate on the right, the left, or in front. In other words, the player had to pass the ball to one of two options, as the third option was expected to have the second ball. For instance, while the player must scan for the body orientation of the player in possession of the second ball to anticipate their passing direction, or for the ball's trajectory to avoid hitting it, the passing solutions are in a static position. Thus, in this task, the players had no intention of progressing on the field and conquering space, as result of it being a static ball-passing task. Despite not revealing significant differences, decrements were also identified following the Low DM task, in which players were told how to control the ball at each moment. In contrast, players showed higher mean values of ball control skills after the High-DM task, possibly because the players had to adapt their ability to control the ball each time according to their teammates' and opponents' positions in order to be successful. Additionally, improvements were also found for the passing DM and execution after the High DM task.

These results may shed some light on the impact of the task design on the subsequent performance, as the manipulation of each task clearly changes the positioning of the players and, consequently, the perceptual–motor landscape and the intentional exploration of possibilities for action [13,52]. In the long-term, such exposure to training tasks that highlight the relevant information for DM in game situations is likely to help players to become attuned with their environment [53]. Altogether, these results suggest that coaches should consider designing tasks that encourage players' to improve their positioning so as to identify and sustain their actions based on the relevant information from the environment [5,54,55]. For this purpose, practice tasks must highlight the process that promotes the co-dependence between the performer and the surrounding environment [41], which can be achieved by using game-based tasks [13] or tasks with reduced variability in the context of play but that promote the information–action coupling required to perform successfully. Such situations expose the players to a guided intentional exploration of the context of play as required in the context of performance [36] and, ultimately, may enhance their performance in competitive settings.

4.2. Comparing the Interventions' Acute Effects between Groups (Between-Group Analysis)

One strategy often adopted by coaches to model the training tasks according to the players' level is to adjust their difficulty and complexity [56] by varying the number of available opportunities for action and, consequently, the DM process [15,54]. For this purpose, coaches may change the boundary conditions during SSGs. For example, Práxedes, Moreno, Gil-Arias, Claver, and Del Villar [36], Machado, Barreira, Teoldo, Travassos, Júnior, Santos, and Scaglia [56], and Pizarro et al. [57] revealed improvements in performances in passing DM and execution in the low-difficulty/DM scenarios (i.e., numerically unbalanced tasks or during SSGs with a lower number of players). Apart from variations in the number of players during SSGs, coaches often vary the level of task DM by adopting more prescriptive and repetitive passes or tasks without opposition [7,40]. In the present study, the level of DM was manipulated by adopting prescriptive and repetitive tasks (i.e., Low DM), without opposition, but with variability and contextual dependence (i.e., Moderate DM) and game-based tasks (i.e., High DM).

When comparing the pre- and post-test interventions between groups, the results showed effects mostly for the ball control variables and between the Low DM and Mod DM tasks. Previous studies comparing repetitive approaches with tasks grounded by variability have found higher brain activation during less predictable practices [58]. Such differences are related to the alpha and theta waves, which are related to the somatosensory information (such as motor, visual, or proprioceptive sensory integration) [59] and motor performance [60]. In contrast, it is expected that players may disengage when exposed to periods of repetitive practice [61], which may affect subsequent practices as well as contributing to performance decrements following the post-test. Additionally, differences were also found between the Low DM and Mod DM tasks for sprinting. In this respect, since Mod DM decreased the ability to find a player in a more offensive position following the intervention, the tactic of sprinting towards the opponents' goal may have emerged as a suitable strategy to progress. In fact, sprinting is the most common action performed prior to a goal [62], which may reinforce the current findings. Additionally, effects were also found between the Low DM and High DM tasks for appropriateness, which refers to the players' ability to receive the ball with the relevant body part (e.g., using the furthest foot, as it allows control of the ball towards the space), with higher values for the High DM group. Following the same rationale, the players were constantly challenged to adapt the way they received the ball during the High DM intervention; that is, while at the first ball reception the player may have numerical superiority, conferring higher space and tempo to receive the ball, during the second one they may have two defenders close, affecting the way in which they must adapt their ball reception, while they may use their chest to receive a high pass during the third ball reception. Altogether, the unpredictability that emerges from a game-based task also seems to stress the players' ability to receive the ball in more suitable conditions to progress.

Overall, these findings have important practical implications for coaches. Despite being aware of the importance of game-based situations, only a limited amount of time is spent with these types of practices [63]. Thus, coaches may reflect on the nature of their practices and the corresponding consequences for their players' learning. This exploratory study intends to provide additional information to assist coaches in designing training tasks. Accordingly, tasks with lower DM seem to stress the frequency of motor skills. However, the lower contextual dependency and DM seem to limit the transfer to subsequent performance. In contrast, game-based situations are likely to help players couple their actions with the relevant information [13], contributing to improvements in their ability to control and pass the ball. However, each manipulation should be analysed to further understand the intentions that the tasks promote in the players' positioning, DM, and action.

Despite the important practical applications derived from the present study, some limitations should be acknowledged. Firstly, and most importantly, the low sample size may prevent us from achieving stronger inferences. Moreover, players with different levels of ability seem to adapt differently to similar game conditions; thus, a more comprehensive understanding might emerge if further studies consider samples of different ages, ability levels, and genders. Additionally, this study adopted an approach in which the intervention lasted for 6 min, which could explain the small effects identified. The extent to which shorter or longer periods might contribute to increased or reduced effects is still unknown and, thus, should be considered by researchers and practitioners. Lastly, one major aim when planning and designing training sessions is to apply tasks that can be transferred to the subsequent game. For example, Práxedes et al. [64] explored how a previous task (5 vs. 5 ball possession in numerical equality or 5 vs. 4 ball possession in numerical superiority) affected players' ability to maintain possession during a subsequent 5 vs. 5 game, finding better results when the players were first given numerical superiority. Therefore, further research is required to better understand how to tailor the training session sequence to optimise the learning environment.

5. Conclusions

The results of this study support a current series of literature suggesting the need for more research that explores motor skill acquisition in team sports. Often, coaches use prescriptive tasks in different stages of performance, such as in youth football to refine technical skills, or at elite levels during congested fixtures to develop specific movement patterns due to the Low DM and external load requirements (e.g., exploring specific passing sequences that were identified as weaknesses during the opposition analysis). Training tasks grounded by low-to-moderate DM can be used to increase the frequency of technical actions. However, as hypothesised, such tasks have lower performance transfer compared to game-based situations—mainly in terms of ball-control-related variables and distance covered while sprinting (Low DM), and in the ability to find players in more offensive positions (Mod DM). These types of tasks have predetermined movement sequences (Low DM) or are performed without opposition (Mod DM) and, thus, do not consider the dynamic cooperation and opposition interactions that characterise competitive performance. In contrast, the High DM task was designed according to those principles, emphasising players' ability to receive the ball oriented to the space. Moreover, as hypothesised, the results from this study showed that more static tasks might limit the players' ability to identify teammates in more offensive positions. Thus, considering the tight time schedules for practice and priorities for development, coaches may carefully consider what practices should be adopted to enhance players' performance.

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References

1. Duarte, R.; Araújo, D.; Folgado, H.; Esteves, P.; Marques, P.; Davids, K. Capturing complex, non-linear team behaviours during competitive football performance. *J. Syst. Sci. Complex.* **2013**, *26*, 62–72. [CrossRef]
2. Folgado, H.; Duarte, R.; Fernandes, O.; Sampaio, J. Competing with lower level opponents decreases intra-team movement synchronization and time-motion demands during pre-season soccer matches. *PLoS ONE* **2014**, *9*, e97145. [CrossRef] [PubMed]
3. Travassos, B.; Goncalves, B.; Marcelino, R.; Monteiro, R.; Sampaio, J. How perceiving additional targets modifies teams' tactical behavior during football small-sided games. *Hum. Mov. Sci.* **2014**, *38*, 241–250. [CrossRef] [PubMed]
4. Gibson, J.J. *The Ecological Approach to Visual Perception*; Lawrence Erlbaum Associates: Hillsdale, NJ, USA, 1986.
5. Fajen, B.; Riley, M.; Turvey, M. Information, affordances, and the control of action in sport. *Int. J. Sport Psychol.* **2009**, *40*, 79–107.
6. Williams, A.M.; Hodges, N.J. Practice, instruction and skill acquisition in soccer: Challenging tradition. *J Sport. Sci* **2005**, *23*, 637–650. [CrossRef]
7. Bergmann, F.; Gray, R.; Wachsmuth, S.; Höner, O. Perceptual-Motor and Perceptual-Cognitive Skill Acquisition in Soccer: A Systematic Review on the Influence of Practice Design and Coaching Behavior. *Front. Psychol.* **2021**, *12*, 772201. [CrossRef]
8. Ford, P.R.; Yates, I.; Williams, A.M. An analysis of practice activities and instructional behaviours used by youth soccer coaches during practice: Exploring the link between science and application. *J. Sports Sci.* **2010**, *28*, 483–495. [CrossRef]
9. Cushion, C.J.; Jones, R.L. A systematic observation of professional top-level youth soccer coaches. *J. Sport Behav.* **2001**, *24*, 4.
10. Hill-Haas, S.V.; Dawson, B.; Impellizzeri, F.M.; Coutts, A.J. Physiology of small-sided games training in football: A systematic review. *Sports Med.* **2011**, *41*, 199–220. [CrossRef]
11. Davids, K.; Lees, A.; Burwitz, L. Understanding and measuring coordination and control in kicking skills in soccer: Implications for talent identification and skill acquisition. *J. Sports Sci.* **2000**, *18*, 703–714. [CrossRef]
12. Williams, M.; Horn, R.; Hodges, N. Skill acquisition. In *Science and Soccer*; Williams, M., Ford, P., Reilly, T., Drust, B., Eds.; Routledge: London, UK, 2003.
13. Davids, K.; Araújo, D.; Correia, V.; Vilar, L. How small-sided and conditioned games enhance acquisition of movement and decision-making skills. *Exerc. Sport Sci. Rev.* **2013**, *41*, 154–161. [CrossRef] [PubMed]
14. Cordovil, R.; Araújo, D.; Davids, K.; Gouveia, L.; Barreiros, J.; Fernandes, O.; Serpa, S. The influence of instructions and body-scaling as constraints on decision-making processes in team sports. *Eur. J. Sport Sci.* **2009**, *9*, 169–179. [CrossRef]
15. Davids, K.; Kingsbury, D.; Bennett, S.; Handford, C. Information-movement coupling: Implications for the organization of research and practice during acquisition of self-paced extrinsic timing skills. *J. Sports Sci.* **2001**, *19*, 117–127. [CrossRef] [PubMed]
16. Pino-Ortega, J.; Rojas-Valverde, D.; Gómez-Carmona, C.D.; Rico-González, M. Training Design, Performance Analysis, and Talent Identification—A Systematic Review about the Most Relevant Variables through the Principal Component Analysis in Soccer, Basketball, and Rugby. *Int. J. Environ. Res. Public Health* **2021**, *18*, 2642. [CrossRef] [PubMed]
17. Rico-González, M.; Pino-Ortega, J.; Praça, G.M.; Clemente, F.M. Practical Applications for Designing Soccer′ Training Tasks from Multivariate Data Analysis: A Systematic Review Emphasizing Tactical Training. *Percept. Mot. Ski.* **2022**, *129*, 892–931. [CrossRef]
18. O'Connor, D.; Larkin, P.; Williams, A.M. Observations of youth football training: How do coaches structure training sessions for player development? *J. Sports Sci.* **2018**, *36*, 39–47. [CrossRef]
19. Casamichana, D.; Castellano, J. Time-motion, heart rate, perceptual and motor behaviour demands in small-sides soccer games: Effects of pitch size. *J. Sports Sci.* **2010**, *28*, 1615–1623. [CrossRef]
20. Nunes, N.A.; Gonçalves, B.; Davids, K.; Esteves, P.; Travassos, B. How manipulation of playing area dimensions in ball possession games constrains physical effort and technical actions in under-11, under-15 and under-23 soccer players. *Res. Sports Med.* **2021**, *29*, 170–184. [CrossRef]
21. Coutinho, D.; Gonçalves, B.; Santos, S.; Travassos, B.; Folgado, H.; Sampaio, J. Exploring how limiting the number of ball touches during small-sided games affects youth football players' performance across different age groups. *Int. J. Sports Sci. Coach.* **2021**, *17*, 545–557. [CrossRef]
22. Pastor-Vicedo, J.C.; Prieto-Ayuso, A.; Contreras-Jordán, O.R.; Clemente, F.M.; Nikolaidis, P.T.; Rosemann, T.J.; Knechtle, B. Teaching and Learning Process of Decision-Making Units in Talented Young Players From U-10 to U-14. *Front. Psychol.* **2020**, *11*, 600. [CrossRef]
23. Sarmento, H.; Anguera, M.T.; Pereira, A.; Araújo, D. Talent Identification and Development in Male Football: A Systematic Review. *Sport. Med.* **2018**, *48*, 907–931. [CrossRef] [PubMed]
24. Till, K.; Eisenmann, J.; Emmonds, S.; Jones, B.; Mitchell, T.; Cowburn, I.; Tee, J.; Holmes, N.; Lloyd, R.S. A Coaching Session Framework to Facilitate Long-Term Athletic Development. *Strength Cond. J.* **2021**, *43*, 43–55. [CrossRef]
25. Balyi, I.; Way, R.; Higgs, C. *Long-Term Athlete Development*; Human Kinetics: Champaign, IL, USA, 2013.
26. Figueiredo, A.J.; Gonçalves, C.E.; Coelho e Silva, M.J.; Malina, R.M. Characteristics of youth soccer players who drop out, persist or move up. *J. Sports Sci.* **2009**, *27*, 883–891. [CrossRef] [PubMed]
27. Murr, D.; Feichtinger, P.; Larkin, P.; O'Connor, D.; Höner, O. Psychological talent predictors in youth soccer: A systematic review of the prognostic relevance of psychomotor, perceptual-cognitive and personality-related factors. *PLoS ONE* **2018**, *13*, e0205337. [CrossRef] [PubMed]
28. Waldron, M.; Worsfold, P. Differences in the Game Specific Skills of Elite and Sub-Elite Youth Football Players: Implications for Talent Identification. *Int. J. Perform. Anal. Sport* **2010**, *10*, 9–24. [CrossRef]

29. Bennett, K.J.M.; Novak, A.R.; Pluss, M.A.; Stevens, C.J.; Coutts, A.J.; Fransen, J. The use of small-sided games to assess skill proficiency in youth soccer players: A talent identification tool. *Sci. Med. Footb.* **2018**, *2*, 231–236. [CrossRef]
30. Williams, A.M.; Reilly, T. Talent identification and development in soccer. *J. Sports Sci.* **2000**, *18*, 657–667. [CrossRef]
31. Forsman, H.; Blomqvist, M.; Davids, K.; Liukkonen, J.; Konttinen, N. Identifying technical, physiological, tactical and psychological characteristics that contribute to career progression in soccer. *Int. J. Sports Sci. Coach.* **2016**, *11*, 505–513. [CrossRef]
32. Amatria, M.; Maneiro, R.; Anguera, M.T. Analysis of Successful Offensive Play Patterns by the Spanish Soccer Team. *J. Hum. Kinet.* **2019**, *69*, 191–200. [CrossRef]
33. González-Víllora, S.; García López, L.; Jordán, O. Decision making and skill development in youth football players. *Rev. Int. Med. Cienc. Act. Fis. Deporte* **2015**, *15*, 467–487.
34. Dunton, A.; O'Neill, C.; Coughlan, E.K. The impact of a spatial occlusion training intervention on pass accuracy across a continuum of representative experimental design in football. *Sci. Med. Footb.* **2020**, *4*, 269–277. [CrossRef]
35. Evangelos, B.; Georgios, K.; Konstantinos, A.; Gissis, I.; Papadopoulos, C.; Aristomenis, S. Proprioception and Balance Training Can Improve Amateur Soccer Players' Technical Skills. *J. Phys. Educ. Sport* **2012**, *12*, 81.
36. Práxedes, A.; Moreno, A.; Gil-Arias, A.; Claver, F.; Del Villar, F. The effect of small-sided games with different levels of opposition on the tactical behaviour of young footballers with different levels of sport expertise. *PLoS ONE* **2018**, *13*, e0190157. [CrossRef] [PubMed]
37. Kelly, A.; Wilson, M. Thinking inside the box: The effect of player numbers on locomotor activity and skill behaviour during competitive match-play in under-9 English academy football. *J. Sports Sci.* **2018**, *36*, 51.
38. Murata, A.; Herbison, J.D.; Côté, J.; Turnnidge, J.; Kelly, A.L. Competitive engineering in the youth sport context: Theory, practice, and future directions. In *Birth Advantages and Relative Age Effects in Sport: Exploring Organizational Structures and Creating Appropriate Settings*; Kelly, A.L., Côté, J., Jeffreys, M., Turnnidge, J., Eds.; Routledge: London, UK, 2021; pp. 222–236.
39. Partington, M.; Cushion, C.; Harvey, S. An investigation of the effect of athletes' age on the coaching behaviours of professional top-level youth soccer coaches. *J. Sports Sci.* **2014**, *32*, 403–414. [CrossRef]
40. Aquino, R.; Puggina, E.F.; Alves, I.d.S.; Garganta, J.M. Skill-related performance in soccer: A systematic review. *Hum. Mov.* **2017**, *18*, 3–24. [CrossRef]
41. Travassos, B.; Duarte, R.; Vilar, L.; Davids, K.; Araujo, D. Practice task design in team sports: Representativeness enhanced by increasing opportunities for action. *J. Sports Sci.* **2012**, *30*, 1447–1454. [CrossRef]
42. García-López, L.; González-Víllora, S.; Gutiérrez, D.; Serra, J. Development and Validation of the Game Performance Evaluation Tool (GPET) in Soccer. *Rev. Euroam. Ciências Deporte* **2013**, *2*, 89–99.
43. Serra-Olivares, J.; Gonzalez-Villora, S.; Garcia-Lopez, L.M. Effects of modification of task constrains in 3-versus-3 small-sided soccer games. *S. Afr. J. Res. Sport Phys. Educ. Recreat.* **2015**, *37*, 119–129. [CrossRef]
44. Mitchell, S.A.; Oslin, J.L.; Griffin, L.L. *Teaching Sport Concepts and Skills: A Tactical Games Approach for Ages 7 to 18*; Human Kinetics: Champaign, IL, USA, 2013.
45. O'Donoghue, P. *Research Methods for Sports Performance Analysis*; Routledge: London, UK, 2010; p. 278.
46. Willmott, A.G.B.; James, C.A.; Bliss, A.; Leftwich, R.A.; Maxwell, N.S. A comparison of two global positioning system devices for team-sport running protocols. *J. Biomech.* **2019**, *83*, 324–328. [CrossRef]
47. Pettersen, S.A.; Brenn, T. Activity Profiles by Position in Youth Elite Soccer Players in Official Matches. *Sports Med. Int. Open* **2019**, *3*, e19–e24. [CrossRef] [PubMed]
48. Hopkins, W.G.; Marshall, S.W.; Batterham, A.M.; Hanin, J. Progressive statistics for studies in sports medicine and exercise science. *Med. Sci. Sport. Exerc.* **2009**, *41*, 3–13. [CrossRef] [PubMed]
49. Cohen, J. *Statistical Power Analysis for the Behavioral Sciences*; Lawrence Erlbaum Associates: Hillsdale, NJ, USA, 1988.
50. Ho, J.; Tumkaya, T.; Aryal, S.; Choi, H.; Claridge-Chang, A. Moving beyond P values: Everyday data analysis with estimation plots. *bioRxiv* **2018**. [CrossRef]
51. Schmugge, T.; Schmugge, T. *Soccer: The 6-Week Plan: The Guide to Building a Successful Team*; Meyer & Meyer Sport, Limited: Aachen, Germany, 2016.
52. Farrow, D.; Reid, M.; Buszard, T.; Kovalchik, S. Charting the development of sport expertise: Challenges and opportunities. *Int. Rev. Sport Exerc. Psychol.* **2018**, *11*, 238–257. [CrossRef]
53. Santos, S.; Coutinho, D.; Gonçalves, B.; Schöllhorn, W.; Sampaio, J.; Leite, N. Differential learning as a key training approach to improve creative and tactical behavior in soccer. *Res. Q. Exerc. Sport* **2018**, *89*, 11–24. [CrossRef]
54. McGuckian, T.B.; Cole, M.H.; Chalkley, D.; Jordet, G.; Pepping, G.-J. Constraints on visual exploration of youth football players during 11v11 match-play: The influence of playing role, pitch position and phase of play. *J. Sports Sci.* **2020**, *38*, 658–668. [CrossRef]
55. McGuckian, T.B.; Cole, M.H.; Jordet, G.; Chalkley, D.; Pepping, G.-J. Don't Turn Blind! The Relationship Between Exploration Before Ball Possession and On-Ball Performance in Association Football. *Front. Psychol.* **2018**, *9*, 2520. [CrossRef]
56. Machado, J.C.; Barreira, D.; Teoldo, I.; Travassos, B.; Júnior, J.B.; Santos, J.O.L.D.; Scaglia, A.J. How Does the Adjustment of Training Task Difficulty Level Influence Tactical Behavior in Soccer? *Res. Q. Exerc. Sport* **2019**, *90*, 403–416. [CrossRef]
57. Pizarro, D.; Práxedes, A.; Travassos, B.; Gonçalves, B.; Moreno, A. How the Number of Players and Floaters' Positioning Changes the Offensive Performance during Futsal Small-Sided and Conditioned Games. *Int. J. Environ. Res. Public Health* **2021**, *18*, 7557. [CrossRef]

58. Henz, D.; Schöllhorn, W. Differential Training Facilitates Early Consolidation in Motor Learning. *Front. Behav. Neurosci.* **2016**, *10*, 199. [CrossRef]
59. Henz, D.; John, A.; Merz, C.; Schöllhorn, W.I. Post-task Effects on EEG Brain Activity Differ for Various Differential Learning and Contextual Interference Protocols. *Front. Hum. Neurosci.* **2018**, *12*, 19. [CrossRef] [PubMed]
60. Meyer, T.; Peters, J.; Zander, T.O.; Schölkopf, B.; Grosse-Wentrup, M. Predicting motor learning performance from Electroencephalographic data. *J. Neuroeng. Rehabil.* **2014**, *11*, 24. [CrossRef]
61. Velasco, F.; Jorda, R. Portrait of Boredom Among Athletes and Its Implications in Sports Management: A Multi-Method Approach. *Front. Psychol.* **2020**, *11*, 831. [CrossRef]
62. Faude, O.; Koch, T.; Meyer, T. Straight sprinting is the most frequent action in goal situations in professional football. *J. Sports Sci.* **2012**, *30*, 625–631. [CrossRef]
63. Partington, M.; Cushion, C. An investigation of the practice activities and coaching behaviors of professional top-level youth soccer coaches. *Scand. J. Med. Sci. Sports* **2013**, *23*, 374–382. [CrossRef] [PubMed]
64. Práxedes, A.; Pizarro, D.; Travassos, B.; Domínguez, M.; Moreno, A. Level of opposition constrains offensive performance in consecutive game situations. An analysis according to game principles. *Phys. Educ. Sport Pedagog.* **2022**, *27*, 291–303. [CrossRef]

children

Article

How Football Players' Age Affect Passing Patterns of Play According to Field Location

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Abstract: This study aimed to characterize the passing patterns that support collective tactical behaviour in football players of different ages (U15, U17, and U19) in different field zones. Two hundred and twenty-eight male players, divided into U15, U17, and U19, participated in the study. Cluster analysis was used to group the passes into three sizes (short, medium, and long). The chi-square test was used to analyse the effect of player age on game-passing patterns in each field zone. The results revealed that long and medium passes were used more in areas close to the goals and short passes in the middle area of the field, concerning all ages ($p < 0.001$). Furthermore, the analysis of the relative distance between the ball carrier and the receiver indicated that older players (U17 and U19) used more distant players to pass the ball in medium and long passes. These results can help coaches design small-sided games according to the players' ages and adjust to the field's space and the numerical relationship, thus creating a greater transfer from training to competition.

Keywords: football; age; field zone; passing; receive

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1. Introduction

Over the years, football has revealed a great evolution concerning its laws, tactical systems, styles of play used, and, particularly, training methods. One of the reasons for this development concerns the increased use of technologies that allow a new understanding of the game [1,2] and a better explanation of the performance factors (physical, technical, and tactical) that characterize teams and players [3,4]. Likewise, scientific research in football has improved the capacity to explain the game [5] and understand the impact of contextual variables (e.g., venue, match status, quality of opposition, and match period) in the style of play and the tactical behaviour of the teams [6,7]. Such knowledge allow coaches to identify the important aspects that support the design of training sessions and ensure a better transfer of practices to competition, i.e., improve the performance of their teams and players [8].

For example, the analysis of positional data, passing patterns of play, or network analysis allow some improvements in the tactical exploration of space–time relations in different game moments by different teams [9,10]. The tactical behaviours of players and teams seem to be identifiable and reveal a signature that is dependent on the relationship they establish between teammates, opponents, and the position of the ball in relation to the goal [11,12].

Moreover, previous studies have shown that, depending on the zone of the field where the ball is located, the players' tactical behaviours vary, causing changes in the collective dynamics between teams [13,14]. Likewise, in the defensive sector, defenders tend to show low variability in displacements and in individual tactical actions (number and type of passes). On the other hand, in the attacking sector, attackers tend to reveal variability in space–time relations to create imbalances in the opponent [15,16]. Moreover, midfielders tend to reveal a greater number of actions in different game contexts due to occupying a more central position on the field, with higher variability in players' relations [17] from which a large part of attacks are built. Thus, in analysis of players, the tactical action must be contextualized based on the variables that constrain their possibilities of action, such as the area of the field, the number of players closest to the ball [18,19], or the location of the teammate who can receive the ball [20].

The way players explore the game's action possibilities, and how the ball moves around the pitch is, however, not only based on the context of play but also on the players' action capabilities [21,22]. For example, older players with more technical–tactical skills tend to play more in width than in depth, enhancing a more elaborate game, while younger players with less skill tend to use a more direct game [23] but with less effectiveness for progression or to create shooting situations [24]. Thus, older and more skilled players generally show a greater capacity to adapt to the existing playing space, allowing the emergence of more functional collective behaviours [25]. On the other hand, at the level of the ball patterns of play, younger players tend to present a random exploration of possibilities for action, with a dependency on passes around specific players and less efficiency in the passes of older players [26]. That is, younger players tend to be less intentional in exploring the free spaces and, at the same time, present less motor efficiency to perform with precision in the available space and time. Therefore, players' age, or even the players' maturation stage, can influence technical actions and motor skills [27], with implications in tactical behaviour and decision-making [28].

Summarizing, it may be considered that the patterns of passes allow the assessment of the offensive style of the teams as well as the teams' qualitative level to adapt to the variation of the existing playing space. Thus, there is a need to compare different age groups to understand the variation of tactical behaviours through the passing pattern [29]. Therefore, this study aimed to characterize the passing patterns that support the collective tactical behaviour of football players of different ages (U15, U17, and U19) by identifying their length, field zone, and relative distance between the passer and the receiver. Variations in the passing patterns of play depending on the field zones where the ball was were expected. Moreover, identifiably different lengths of passing and the relative distance of the players that receive the ball, according to variations in players' age, were expected.

2. Materials and Methods

2.1. Participants

A total of two hundred and twenty-eight male players who competed in the Portuguese national first division for each age group was represented by under 15 (n = 76 players, age 14.4 $\pm$ 0.4 years, height 1.61 $\pm$ 0.07 weight 52.2 $\pm$ 9.0, biological maturation 84% middle and 16% early), under 17 (n = 76 players, age 15.6 $\pm$ 0.5 years, height 1.74 $\pm$ 0.05, weight 63.1 $\pm$ 7.5, biological maturation 94% early and 6% middle), and under 19 (n = 76 players, age 17.7 $\pm$ 0.5 years, height 1.78 $\pm$ 0.09, weight 75.3 $\pm$ 9.3, biological maturation 100% early).Three different clubs participated in each age group.

2.2. Procedure

A total of nine games were played using the official rules (three by age).Moreover, biological maturation was calculated for boys using the maturity offset formula (MO) = $-7.999994 + (0.0036124 \times (\text{age} \times \text{height}))$; $R^2 = 0.896$; SEE = 0.542 [30].

The coaches defined the team composition in each simulated game to ensure balanced and competitive matches. Positional data of all the players were collected using individual global positioning system [GPS] units at 10 Hz (S5, Catapult Innovations, Melbourne, Australia). Goalkeepers were not included in the study. GPSs were turned on 15 min before each game. The games were recorded using a camera (Panasonic HC-V160).

Notational analysis was performed by recording the following player actions: passing the ball, receiving the ball, shooting, recovering the ball, and fouls. For this analysis, the software LongoMatch (version 1.3.7., Barcelona, Spain) was used, considering the time of each action for synchronizing the ball events with the GPS positional data. In addition, a visual representation of each simulated match was processed, presenting the ball position and displacement. Finally, this representation was used for possible notational error correction by comparing it with the original video [31].

The field was identified into different six zones according to previous studies [13] (Figure 1). The position of the ball passer and ball receiver was classified according to those different zones of the field for the analysis of the passes pattern. Zone 1 (Z1) is located near the team's own goal and zone 6 (Z6) is located near to the opponent's goal.

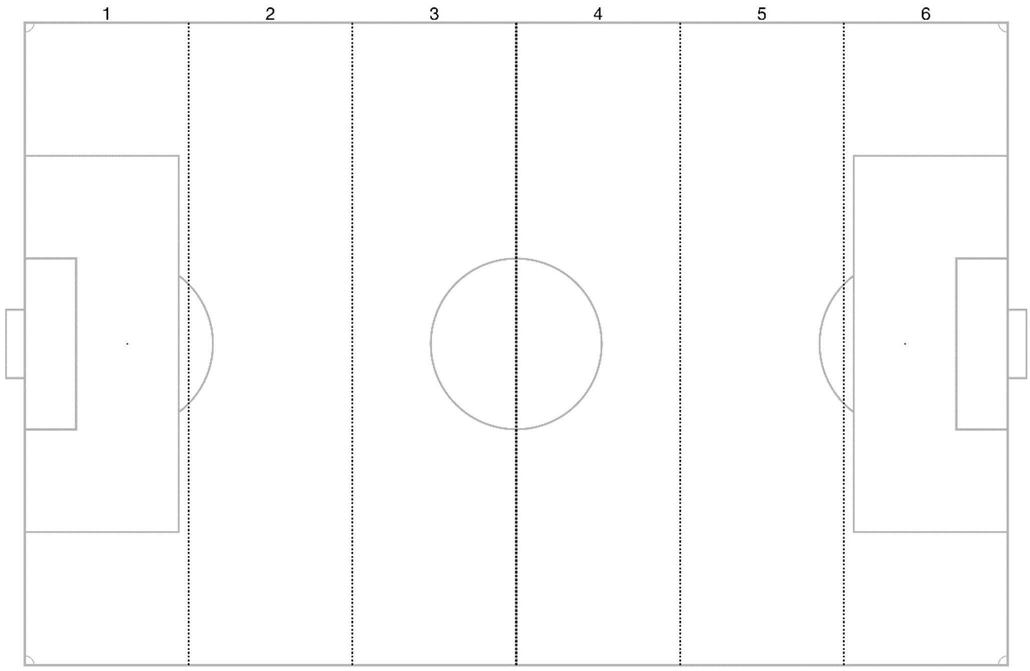

Figure 1. The field was divided into different six zones.

Attacking field players' distance to the ball carrier were also calculated, as well as their relative distance, ranked for every moment of the match, from the closest player (P1) to the furthest player (P9) [32].

2.3. Data Analysis

Through a cluster analysis, the passes (total = 4537; U15 = 1184; U17 = 1893; U19 = 1460) were grouped into long, medium, and short using the k-means method, computed per age group. Calculations were made to obtain the averages of the long passes (31.67 m $\pm$ 6.72), the medium passes (16.69 m $\pm$ 2.93), and the short passes (8.29 m $\pm$ 5.62). In order to compare the pass distribution, considering the pitch zones, the pass range, and the ages, the simple chi-square test was used (contingency table) with a defined significance level of $p < 0.05$. The adjusted residues were computed for pairwise comparison to reveal the differences within each group [33]. The pairwise p-value was calculated using the Bonferroni correction method. For statistical analysis, the jamovi project software was used (version 1.6).

3. Results

Table 1 reveals the mean value of long, medium, and short passes (mean ± standard deviation) in relation to players' age and considering the six zones of the field. In general, in all the players' age groups, the short passes turned out to be the most used (U15—44.7%; U17—49%; U19—45.3%), followed by medium (U15—39.3%; U17—37.9%; U19—40%) and, in a much lower quantity, long passes (U15—16%; U17—13%; U19—14.7%) (Table 1).Pairwise comparison revealed that U15 used more long passes than U17 and U19.

Table 1. Descriptive analysis of passes length by age.

Age	Zone	Passes Length					
		Short		Medium		Long	
		n (%)	m ± sd	n (%)	m ± sd	n (%)	m ± sd
U15	1	2.8	8.39 ± 2.63	3.9	18.49 ± 2.53	2.4	29.69 ± 5.00
	2	6.8	8.23 ± 2.54	6.1	16.93 ± 3.06	2.2	29.75 ± 8.44
	3	10.9	8.54 ± 2.44	9.8	16.37 ± 2.94	3.2	33.99 ± 8.67
	4	13.4	8.26 ± 2.61	8.3	16.55 ± 3.01	3.9	30.40 ± 6.76
	5	7.9	8.23 ± 2.55	6.7	16.68 ± 2.98	1.6	32.35 ± 10.14
	6	3.0	8.74 ± 3.00	4.6	16.96 ± 3.11	2.8	32.23 ± 7.62
	Total	44.7	8.36 ± 2.57	39.3	16.82 ± 3.00	16.0	31.56 ± 7.91
U17	1	2.4	8.14 ± 2.73	2.9	16.50 ± 2.85	2.1	39.12 ± 20.35
	2	8.6	8.19 ± 2.68	6.9	16.71 ± 2.80	2.0	30.32 ± 9.46
	3	12.6	7.96 ± 2.66	9.1	16.48 ± 2.90	2.2	32.40 ± 7.96
	4	11.8	8.31 ± 2.50	7.8	16.47 ± 2.86	2.9	31.21 ± 7.26
	5	9.2	8.19 ± 2.62	6.8	16.19 ± 2.88	2.2	29.86 ± 5.81
	6	4.5	8.12 ± 2.94	4.4	16.79 ± 3.13	1.5	38.85 ± 21.25
	Total	49.0	8.15 ± 2.65	37.9	16.50 ± 2.89	13.0	33.04 ± 12.92
U19	1	1.6	8.37 ± 2.75	3.3	17.32 ± 2.48	2.2	31.58 ± 7.69
	2	8.3	8.36 ± 2.66	7.3	16.80 ± 2.82	2.3	29.39 ± 6.78
	3	11.6	8.30 ± 2.56	9.4	16.49 ± 2.78	2.6	30.80 ± 5.76
	4	13.7	8.24 ± 2.60	10.6	16.38 ± 2.87	3.9	29.99 ± 6.31
	5	7.6	8.40 ± 2.68	6.0	16.75 ± 3.19	2.0	28.90 ± 5.37
	6	2.5	9.18 ± 2.33	3.4	17.53 ± 2.95	1.7	32.60 ± 7.47
	Total	45.3	8.37 ± 2.60	40.0	16.76 ± 2.87	14.7	30.42 ± 6.57

n: relative frequency; m ± sd: Mean ± standard deviation.

However, statistically significant differences were noticeable (χ^2 = 113.0, p > 0.001) in the occurrence of different types of passes according to the field zones. The significant variations were recorded in the long passes in zone 1 (p < 0.001), zone 3 (p = 0.000), and zone 6 (p = 0.000) and in the short passes in zone 1 (p = 0.000), zone 4 (p = 0.001), and zone 6 (p = 0.000).There were no significant differences in the medium passes. In the zones nearest to the goal (zones 1 and 6), medium passes were mostly used, while short passes were predominantly used in the medium zone of the pitch (zones 2 to 5). In the end, short passes occurred less in zone 1 and long passes in the other zones (Figure 2). Overall, the teams revealed a relatively higher frequency of medium and long passes than short passes closer to the goal.

Considering the variation in the type of passes according to the pitch zones by age group, the results revealed significant differences for all the age groups analysed (U15, χ^2 = 41.6, p < 0.001; U17, χ^2 = 39.9, p < 0.001; U19, χ^2 = 53.5, p < 0.001) and the types passes analysed (long, χ^2 = 18.7, p < 0.044; short, χ^2 = 20.1, p < 0.029), except for medium passes (χ^2 = 15.0, p = 0.132).

Moreover, in the distribution of passes by each zone, the results revealed significant differences regarding long and short passes in zone 6 (p = 0.000), with a value above that expected in the U15.

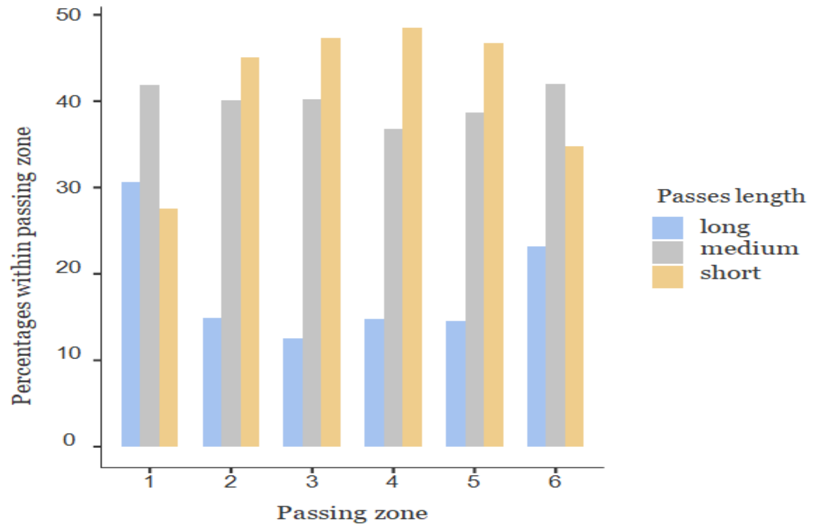

Figure 2. Distribution of the total number of passes by field zone.

Significant differences appeared in long and short passes in zone 1 and 3 (p = 0.000), with a value above that expected for long and below for short passes in the U17. Significant differences were reported in long and short passes in zone 1 (p = 0.000), with values above the expected for long and below for short passes in the U19. In general, long passes exceeded expectations in the areas close to the goals and were below expectations in the middle areas of the field. In opposition, short passes were below those expected in the areas close to the goals and above the expected in the middle areas of the field.

Moreover, we observed significant differences in the players who received the ball considering age in long passes (χ^2 = 32.2, p = 0.010) and medium passes (χ^2 = 31.8, p = 0.011).

Concerning short passes, in all ages, the player who received the most passes was P1. In this type of pass, there were only differences in the distribution for the fifth player, with the U17 considering this player at this distance (Figure 3). Regarding medium passes, the player who received more passes in the U15 was P2 (p > 0.05); in the U17 (p = 0.000) and U19 (p = 0.000), it was P3. As for long passes, the player who received more passes in the U15 was P5 (p = 0.000); in the U17 (p = 0.000) and U19 (p = 0.000), the player who received more passes was P6. The results show a trend for the younger players to use relatively closer players for long and medium passes compared to older players.

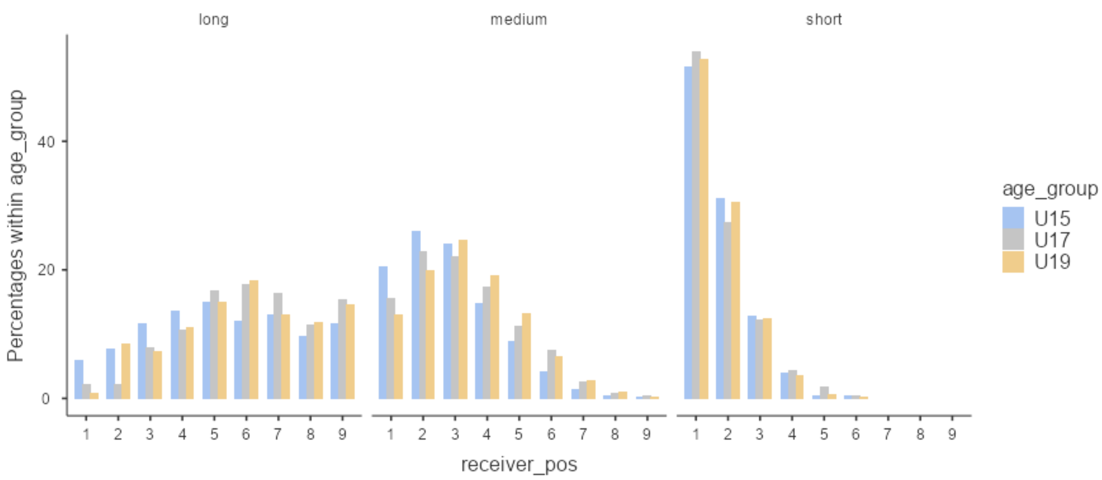

Figure 3. Passing distribution relative frequency of completed passes considering the relative distance between the ball receiver and the ball carrier, per age group and pass length.

4. Discussion

This study aimed to characterize the passing patterns that support the collective tactical behaviour of football players of different ages (U15, U17, and U19). According to our expectations, some variations in the passing patterns of play were observed according to the field zones of the ball where the pass was performed. For example, in all ages, the most used pass in the areas close to the goals was the medium pass, and in the medium zone, it was the short pass.Moreover, according to our expectations, variations in age category promoted variations in the type of most frequent passes and in the player that receives the ball.

4.1. Effect of Field Zones

In the analysis of the effect of the variation of the zones in which the ball was located, we verified that, in zone 1, medium passes were the most used. In line with previous studies, in zone 1, teams in possession of the ball tended to have numerical superiority, with great values of individual areas per player, regardless of age [17,18]. Therefore, in this play area, near the team's own goal zone, the players needed to use medium and long passes that allowed the creation of space to start the offensive game safely and, consequently, to advance on the field and pass the opponent's first defensive line.

In the middle area of the field (Z2 to Z5), there was an increase in short passes and a decrease in long passes. In these areas, the short pass was the most used, suggesting that teams, regardless of age, sought to establish functional relationships between the closest players to create a numerical advantage in the group relationships between the players closest to the ball [34] and, in this way, attempt to overcome direct opponents and create defensive imbalances for the opponent [9].

While zone 2 is characterized by the space where the organized attack begins, normally with little pressure on the ball and maintaining the numerical superiority of the attack, in zones 3 and 4, the individual playing area per player is smaller compared to the zones close to the goals [13,14], promoting more ball possession for the exploration and creation of progression possibilities [18] and more possibilities for shorter passes. As verified in previous studies, zones 2 to 5 correspond to the areas of the field with high values of pass variability in view of the space constraint to play and the plasticity in the offensive tactical behaviour necessary to promote progression in the game area [35].

In zone 6, with the decrease in distance to the opponent's goal, the most used type of pass was the medium pass due to the change concerning the objectives of ball circulation [creating imbalances to finish] and the emergence of possibilities to shoot on goal [11]. In this area, there tends to be a lower number of passes compared to the middle area of the field due to the proximity of the opposing goal that motivates the dribble and the shot. In this area, the team in possession of the ball tends to be outnumbered, and the short distance to the defending goal enhances the emergence of individual actions on the ball at greater risk [36]. The goal's location proved to be an informational invariant that conditioned the players' interpersonal relationships and individual and collective behaviours [11,12]. The field areas motivate the players' need to explore different possibilities of action, so as to discover the best solution according to the game requirements [23].

4.2. Effect of Players Age on Field Zone Dynamics

The effect of age on the different types of passes showed significant differences in long and short passes. The results revealed that younger players (U15) tend to use long (Z6) and medium (Z5 and Z6) passes more than older players (U17 and U19). This evidence is in line with previous studies, which revealed that younger players tend to adopt behaviours that allow them to approach the opponent's goal faster compared to older players [37].

On the contrary, U19 and U17 tended to use more long, medium, and short passes in zone 4 and zone 5 compared to U15. Previous studies suggest shorter distances between strikers and defenders in the middle zone of the field [38]. This spatial–temporal decrease potentiates variability in the possibilities for action depending on the variability of the spatial occupation of teammates and opponents [39], leading to the emergence of greater variability in the types of passes in order to obtain more functional actions adjusted to the conditions encountered [40].

The data suggest that older players showed greater variability in passes and showed greater adaptability in smaller playing areas [37]. In line with other studies, older players revealed a greater adaptability to the effects of manipulating the playing areas compared to younger players [21,41]. Thus, the greater game experience and consequent ability to functionally explore possibilities for action [42] of older players makes them more efficient in passing and gives them a better occupation of field spaces to receive the ball [39]. Our data also suggest that the players who most often received the ball were the closest to the carrier in the U15, regardless of the pass type. On the other hand, older players passed the ball more often to teammates, with more distant relative positions according to the pass length. For example, in the long pass, the player who received the ball most was P6 in U17 and U19. In the medium pass, it was P3 in the U19, and, with similar values, it was P2 and P3 in the U17, while, in short passes, the players closest to the ball (P1 and P2) revealed a greater tendency to receive the ball, regardless of age. Older players' ability to pass to more distant players may be due to their apparent advantages in body mass [44] and level of maturity compared [43,44] to younger players. The data suggest that the U15 made more long passes to the same relative position of the receiver compared to the U17 and U19, which is in line with another study that showed higher values of individual areas per player in the U15 level [37].

Moreover, older players with more playing experience are more flexible to the game dynamics [25,40], while younger players tend to play with more rigid behaviours [26]. However, greater knowledge of the game allows players to gather more and better information from the environment, perceiving more possibilities for action [44]. The study suggests that the sizes of passes performed in the soccer game were influenced according to the field area and player's age. In practical terms, these results reinforce the fact that the creation of exercises should consider the variation of the field location and the use of different numerical relationships in order to achieve a greater adjustment to the game conditions and ensure greater transfer between training and competition [16].

Due to the obtained results, and in order to better prepare the players to explore the best passing actions in zone 1, we suggest that the design of the should include the numerical superiority of attacking team [17], with more than four players in the defence, in order to clearly define the first defensive line and space to explore in-between lines [45]. The space used should be manipulated to allow players freedom of action in carrying medium passes, but also long and short ones according to the spatial–temporal relations with opponents. The manipulation of spaces should be considered according to the age of the players, with wider spaces for U15 than for U19 [37]. We also suggest that coaches could introduce two goals that the defensive team can use to score when recovering the ball to increase the feeling of danger in the case of losing ball possession [46].

Regarding zones 2 to 5, we suggest that the design of the SSCGs should include a numerical equality of teams from 5×5 to 8×8 [17,47], and promote variability in the exploration of short to medium passes both laterally and longitudinally. For that, the manipulation of spaces should be considered according to the age of the players and number of players involved, with wider spaces for U15 and U17 than for U19 [37]. The use of larger spaces and fewer players, particularly to youth players, tends to increase the number of individual actions in the exploration of possibilities for play due to the low restrictions in the spatial–temporal conditions [48]. We also suggest that coaches could manipulate the field such as the orientation (regular, square, triangle) [49], or even restrict the spaces that players could use in the field [29], to promote an adaptive capacity to explore the environment and explore the possibilities for short and long passes according to the conditions of the environment. Moreover, by considering the restriction of space and time to play and the large number of players involved in the zones 2 to 5, we suggest the manipulation of the number of touches as a constraint to improve players' capacity to adjust the body position according to the game flow, constantly pick up the information from the environment before to have the ball possession [50], and promote the passing skill [51].

In zone 6, we suggest that the design of the SSCGs should include numerical relations up to 10 players (5 × 5) with a playing area that will enable possibilities of action in the variety of medium and long passes. In this area, we suggest that the design of the SSCGs should include numerical equality to promote the variability of short and medium passes and numerical superiority in the attacking team of two or more players in relation to the opponent to allow more shooting opportunities [32]. Moreover, the zone of the field and the manipulation of spaces should be considered according to the age of the players and number of players involved, with wider spaces for U15 than U17 and U19 [37]. We also suggest the use of several goals [three to six] to promote greater distances between the players of one's own team and those of the opponent team in order to increase the variability of the individual and collective behaviours of the teams [46].

5. Conclusions

This study suggests, in line with the data from the game, the need to expose players to environmental conditions during training which are appropriate for the type of passes intended for the game. The ratio number of players and space motivates different ways of exploring the game depending on the players' own abilities [52]. For this, in the design of small games, the coach must consider the players' age to adjust accordingly to the game area and its proximity to the goal and the ratio number of players/game space.

Besides the study's contribution for practical purposes, some limitations should be acknowledged. Firstly, the games were not official. Thus, it reduces the competitive levels of an official game, despite ensuring a controlled environment. In addition, the teams played according to their own game model without any control of playing formations used over the matches (e.g., Gk + 4 + 4 + 2 or Gk + 4 + 3 + 3).

Future studies may consider the directionality of passes to help understand the playing style of teams and relate it to the types of passes in the different offensive phases of the game. The distance between strikers and defenders should also be considered in future studies to understand the type of pass with the proximity of the defender in relation to the ball receiver. Moreover, further research should consider not only the age/category of players but also their maturation stage and the relationship with the type of passes performed. The maturation stage should be considered in all studies with youth players due to its implications in their characterization of capabilities for action.

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References

1. Link, D.; Hoernig, M. Individual ball possession in soccer. *PLoS ONE* **2017**, *12*, e0179953. [CrossRef] [PubMed]
2. Rein, R.; Memmert, D. Big data and tactical analysis in elite soccer: Future challenges and opportunities for sports science. *Springerplus* **2016**, *5*, 1410. [CrossRef] [PubMed]
3. Davids, K.; Araújo, D.; Correia, V.; Vilar, L. How small-sided and conditioned games enhance acquisition of movement and decision-making skills. *Exerc. Sport Sci. Rev.* **2013**, *41*, 154–161. [CrossRef]
4. Gollan, S.; Bellenger, C.; Norton, K. Contextual Factors Impact Styles of Play in the English Premier League. *J. Sport. Sci. Med.* **2020**, *19*, 78–83.
5. Sarmento, H.; Clemente, F.; Harper, D.; Costa, I.; Owen, A.; Figueiredo, A. Small sided games in soccer—A systematic review. *Int. J. Perform. Anal. Sport* **2018**, *18*, 693–749. [CrossRef]
6. Fernandez-Navarro, J.; Fradua, L.; Zubillaga, A.; McRobert, A.P. Evaluating the effectiveness of styles of play in elite soccer. *Int. J. Sport. Sci. Coach.* **2019**, *14*, 514–527. [CrossRef]
7. Lago, C. The influence of match location, quality of opposition, and match status on possession strategies in professional association football. *J. Sport. Sci.* **2009**, *27*, 1463–1469. [CrossRef]
8. Gonçalves, B.; Coutinho, D.; Exel, J.; Travassos, B.; Lago, C.; Sampaio, J. Extracting spatial-temporal features that describe a team match demands when considering the effects of the quality of opposition in elite football. *PLoS ONE* **2019**, *14*, e0221368. [CrossRef]
9. Aquino, R.; Machado, J.C.; Manuel Clemente, F.; Praça, G.M.; Gonçalves, L.G.C.; Melli-Neto, B.; Ferrari, J.V.S.; Palucci Vieira, L.H.; Puggina, E.F.; Carling, C. Comparisons of ball possession, match running performance, player prominence and team network properties according to match outcome and playing formation during the 2018 FIFA World Cup. *Int. J. Perform. Anal. Sport* **2019**, *19*, 1026–1037. [CrossRef]
10. Gama, J.; Dias, G.; Couceiro, M.; Sousa, T.; Vaz, V. Networks metrics and ball possession in professional football. *Complexity* **2016**, *21*, 342–354. [CrossRef]
11. Headrick, J.; Davids, K.; Renshaw, I.; Araújo, D.; Passos, P.; Fernandes, O. Proximity-to-goal as a constraint on patterns of behaviour in attacker–defender dyads in team games. *J. Sport. Sci.* **2012**, *30*, 247–253. [CrossRef]
12. Laakso, T.; Travassos, B.; Liukkonen, J.; Davids, K. Field location and player roles as constraints on emergent 1-vs-1 interpersonal patterns of play in football. *Hum. Mov. Sci.* **2017**, *54*, 347–353. [CrossRef] [PubMed]
13. Fradua, L.; Zubillaga, A.; Caro, O.; Iván Fernández-García, A.; Ruiz-Ruiz, C.; Tenga, A. Designing small-sided games for training tactical aspects in soccer: Extrapolating pitch sizes from full-size professional matches. *J. Sport. Sci.* **2013**, *31*, 573–581. [CrossRef] [PubMed]
14. Tenga, A.; Zubillaga, A.; Caro, O.; Fradua, L. Explorative Study on Patterns of Game Structure in Male and Female Matches from Elite Spanish Soccer. *Int. J. Perform. Anal. Sport.* **2015**, *15*, 411–423. [CrossRef]
15. Gonçalves, B.; Figueira, B.; Maçãs, V.; Sampaio, J. Effect of player position on movement behaviour, physical and physiological performances during an 11-a-side football game. *J. Sport. Sci.* **2014**, *32*, 191–199. [CrossRef]
16. Laakso, T.; Davids, K.; Liukkonen, J.; Travassos, B. Interpersonal Dynamics in 2-vs-1 Contexts of Football: The Effects of Field Location and Player Roles. *Front. Psychol.* **2019**, *10*, 1407. [CrossRef] [PubMed]
17. McGuckian, T.B.; Cole, M.H.; Chalkley, D.; Jordet, G.; Pepping, G.-J. Constraints on visual exploration of youth football players during 11v11 match-play: The influence of playing role, pitch position and phase of play. *J. Sport. Sci.* **2020**, *38*, 658–668. [CrossRef] [PubMed]
18. Caro, O.; Zubillaga, A.; Fradua, L.; Fernandez-Navarro, J. Analysis of Playing Area Dimensions in Spanish Professional Soccer: Extrapolation to the Design of Small-Sided Games with Tactical Applications. *J. Strength Cond. Res.* **2019**, *35*, 2795–2801. [CrossRef]
19. Passos, P.; Amaro e Silva, R.; Gomez-Jordana, L.; Davids, K. Developing a two-dimensional landscape model of opportunities for penetrative passing in association football—Stage I. *J. Sport. Sci.* **2020**, *38*, 2407–2414. [CrossRef]
20. Vilar, L.; Araújo, D.; Davids, K.; Button, C. The role of ecological dynamics in analysing performance in team sports. *Sport. Med.* **2012**, *42*, 1–10. [CrossRef]
21. Olthof, S.; Frencken, W.; Lemmink, K. The older, the wider: On-field tactical behavior of elite-standard youth soccer players in small-sided games. *Hum. Mov. Sci.* **2015**, *41*, 92–102. [CrossRef]
22. Duarte, R.; Araújo, D.; Correia, V.; Davids, K.; Marques, P.; Richardson, J. Competing together: Assessing the dynamics of team-team and player-team synchrony in professional association football. *Hum. Mov. Sci.* **2013**, *32*, 555–566. [CrossRef]
23. Almeida, C.; Volossovitch, A.; Duarte, R. Influence of scoring mode and age group on passing actions during small-sided and conditioned soccer games. *Hum. Mov.* **2017**, *18*, 125–134. [CrossRef]
24. Varley, M.C.; Fairweather, I.H.; Aughey, R.J. Validity and reliability of GPS for measuring instantaneous velocity during acceleration, deceleration, and constant motion. *J. Sport. Sci.* **2012**, *30*, 121–127. [CrossRef]
25. Silva, P.; Aguiar, P.; Duarte, R.; Davids, K.; Araujo, D.; Garganta, J. Effects of Pitch Size and Skill Level on Tactical Behaviours of Association Football Players During Small-Sided and Conditioned Games. *Int. J. Sport. Sci. Coach.* **2014**, *9*, 993–1006. [CrossRef]
26. Grund, T.U. Network structure and team performance: The case of English Premier League soccer teams. *Soc. Netw.* **2012**, *34*, 682–690. [CrossRef]

27. Philippaerts, R.M.; Vaeyens, R.; Janssens, M.; Van Renterghem, B.; Matthys, D.; Craen, R.; Bourgois, J.; Vrijens, J.; Beunen, G.; Malina, R.M. The relationship between peak height velocity and physical performance in youth soccer players. *J. Sport. Sci.* **2006**, *24*, 221–230. [CrossRef]
28. Sevil-Serrano, J.; Práxedes, A.; García-González, L.; Moreno, A.; Del Villar, F. Evolution of tactical behavior of soccer players across their development. *Int. J. Perform. Anal. Sport* **2017**, *17*, 885–901. [CrossRef]
29. Gonçalves, B.; Coutinho, D.; Santos, S.; Lago-Penas, C.; Jiménez, S.; Sampaio, J. Exploring Team Passing Networks and Player Movement Dynamics in Youth Association Football. *PLoS ONE* **2017**, *12*, e0171156. [CrossRef]
30. Moore, S.A.; Mckay, H.A.; Macdonald, H.; Nettlefold, L.; Baxter-Jones, A.D.; Cameron, N.; Brasher, P.M.A. Enhancing a Somatic Maturity Prediction Model. *Med. Sci. Sport. Exerc.* **2015**, *47*, 1755–1764. [CrossRef] [PubMed]
31. Folgado, H.; Bravo, J.; Pereira, P.; Sampaio, J. Towards the use of multidimensional performance indicators in football small-sided games: The effects of pitch orientation. *J. Sport. Sci.* **2019**, *37*, 1064–1071. [CrossRef]
32. Vilar, L.; Duarte, R.; Silva, P.; Chow, J.Y.; Davids, K. The influence of pitch dimensions on performance during small-sided and conditioned soccer games. *J. Sport. Sci.* **2014**, *32*, 1751–1759. [CrossRef]
33. Campbell, I. Chi-squared and Fisher-Irwin tests of two-by-two tables with small sample recommendations. *Stat. Med.* **2007**, *26*, 3661–3675. [CrossRef] [PubMed]
34. Duarte, R.; Araújo, D.; Freire, L.; Folgado, H.; Fernandes, O.; Davids, K. Intra- and inter-group coordination patterns reveal collective behaviors of football players near the scoring zone. *Hum. Mov. Sci.* **2012**, *31*, 1639–1651. [CrossRef]
35. Clemente, F.; Couceiro, M.; Martins, F.; Mendes, R.; Figueiredo, A. Soccer team's tactical behaviour: Measuring territorial domain. *Proc. Inst. Mech. Eng. Part P J. Sport. Eng. Technol.* **2015**, *229*, 58–66. [CrossRef]
36. Vilar, L.; Esteves, P.; Travassos, B.; Passos, P.; Peñas, C.; Davids, K. Varying Numbers of Players in Small-Sided Soccer Games Modifies Action Opportunities During Training. *Int. J. Sport. Sci. Coach.* **2014**, *9*, 1007–1018. [CrossRef]
37. Olthof, S.; Frencken, W.; Lemmink, K. A Match-Derived Relative Pitch Area Facilitates the Tactical Representativeness of Small-Sided Games for the Official Soccer Match. *J. Strength Cond. Res.* **2019**, *33*, 523–530. [CrossRef] [PubMed]
38. Zubillaga, A.; Gabbett, T.; Fradua, L.; Ruiz-Ruiz, C.; Caro, O.; Ervilla, R. Influence of Ball Position on Playing Space in Spanish Elite Women's Football Match-Play. *Int. J. Sport. Sci. Coach.* **2013**, *8*, 712–722. [CrossRef]
39. Menuchi, M.; Moro, A.R.P.; Ambrósio, P.E.; Pariente, C.A.B.; Araújo, D. Effects of Spatiotemporal Constraints and Age on the Interactions of Soccer Players when Competing for Ball Possession. *J. Sport. Sci. Med.* **2018**, *17*, 379–391.
40. Silva, P.; Duarte, R.; Sampaio, J.; Aguiar, P.; Davids, K.; Araújo, D.; Garganta, J. Field dimension and skill level constrain team tactical behaviours in small-sided and conditioned games in football. *J. Sport. Sci.* **2014**, *32*, 1888–1896. [CrossRef]
41. Canton, A.; Torrents, C.; Ric, A.; Gonçalves, B.; Sampaio, J.; Hristovski, R. Effects of Temporary Numerical Imbalances on Collective Exploratory Behavior of Young and Professional Football Players. *Front. Psychol.* **2019**, *10*, 1968. [CrossRef] [PubMed]
42. Hewitt, A.; Greenham, G.; Norton, K. Game style in soccer: What is it and can we quantify it? *Int. J. Perform. Anal. Sport* **2016**, *16*, 355–372. [CrossRef]
43. Asadi, A.; Ramirez-Campillo, R.; Arazi, H.; Sáez de Villarreal, E. The effects of maturation on jumping ability and sprint adaptations to plyometric training in youth soccer players. *J. Sport. Sci.* **2018**, *36*, 2405–2411. [CrossRef] [PubMed]
44. Silva, P.; Travassos, B.; Vilar, L.; Aguiar, P.; Davids, K.; Araújo, D.; Garganta, J. Numerical relations and skill level constrain co-adaptive behaviors of agents in sports teams. *PLoS ONE* **2014**, *9*, e107112. [CrossRef]
45. Travassos, B.; Monteiro, R.; Coutinho, D.; Yousefian, F.; Gonçalves, B. How spatial constraints afford successful and unsuccessful penetrative passes in elite association football. *Sci. Med. Footb.* **2022**, 1–8. [CrossRef]
46. Travassos, B.; Gonçalves, B.; Marcelino, R.; Monteiro, R.; Sampaio, J. How perceiving additional targets modifies teams' tactical behavior during football small-sided games. *Hum. Mov. Sci.* **2014**, *38*, 241–250. [CrossRef]
47. Caro, O.; Fradua, L.; Zubillaga, A.; Fernandez-Navarro, J. *Analysis of Small Game Areas of 4vs4 and 7vs7 in Spanish Professional Football*; University of Granada: Granada, Spain, 2014; pp. 231–235.
48. Nunes, N.; Gonçalves, B.; Coutinho, D.; Nakamura, F.; Travassos, B. How playing area dimension and number of players constrain football performance during unbalanced ball possession games. *Int. J. Sport. Sci. Coach.* **2021**, *16*, 334–343. [CrossRef]
49. Coutinho, D.; Gonçalves, B.; Santos, S.; Travassos, B.; Wong, D.P.; Sampaio, J. Effects of the pitch configuration design on players' physical performance and movement behaviour during soccer small-sided games. *Res. Sport. Med.* **2018**, *27*, 298–313. [CrossRef]
50. Oppici, L.; Panchuk, D.; Serpiello, F.R.; Farrow, D. Futsal task constraints promote transfer of passing skill to soccer task constraints. *Eur. J. Sport Sci.* **2018**, *18*, 947–954. [CrossRef]
51. Coutinho, D.; Gonçalves, B.; Santos, S.; Travassos, B.; Folgado, H.; Sampaio, J. Exploring how limiting the number of ball touches during small-sided games affects youth football players' performance across different age groups. *Int. J. Sport. Sci. Coach.* **2021**, *17*, 545–557. [CrossRef]
52. Laakso, T.; Davids, K.; Luhtanen, P.; Liukkonen, J.; Travassos, B. How football team composition constrains emergent individual and collective tactical behaviours: Effects of player roles in creating different landscapes for shared affordances in small-sided and conditioned games. *Int. J. Sport. Sci. Coach.* **2021**, *17*, 346–354. [CrossRef]

children

Article

Flexible Training Planning Coupled with Flexible Assessment: A 12-Week Randomized Feasibility Study in a Youth Female Volleyball Team

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Abstract: According to the Quality Education and Gender Equality ambitions established at the 2030 Agenda for Sustainable Development Goals, we aimed to test the feasibility of a flexible planning and assessment process, using ongoing, bidirectional feedback between planning and assessment. Eighteen players (11.5 ± 0.5 years of age) from a U13 female volleyball team were randomized into an experimental group (in which the plan could be changed daily) or a contrast group (pre-defined planning, adjusted monthly). The pedagogical intervention lasted three months. Besides ongoing daily assessments from the training practices, the Game Performance Assessment Instrument was adopted as a starting point for the weekly assessments in 4 vs. 4 game-forms (i.e., the instrument was modified monthly based on feedback from the training process). Information from daily and weekly formal assessment was used in the planning of the experimental group, and monthly in the contrast group. Data suggested that pre-established and strict planning (even updated monthly) failed to fit current learner needs. Over 12 weeks, the pre-established planning suffered regular modifications in the experimental group, and the assessment tool changed monthly. In conclusion, both planning and assessment should be open and flexible to exchange information mutually, and support the design of tailor-made learning environments.

Keywords: meta-assessment; bidirectional feedback; flexible planning; qualitative randomized study; volleyball

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1. Introduction

Quality in Education and Gender Equality are two core items (goals 4 and 5, respectively) of the 2030 Agenda for Sustainable Development Goals (SDGs). The endless search for better learning strategies (point 4), framed upon learner-centered approaches [1,2], and the breaking away from the common application of investigation protocols in male samples (point 5)—which is typical of Sports Sciences [3,4]—are pinpoints of this work. Learning depends on inner transformations, producing complex, interwoven interactions between educational environments and intra and interindividual differences in response to dynamic, evolving paths (i.e., bidirectional stimuli and interactions) [5,6]. Consequently, predicting the results of any learning process, in terms of its magnitude, quality and timings, is a very difficult—perhaps impossible—task [7,8]. The non-linear nature of educational settings entails that identical inputs may produce vastly different outputs, whereas other inputs may result in the same output [9,10]. *Actual* learning should therefore be deeply intertwined with planning and assessment, but these are often essentially predetermined and/or standardized [11–13].

Planning the learning process is thoroughly recommended, but the level of detail and time ahead might be questionable [13,14]. In contradiction with non-linear premises, teaching and training processes tend to over-emphasize pre-planning, including pre-established contents and their sequences, as well as time restrictions based on the idea that each training phase will enhance the subsequent one in a predictable manner (i.e., periodized programs) [14,15]. In sports training, coaches often use periodized programs, which establish the sequence and timing of events [8,16]. This kind of approach could force coaches to follow pre-planned content, ignoring important incoming information from the learners. For instance, in team sports, Gavanda et al. [17] aimed to compare different resistance training programs (all of them pre-established) in American football and did not find any benefit of one to the others, which shows the inability to predict the players' response to practice. The motivation behind this study is based on the idea that there is no optimal sequence to learning skills [18]. Therefore, the best way to drive the planning is by constantly assessing and screening the unfolding of the actual learning process, detecting fragilities and opportunities to act over time [8,13].

For responding to non-linear features of education and learning [9,19], perhaps there should not exist strict start and end points to each block of content; moreover, the timing of each content section should be established individually [8,20]. Furthermore, flexible plans, coupled with ongoing flexible assessments, may respond better to the non-linearity of learning, keeping the focus of the process on the learner instead of the planning [21,22].

Assessment tools should be applied continuously and incorporate flexible features [23,24]. In this vein, assessments should occur with a certain regularity (preferably ongoing, i.e., "each exercise is a test") to create a more accurate picture of the *real* improvement on learning. Complementary to this, being flexible enough to adapt to different moments and needs of the learners (i.e., move away from standardization and become an evolving process) is important [11,25]. In this regard, recently, Atkinson and Brunsdon [24] applied a flexible approach to assess students in Physical Education classes that adapt better to their needs, especially in soccer, basketball and volleyball underlying that assessment in sports should go beyond measuring performance. However, currently most of the assessment tools used in Physical Education and sports training, as EUROFIT of FMS, regulate their assessment based on average values (abstract, and away from the real context) acting like a "one-size fits all", and ignoring the individuality of the learner and the context [26–28].

Evaluating the assessment tools and reflecting on their utility in planning is called "meta-assessment", and it is fundamental to keep an open path between planning and assessment [25,29]. A straight connection between planning and assessment implies a bidirectional exchange of information [11,13]. So, planning should constantly inform the assessment about the main goals and execution criteria to fulfill [11]. Concomitantly, this information might result in a deeper reflection on assessment: whether the criteria are adjusted to the learners, and whether the assessed content is related to established planning goals [24]. Doing so, sport practitioners are working on building appropriate learning environments. Appropriateness emerges as a concept whose application varies depending on the individuals and the context in which they operate, and build their sporting identity [30].

For studying bidirectional links between planning and assessment, volleyball portrays an adequate application field given its technical rigor, as well as dynamic and complex action possibilities among players [31,32]. Studies focused on pedagogical interventions in the context of volleyball are usually performed with pre-defined planning. To exemplify, Sgrò, et al. [33] aimed to examine the effect of a determined instruction plan in volleyball learning; however, during the 13-week period, the plan was not adjusted based on the learner's evolution. This largely contrasts with our idea of using the assessment as a source of information to correct planning. The same occurs with the assessment tools used in those studies, which are the same at the beginning and end of the pedagogical intervention [33,34]. Besides that, the application of randomized interventions in sports training and scholarly contexts might bring some implementation issues, especially when those applications imply the whole training time, and are across every training day. This randomization process implies the total division into different groups that do not mix in any part of the learning process.

This study aimed to test the feasibility of flexible planning coupled with a flexible assessment process in a longitudinal experimental trial (12-weeks) with parallel randomization, launching ongoing, bidirectional feedback between plan and assessment of learning—especially of the dynamic, ongoing process of assessing and readjusting the planning in a young female volleyball team (i.e., real-life context). Overall, this project presents the novelty of an evolving planning and assessment process, due to its strong, ongoing, and bidirectional links, enhancing a process-focus instead of a traditional product-focus design. Furthermore, to guarantee that the effects in learning were not merely due to time effects, the longitudinal nature of the intervention, along with the implementation of two contrasting randomized groups ensured a greater quality of data interpretation.

2. Material and Methods

2.1. Design

We adopted the CONSORT guidelines [35]. The purpose was to implement longitudinal experimental research with parallel randomization that effectively assessed qualitative and quantitative learning changes when comparing two approaches to planning. All the data were collected in the training facilities of the club, throughout 12-weeks in a total of 34 training sessions. The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Faculty of Sport of the University of Porto (CEFADE 30 2021), and financed by the Portuguese Foundation for Science and Technology (reference: EXPL/CED-EDG/0246/2021). The original protocol is available in the English language upon reasonable request.

2.2. Participants

The sample was eligible by convenience [36], consisting of a female mini-volleyball team (n = 18, age 11.5 $\pm$ 0.5) in one of the most prestigious Portuguese volleyball clubs. These players were considered 'information-rich' due to being at the beginning of their sporting pathway, so they did not have tactical or technical preconceptions on volleyball practice and were actively engaged in participation. The club has more than 100 national titles in volleyball, participation in European competitions, and is known for its excellence in younger teams. It also has top training facilities which largely helped the practice conditions, and consequently the data collection. The previous coaching staff had divided 18 players into two teams: A (more advanced) and B (less advanced), according to their skill level. Any player could be excluded from the investigation if, at any moment, they left the club or withdrew from the practice of volleyball. During the 12-week period, the coaching staff were able to deliberate whether any other player of that age should be integrated into this investigation. In this case, the referred player should be randomized into one of the groups. The team was composed of 10 players deemed of skill level A (most advanced, 11.3 $\pm$ 0.3 years of age) and 8 players deemed of skill level B (less advanced—11.9 $\pm$ 0.3 years). Skill level was determined here in a comparative manner, and skill level A did not necessarily mean a high absolute skill level. Upon randomization, the experimental group was composed of 9 athletes (5 from level A and 4 from level B; 11.6 $\pm$ 0.5 years) and the contrast group of 9 athletes (4 from level A and 5 from level B; 11.3 $\pm$ 0.5 years). Upon beginning this research, whereby two of the authors became the coaches of this team, the players from both teams were randomized into two separated groups of 9 players (i.e., using an allocation ratio of 1:1) through the tool http://random.org/sequences accessed on 30 March 2022. The randomization was performed by a researcher not engaged with the interventions, and unknown to who the athletes were. To further ensure concealment of allocation sequence, the main researcher (who also implemented the interventions) only had access to the groups on the first day of the intervention. The first author plays a double role in this investigation as head coach and researcher [37]. The players and their parents were fully informed on the research goals and signed an informed consent form that had been previously approved by the Ethics Committee. Anonymity was ensured (e.g., not using the proper names of players) and players were also informed of the possibility of withdrawing their participation at any moment. Figure 1 synthesizes the study design.

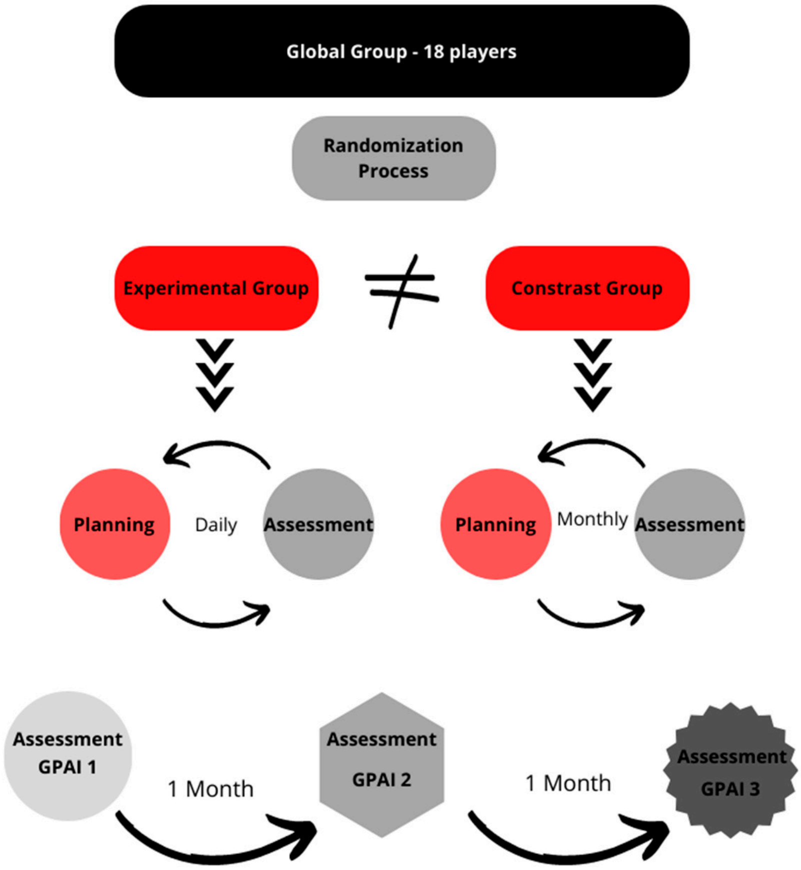

Figure 1. Study design.

2.3. Interventions

Upon an initial diagnostic evaluation of the players' skills during the first week of practice, a periodized program was designed as described in Supplementary Material: Figure S1 (Periodized planning), with a weekly formal assessment moment every Saturday, as it was the last training session of the week. This periodized program focused largely on tactical and technical contents (i.e., on learning the specific volleyball actions) and not on physical or psychological factors. Both groups were guided by the same Game Model (GM). The GM established technical and tactical principles of play, which are fundamental for team organization [38,39]. Thereby, those principles largely informed the initial planning. Specifically, the creation of the GM was conducted according to the technical and tactical skills of players, their past experience in the sport, and the club's philosophy. This philosophy is based on a long-term sports development, preparing the youth players to integrate into the adult team, which has competed in the highest Portuguese division for decades. This investigation occurred during the last 3 months of the season; therefore, the previous coaching team that had a reasonable knowledge of the players' skills and team dynamics, established the GM. The GM required some advanced control of the basic volleyball actions (e.g., set, pass, and spike) as well as a reasonable level of game-related knowledge (e.g., exploring different attacking zones and tempos). The attacking zone is determined by where the attacker contacts the ball according to the zones of the volleyball court, while attacking tempo is defined by the relative timing between the attacker and the setter's actions [40].

The experimental group followed an open learning process with regular interchanging information between planning and assessment, whereby the planning could be altered daily. Thus, the planning process tried to satisfy the players' needs in different moments, and the adaptations performed to the initial planning were based on ongoing assessments (i.e., the coaches' daily perceptions of how the players were evolving and adapting to the training process, including daily field notes). Weekly discussions between the head coach/main researchers and the research team complemented the planning process. Conversely, the contrast group followed a pre-planned, periodized intervention, which could only be adapted monthly. Therefore, both groups could deviate considerably from the original periodized plan, although those deviations would occur at different time points. Importantly, although the plans had to be followed for at least 1 month in the contrast group (i.e., the contents and their specificities had to be respected for that period), the specific exercises and their sequences could be planned daily to better deliver a proper pedagogical process.

2.4. Assessment

We emphasized the idea of turning every practice into an assessment moment, where the coach was responsible for taking notes on the performance of players, planning limitations during the learning process, and thoughts on how players were reacting to the current planning. This ongoing assessment provided ongoing insights that were used to understand the players' evolution as well as individual needs and helped the coach and research team to reflect about the learning process. Therefore, ongoing bidirectional links were established between planning and assessment. All of the information collected during the daily practices (through reflections), was complemented by punctual formal assessments that were held in every last session of the training week (Saturday), during 10 min of 4 vs. 4 games between both groups. The games were recorded by an HD camera in the back of the court and at around 2 m height to have a clear vision of both sides of the court. Here, the baseline assessment tool was the Game Performance Assessment Instrument (GPAI) [41], as it delivers a holistic overview of how the learning process is translating into meaningful behaviors in game-like situations. The starting version of the GPAI was the one used in the INEX study [42]. In this specific study, the GPAI was divided into four major analyses: efficiency; efficacy, adjustments, and decision-making. In each one of those categories, every contact of the player with the ball was considered as "appropriate" or "inappropriate", depending on whether they fulfilled the pre-established criteria or not. During the day, after the formal assessment (i.e., on Sunday), the data collected by the video was analyzed (every time by the same person belonging both to the research and coaching teams) in a qualitative and quantitative fashion. All the actions were analyzed with a qualitative approach, according to GPAI criteria. Then, GPAI turned the "appropriate" and "inappropriate" actions into quantitative indexes of efficacy, efficiency, performance, and decision-making.

Both the GPAI outcomes and the daily reflections derived from the training process were discussed between the research team and coaches each Monday to plan the following practices of the experimental group, and for outlining potential necessities for the contrast group (which could only be implemented after one month). Once a month, a special meeting between the research team and the coaching staff was held to debate the developments of the training process within the contrast group and determine changes to the planning. Moreover, the starting version on GPAI was changed every month both for its categories and respective criteria (i.e., meta-assessment process), according to coaching feedback of their specific concerns, as well as players' evolution in game-related knowledge. Doing so, we aimed to fit the assessment tool as much as possible to players' needs in every moment.

Considering the goals and nature of this randomized study, the outcomes are mostly qualitative, attempting to provide an account of the evolution of this process of bidirectional links between planning and assessment. Since meta-assessment was employed, not even the original GPAI can be directly compared to the endpoint GPAI, as the instrument was strongly modified during this study (as this was one of the goals established by the research team and it is coherent with a flexible approach to planning). This is possible to verify in Supplementary Material.

2.5. Blinding

Due to the ethical concerns involved with this study, both those implementing the interventions and those participating in them (i.e., the players) were fully aware of the goals of this trial, although the players were not aware if they had been incorporated into the experimental or contrast group. The main author was not blinded to the interventions, but the remainder of the research team was, and the weekly meetings (and the changes emerging from those meetings) were decided with most of the research team remaining blinded to the participants in each intervention (apart from the main author).

2.6. Data Analysis

Data analysis can be divided into three major aspects: (i) descriptive and ongoing report of a player's evolution through the daily performance in practice; (ii) reflection about the learning-process, its implications on the assessment tool, and the barriers and opportunities on the randomized intervention; (iii) analysis of GPAI data—more important than the comparison of performance between different moments, the interpretation of data to guide subsequent planning, and adaptation of the assessment tool in research-coaching meetings.

3. Results

All 18 players finished the season, and thereby 100% of the eligible sample was recruited and completed the experiment (Figure 2). The focus of the results was not on the individual evolution of the players, but the adaptations to the planning performed in both groups, and the readjustments performed throughout the assessment moments. The analyses were focused on the training process, namely the interplay between planning and assessment in both groups, and the barriers and opportunities associated with this type of research.

3.1. Adaptation of Planning in Light of Ongoing Assessments

The starting point for planning and determination of drills in training and the pedagogical strategies used were deeply connected with the players' skill level, and consequently GM premises. The first assessment moments (i.e., the coach's perceptions during the 1st and 2nd training weeks) suggested that the initial planning required adjustments. At this point, a low understanding of the game (high values of inappropriate actions in tactical domains, such as spike and upper-hand/tennis serve), and consequently a weak interpretation and execution of the game, were noted in both groups. In this way, we noticed that the GM was, in part, misadjusted from reality, and required adjustments. Ethically though, no decisive conclusion should be stated at the moment: (i) on the one hand, the experimental group may seem to benefit from more agile changes to the planning that are better adjusted to their current state of development; (ii) on the other hand, it is possible that a more stable plan could provide the necessary stability, and that the contrast could benefit from persisting for an extended period before changing the overall plan.

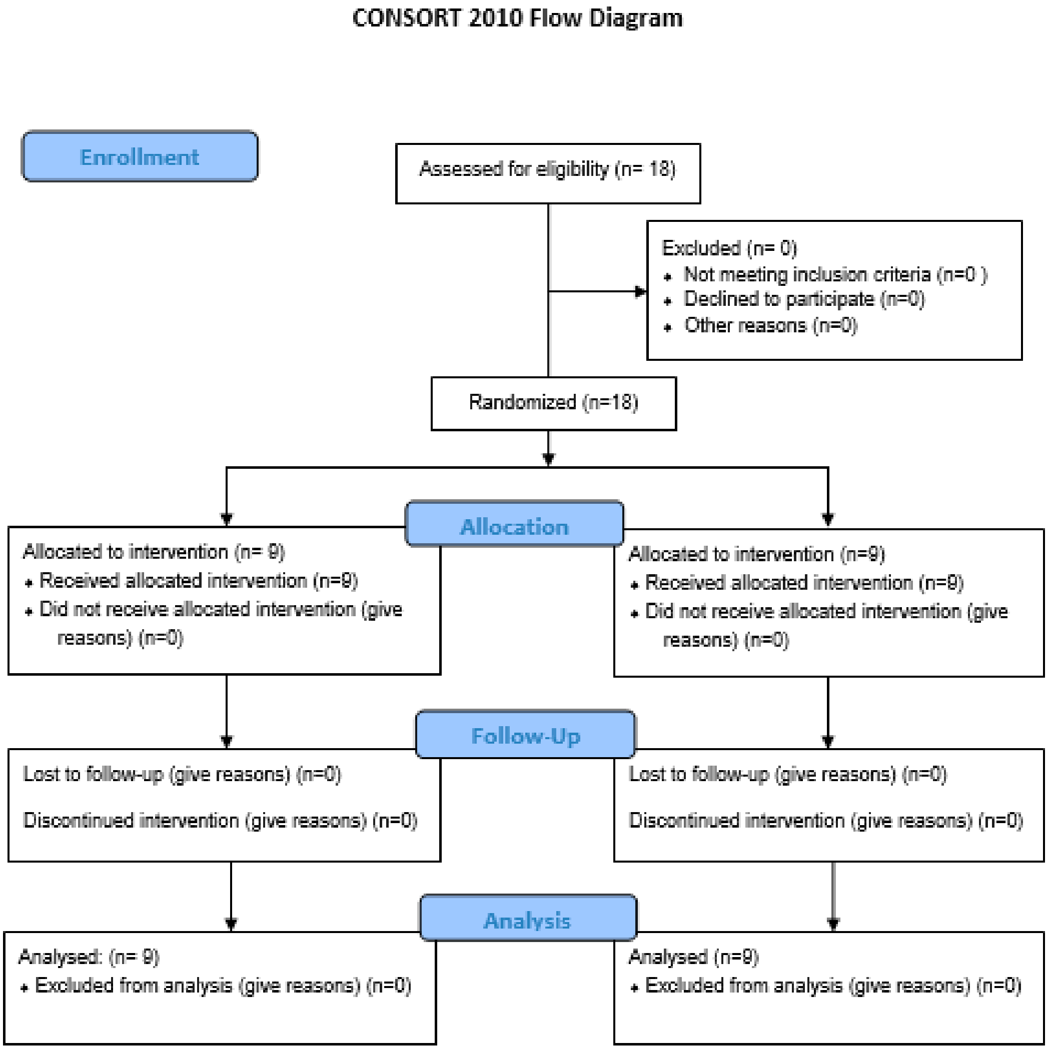

Figure 2. Work-flow randomization process (CONSORT).

To exemplify, we felt the necessity to spend much more time practicing (i.e., was the central topic of the week for 12 weeks in the experimental group, and only in 8 weeks of the contrast group) basic ideas of passing and setting to create better conditions to spike. We implemented those adaptations in the experimental group, while the contrast group spent some time working on the spike technique and approach. Despite being subjected to the pre-planned contents, the contrast group benefited from adjustments in the exercises, which were progressively more tailor-made to help the players in the contrast group to evolve.

We thought that it could be possible to reach more advanced volleyball actions such as (i) jump-float serve; (ii) different attack tempos; (iii) jump-set; (iv) variations in attack in zone 3, as they were part of the GM. However, during the initial weeks, we noticed that the experimental group should follow a strongly different progression, specifically requiring a less ambitious plan (i.e., more strongly focused on some basic game actions, such as passing, setting, and displacement), especially from the 3rd week of intervention onward (Supplementary Material: Figures S1 and S2). Those differences were based on daily field notes, and useful information from the GPAI assessments. After the first month of the intervention (i.e., in May), some of the initial goals were readjusted in the contrast group, such as different attacking tempos that were withdrawn from the planning. At the end of the second month, we noticed that a few pre-established contents were too advanced for the real state of the performance of the whole group, such as jumping set or variations in attack on zone 3. During the last month of the intervention, the major difference between groups was the introduction (as pre-established) of the jump-serve and the introduction to blocking ideas that were also not used in the experimental group.

Ongoing feedback between planning and assessment was the significant input of this investigation into the learning process. For example, the utility of exploring the attack on zone 3 in May, or even the approach to attack, and how to attack a high ball all in the same month. Near the beginning of the second month, this point turned into a growth opportunity, as a coach. Sometimes we felt the content planned for the contrast group was not the most adjusted and still created stimulating tasks for the learner, based on that pre-established content. During the month of June, we tried to introduce the block, and automatically felt that this was unimportant entirely.

3.2. The Contribution of the More Formal Weekly Assessments

During the process, the GPAI was considerably modified to fit the players' necessities and the coach's concerns (e.g., to assess the set action in different contexts such as passing and setting; change service assessment to only one category—upper-hand service). Those changes occurred in efficacy measures (e.g., removing punctuation from passing and digging), efficiency (e.g., adding different weights to continuing attacks), decision-making (e.g., when attacking instead of attacking to the right spot), and adjustment criteria (e.g., reading and reacting to a Freeball situation—i.e., occurs when the opponents predictably send an easy ball, thus not having the possibility of attack [32]). All of those adjustments will be developed further. Accordingly, from the first GPAI version to the last one, almost all the criteria were modified and adjusted considering the analysis of coaching staff and the players' needs—see examples in Supplementary Material: Figures S3–S5.

To exemplify, we excluded the "underhand and jump serve" and combined all the observation grids for the "overhead serve". In the first GPAI modifications (version 2) we made a few adjustments in the technical criteria of setting and passing; however, in the second moment we felt the need to change the criteria slightly: the set as a volleyball action is different when is used as first contact (i.e., dig or receive), or as the second contact (i.e., setting). For this reason, we split the set assessment into two categories: the first contact, and the second contact with different criteria to assess the "same action". In addition, the need for understanding whether the players read and react correctly to a freeball situation emerged because that game phase has specific characteristics. Therefore, a category of 'freeball' was created to analyze if the setter could run this type of transition, and if the defenders adopted the correct behavior (i.e., an appropriate occupation of the pitch).

We adjusted some criteria about spike and serve actions (GPAI version2), since we felt that the players were so focused on changing and improving technical issues that they neglected the tactical issues (i.e., to where should I serve or attack?). So, in GPAI version 2, we removed all the decision-making categories to attack and serve. Later, in the third GPAI, we returned to analyze the decision-making in attacking, but we completely changed assessment lenses. Instead of looking at whether the player attacks in the right spot, we assessed whether, in the right conditions, the player chooses to spike. Doing so, we had a different viewpoint of the attack once we were concerned about the player being capable of spiking in the right spot (i.e., making the best decision), as well as controlling the technique and knowing how and when to use it. The blocking action follows, in part, the spike assessment. Once that occurs, we start assessing the technique demands and finally assessing whether the player decided correctly when they should block or not.

Evaluations of actions' efficacy were adapted over time from the first version of GPAI that only contemplates three categories: (i) error; (ii) continuation; and (iii) point. Additionally, all the game fundamentals (i.e., service; reception; set; spike and block) were considered in the same way, even when they have considerable contextual differences. Thus, we decided to remove the point criteria of continuous actions, and adjust the terminal actions based on Palao et al. [43] by creating different weights according to the difficulties imposed on the opponent.

The meta-assessment or assessing the assessment occurred during the monthly meetings between the coaching and research team. Those adaptations were consequence of reflective moments on the planning, and how the assessment tool could be adapted to accomplish learning goals. In terms of efficiency, the initial version of GPAI had 23 variables within different volleyball actions; in contrast, the final version had only 13 variables focused on the same volleyball actions—see Tables S1 and S2 in Supplementary Material. Moreover, to keep the data collection simple and precise, the "adjustments" that contemplate the tactical behavior of the player in the game context also decrease, from 13 to 11 variables.

3.3. Barriers and Opportunities: On the Feasibility of Implementing This Research Design

With the *randomization* into two groups with different planning methodologies, the coaching staff had to plan two different practices, and at the same time be able to guide different exercises with their specificities and goals. To correctly apply this process, we needed a larger coaching staff. For instance, several players that started playing volleyball to enjoy more time with friends were set up to practice in separate groups; this could, in part, influence their motivation to practice, as it was verbally expressed by a few players in the beginning of the pedagogical intervention. To minimize the damage of that split, in the last training before competition, part of the practice participants were divided into teams (as they will play in the tournament) and not into groups (experimental and contrast); this time, around 30 min in one sporadically organized session did not represent a bias in the training division.

A mixed-level group (i.e., players from team A and players from team B performed together) started as a problem, especially regarding the motivational issues of the most advanced players. However, it became helpful for several reasons: (i) the building of a more extended and cohesive group of players, that did not practice only in small teams, which became visible in tournaments with players of different groups supporting each other; (ii) players practiced with higher-skilled players and with lower skilled players, turning the whole group into more extended and homogeneous one which, even if it not the most essential thing in the short term, could be a significant input for the club in a medium-long term; (iii) all these features contributed to a more diverse environment for practice, as playing with different athletes exposed each player to different constraints and promoted different strategies.

The adherence rate of players was similar in the experimental groups (mean: 78%, minimum: 60%, and maximum: 90%) and contrast group (mean: 81%, minimum 65%, and maximum: 94%) consistent with a realistic training process, especially with such young players who were not yet engaged in weekly formal competitions. Non-adherence to practice can cause multiple issues, such as a lot of time between training stimuli, and missing learning moments of specific content.

Many *external constraints* have also affected the application of pre-established planning. As an example of such external constraints, we had to deal with the inhibition of using the training hall to practice due to other competitions; on two consecutive Mondays, the group was forced to cancel the practice, and it became impossible to develop the pre-established planning in the contrast group. In that case, we kept the planning and went through the missing session. In this vein, other moments forced the coaches to develop the training in different training gyms, with extra space, number of balls or number of courts available.

3.4. Endpoints: Convergences and Divergences between the Two Paths

Besides monthly adaptations in the planning of the contrast group, at the end of the intervention, there were a few relevant differences between the planning of both groups such as introduction to jump-float serve, blocking and jump-setting in the contrast group, which the experimental one did not follow. Ongoing assessment, especially through daily reflections after practice, resulted in a simpler planning with essential actions in the experimental group, while the pre-established planning (i.e., contrast group) was more ambitious. Moreover, this discrepancy meant that the experimental and contrast groups followed (at least in part) different paths during the learning process. However, the monthly adjustments in the pre-established planning (i.e., contrast group) considerably contributed to reducing the gap in the differences between planning for the experimental and contrast groups.

Most of the athletes ended the 12-week intervention more proficient than they were in the beginning. However, the essential question at this point was "what does the coach/teacher think that is more important to this specific group of learners?". In our intervention it was clear that, based on the club's philosophy, to improve passing and setting one should guarantee sustainable interpretation of GM, and only with the control of those actions, should the players be able to interpret and use correctly most advanced actions (such as the jump-set or spike).

Both experimental and contrast groups had carefully planned practices, and players improved their overall performance in the game. In competition, although the practice group was different from the competition one, we noticed a stronger spirit of mutual help between the whole group of players, which it is a considerable positive point in this process. Here, the most important outcome is that the whole group (i.e., both experimental and contrast) improved in the interpretation of GM, and in execution of volleyball actions. In this sense, even though the experimental and contrast groups followed different paths, especially in planning contents, it is important to notice that both improved their performance in official competitions.

4. Discussion

The present study explored the feasibility of a randomized investigation in a youth female volleyball team, namely how a flexible planning interplay with an ongoing and adaptable assessment, could cooperate to improve learning [11,13]. The results showed that the bidirectional feedback between planning and assessment is feasible, as well as this exchange of information resulting in ongoing changes in planning and in the way as players were assessed [12,21]. Accordingly, the weekly assessment was revealed to be important, not only to determine the qualitative and quantitative aspects of a player's performance, but also to enable coaches to devise appropriate learning contexts according to players' needs (i.e., by constantly informing plans on possible readjustments). Thereby, one of the main results of the study was the adaptation made to the assessment tool over time (i.e., meta-assessment), and according to the development of players. Moreover, our data demonstrated that all the pedagogical interactions between coach and player can turn into informal assessment moments and provide useful insights into following learning tasks. The assessment tool, in this specific case the GPAI, became of paramount importance, especially regarding its flexible features.

4.1. The Need for a Flexible Approach to Planning

Planning in a flexible fashion opens the door to adapt not only according to external issues (i.e., training facility unavailability) [44], but also by considering internal processes (i.e., learner's development) as it was recognized in this study [45,46]. After the implementation of this investigation, it became clear that there are multiple factors influencing the planning of the learning process that are out of control of the teacher/coach (e.g., external constraints as training center issues, adherence of players to practice) [47]. As it is possible to notice in our study, the comparison of content between the groups' planning rarely matched. From the first moments, after a period of diagnosed assessment due to a specific deficit of game knowledge, coupled with some difficulties in performing many technical actions, led the coaching staff to re-think the following planning. This means that even "just" one month ahead, it was not possible to predict players' evolution [48]. This finding is in sharp contrast with the study of Pliauga, et al. [49], where it is assumed that, in long-term planning, coaches/teachers know a priori the outcome promoted by different training approaches. Conversely, our findings strongly corroborate the assumptions of Niemi [50], namely that the non-linear nature of learning makes the outcome promoted by a training session unpredictable, and enhances the need for continuous adaptations to learners' needs over time.

So, it is urgent to change the paradigm of planning from pre-established content and timing to a flexible approach [8,51]. In this investigation, both groups received largely different planning, even after a periodical adaptation of the contrast group. There were other issues identified and reflected on by the coaching staff during the process, sometimes thinking how fair it is to expose a group to a practice exercise that is not the most appropriate (i.e., contrast group). Even so, independently of the content, improving a specific technique and using an action to increase game-related knowledge was possible. The essential important feeling, so far, was to show all the players that the experimental group was not "more important" than the contrast group. Thus, following an appropriateness-based intervention, the coach adapted each skill so that players could feel that every exercise of every group was useful to help them become better players.

4.2. The Need to Rethink Assessment

Across the pedagogical intervention, we observed that a substantial part of the assessment was conducted in a daily routine, through analysis of training and response of learners to practice [52]. Complementary to this, GPAI punctual and formal assessment added more information and some precise data to ongoing assessment, enhancing the learning process [41,53]. The first version of GPAI, broadly used in the literature was, in part, decontextualized. Underpinned with general technical ideas, some technical criteria were so generic that they did not provide helpful insight to the coaching staff. For example, in the first version of GPAI we assessed whether the player gets ready to attack after a dig. However, such an action might not be possible when, for instance, the setter digs the ball. Thus, our data showed the importance of using a representative assessment tool (i.e., contextualized to practice) that evaluates the learners' performance and evolution accurately. Such an assumption contradicts the other studies that applied a single unmodified version of GPAI. For instance, studies used GPAI to compare technical and tactical behaviors with different court sizes in small-sided games [53]. In this way, the same criteria were used to different constraints (i.e., court size). In our investigation, we created a deep connection between planning and the assessment, raising the question of how we could build assessment tools that were constantly adapted over different learning moments [13,24].

Assessment should be applied as a regulator of the learning process and a collection of valuable insights that might be used to adapt subsequent teaching procedures. For example, our change of assessing the "set" and contextual interference in the same volleyball action—as they have other technical demands, such as the point of contact with the ball (higher is setting) or the use of the legs in the action (more critical in dig or reception). Therefore, during the investigation, we created constant updated versions of GPAI, more precise and capable of aiding the coaching staff in a more direct, quicker, and easier fashion—all versions in Supplementary Material—Figures S3–S5. However, traditionally, assessment occurs in a formal way and at very specific time points during a learning process [54]. A clear example of that is the scholar context where assessment normally takes place at the end of a module, or period to grade students (i.e., summative assessment) [55]. In this way, the content is the center of the learning process and not the learner, as we argue [25].

So, assessment should be much more than just a formality, but a pedagogical tool that ongoingly informs the educational praxis as is suggested by Dixson and Worrell [56] or Leenknecht, et al. [57]. Additionally, the forms of assessment applied might be more variable: not limited to formal assessments such as exams or tests, but also promoting moments of self or peer-assessment, and consequently engaging learners in the learning process [58,59]. All the data collected were both in the formal assessment (i.e., GPAI) and ongoing informal assessment (i.e., daily practice, coaches' notes) which were used to adjust the planning and design of learning environments of the experimental group during training sessions. Formative assessment only occurs when the outcome of the assessment is truly used in other learning activities [12,60]. It is critical to change the mindset of how we look at assessment, by putting the learner in the center of the process and thinking about how it can cooperate with learning [22].

4.2.1. The Need for an Ongoing, Flexible Assessment

The main goal of assessment should not be to take different pictures, such as a snapshot of individual learning moments, but to create a more global view, or movie, of the process that allows for a more in-depth understanding regarding the evolution of the learner over time and consequently, to support the learning process [30,61]. We adapted the GPAI formulas for the efficacy and efficiency formula considering three actions for scoring points in volleyball (service, spike, and block), and actions that usually do not score points (passing, setting, and digging). By passing and setting, we can increase the possibility of scoring, but these actions usually do not allow for scoring a point [62]. In our viewpoint, this modification allows the coach and the player to more deeply understand the consequences of their own attack on the opposite team. Therefore, if we want the planning to be as flexible and moldable as possible to learners' needs, coaches and teachers should be able to detect those needs [8].

Ongoing assessment seems to be, so far, the best way to see deficits in the learning process, as well as to be capable of measuring the learners' evolution [63,64]. If the learner has other issues to solve over time, the assessment used should be able to detect various problems [30]. To deal with such complexity, assessment tools should acquire a flexible characteristic (i.e., being moldable, capable of measuring different variables, and changing the criteria) [24]. Flexible assessment tools ensure a clear overview of learners' performance depending on their own needs [24,65]. To complement that, an ongoing use of those assessments allows the coach/teacher to detect different fragilities, and plan accordingly [66]. For example, suppose the significant difficulties an athlete, when learning to set in volleyball, will probably have with issues in the hand positions or reading the ball's trajectory. Though, after a training period (to some players it might be a week, to others it might be a month or more), the challenges that players will face might be completely different, such as attacking player tempo or blocking opposition.

4.2.2. The Role of More Punctual, Formal Assessments

Ongoing assessments during the week provide the coach with a considerable amount of data and valuable insights into the following week's planning—as are daily reflection on the process and the response of learners to the practice [67]. That importance of reflection towards better planning strategies, and consequently better practices, is referred to by Downham and Cushion [68] while interviewing high-level coaches. In addition, ongoing assessment during the practices was always restricted to content used in those practices (i.e., if the practice does not explore the spike action for example, during the week we cannot understand the true needs of the learners in that action). To complement this idea, a formal weekly assessment allowed the coach to have a more precise overview about the performance of the players in the real game scenario (i.e., it is actually representative of teaching-learning context).

Besides the crucial importance of the ongoing assessment of the learning process [69,70], a punctual moment could have important pedagogical implications [71,72]. In a certain way, in daily practice we can only extract information about the content that we practice; for instance, if I focus on the service action, I will have more data and conclusions about that specific moment. When we create an open assessment moment, even if the tool's design had criteria, we allow the learner to express their performance with much more "freedom," allowing us to detect different fragilities from daily practice. Those moments could act like motivational benchmarks in the learners' process. In our study, weekly assessments of 4 vs. 4 games became one of the most desired moments of the week for many reasons: players want to compete, and essentially, the evaluation was constituted by something they enjoyed (i.e., playing volleyball). If on one hand, Shepard, Penuel, and Pellegrino [60] incentivize the formative assessment instead of using punctual assessment and grading to motivate students, on the other hand, both processes can complement each other.

4.2.3. Meta-Assessment as a Pedagogical Imperative

The meta-assessment, as an adaptation of the assessment tool to learners' needs should be imperative to every learning process [71]. Staying away from the conventional idea of a pre-established tool with defined contents, tasks, and criteria, it seems to be time to move into more flexible and adaptable assessment tools. In this intervention, meta-assessment resulted in three structural modifications to the GPAI assessment tool. Those processes of meta-assessment might fit with different subjects addressed during a determined period, and constantly adapted to the group and the moment. This premise strongly supports the inter and intra-variability inherent to any learning process, which implies that not all learners should follow identical sequences and timing of educational contents, as advocated by van de Ruit and Grey [46] and Raviv, et al. [73].

We experienced the monthly special meeting between researchers and coaches as a rich moment of reflection, sharing and thinking about how we could extract useful information from the formal assessment. At the same time, those meetings not only focused on the assessment process, but also on how we manage the planning according to the new goals. In this vein, the assessment should not be the same for all the groups or even, to all the learners; it should be capable of being adapted according to the needs of the specific group of athletes, or a class [56,74]. So, this process of adaptation and changing the assessment mechanism implies deep reflection on evaluating one's own assessment tool [29,75]. First, the constant adaptation of the tool implied a constant adaptation of the observer. Therefore, the first assessment, after changing GPAI, took more time due to adapting to new criteria and categories. Although, it was an excellent moment of reflection about what the coaches want from the players, how they want them to do each action, and what the following steps are in learning volleyball, coaches and teachers should often ask themselves: "is the assessment giving me useful insights?"; "is the assessment related to the actual planning?"; "what changes could be made in assessment to better respond to my worries?"; and beyond that, "is the assessment responding to players worries and needs?". Concluding, the adaptations in the categories of GPAI allow us to have a more precise view of the game and players' needs; however, the constant adaption also had a few issues. We proceed to this adjustment because all of the players completely dominated "underhand service", so it is an action that does not challenge the player. Moreover, it is not a technique used in most advanced levels of the game (i.e., from the beginning 6 × 6 to the senior levels). Consequently, it will not give any useful insight into the subsequent planning; on the opposite side, the jump serve is an action that the players cannot use in official competitions and, most importantly, none of them can execute. Figure 3 synthesizes the workflow of implementation, assessment, and planning.

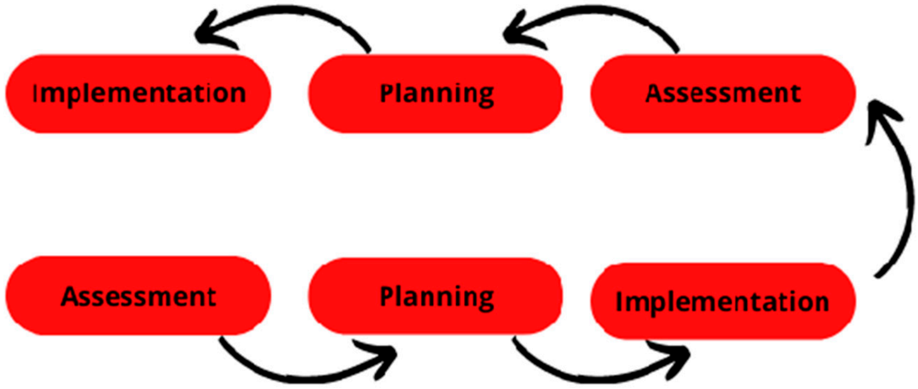

Figure 3. Workflow of assessment adaptation to the process.

4.3. The Need for Ongoing Feedback between Planning and Assessment

The initial planning was designed after an informal assessment that intended to diagnose the players' abilities, and conversation with prior coaching staff about their level and the necessities of the team. The planning should be conducted by creating strategies in order to fulfill major difficulties of learners, and take them to the next level of performance [22,76]. Diagnostic assessment, commonly used in school and sports training, can be a useful tool to direct the first planning period (a session or a week, for example) [55,66]. The diagnostic assessment should be able to show what the global level of the learner in a certain activity are (i.e., what are the major difficulties of the students in a 4 vs. 4 volleyball game?). After that first assessment moment, all the planning gets a basic intent: to get better and improve in those difficulties [77,78]. Planning and assessment should cooperate in interdependence, responding to non-linear features of the learning process [13,79]. In this way, we acted differently from the majority of longitudinal experimental studies where there is no exchange of information between assessment and planning. As an example, Leonardi, et al. [80] examined the changes in tactical performance of female basketball players during a 4-month period, but without ongoing feedback, only focusing on the final product. Assessment moments might measure the evolution of learning, and constantly inform what should be the priorities in the subsequent planning [11,81]. During the 12-week process, we experienced this deep connection between planning and assessment. Over the time, the coach took notes about the difficulties of players, and some specific worries that should be analyzed by the assessment tool. At the same time, in the beginning of each week, in the research-coaching meeting we discussed the players' performance during the assessment, as well as coaches' feelings during the week and how those could be turned into useful information for planning. Maybe if there were specific issues detected, those might be used in subsequent planning and be the focus of the next assessment. For instance, what specific issues of passing were addressed in the training session? The assessment should focus on having a true idea of learned aspects and major difficulties. Here, we create a richer environment when both processes change useful insights.

4.4. From Design to Implementation: Feasibility Issues

This 12-week study *questions the feasibility of a randomized and longitudinal study* in a youth sports team. We aimed to understand the major difficulties within the implementation of different planning approaches into randomized groups, and how we can be able to solve them. Besides that, we intended to explore what opportunities emerge from this approach in a sports training context. Usually, 18 players represent only one group in a practice setting (i.e., one team, under one global training planification). Only under these conditions (i.e., a proper coaching staff), was it possible to provide constant feedback and have a positive interaction with players in both groups. Moreover, and according to adherence rates of players, we felt that independently of the group (experimental or contrast), there were particular cases of athletes with around 60% adherence. Here, learning improvements were difficult due to the absence of training stimuli. The idea of maintaining the pre-established plan, independent of adherences, was even more difficult than the learning adaptations.

During those 12 weeks, we attempted as much as possible to increase the number of coaches participating in practice, which did not happen all the time. Those moments (when only one coach was responsible for the eighteen players in two different groups) demanded an extra-effort from the coach and might not have created the ideal conditions for practice. The coaching team sought to fulfill this gap by creating moments before the practice for players to practice volleyball without imposed rules, and with the teams created by themselves. In this way, the sorts of players that are more motivated by being with their friends maintain those moments. Other strategy to solve this specific problem was a punctual game situation, where the experimental and contrast group played against each other but with different constraints to each team, maintaining the focus of the main goal within the practice. For example, the experimental group is focused on improving their attack on zone 3 and they might win an extra point when they score attacking on zone 3; or if the contrast group has their major focus of the week on serve and passing, they get an extra point for serving and passing well.

The randomization of the whole group into experimental and contrast groups was the most accurate solution to establish two different groups with the same technical and tactical baseline. However, it created some specific issues as the motivation to practice at this particular age, and in female sports, focuses especially on friendship [82,83]. In this case, we created some specific strategies to try to attenuate those side effects of group randomization. Besides the randomization to investigate issues, players from experimental and contrast groups might belong to the same team and play together in official tournaments. Therefore, players that compete together in official competitions might practice separately during the week. We tried to minimize the issue of training separately, planning the last training session before the tournament by teams (i.e., as they will play in tournament), instead of planning by groups (i.e., experimental and contrast).

5. Practical Implications and Future Research Directions

As the benefits of flexible assessment and planning were promising in this investigation, we suggest that this kind of design and approach should be deeply tested in further studies. Recommendations for future studies can be seen in Figure 4.

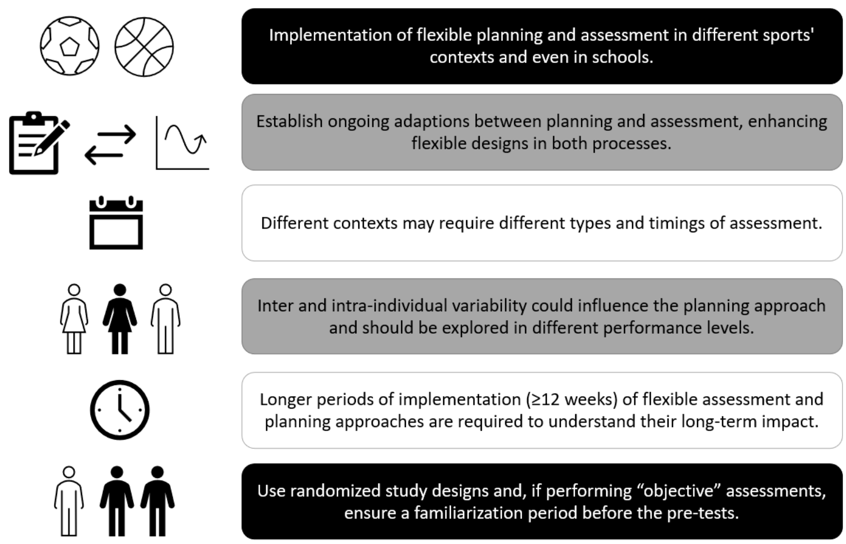

Figure 4. Suggestions for future research in bidirectional feedback between planning and assessment.

6. Limitations

During the application of the project, the majority of the limitations were related to the parallel randomization of the group and subsequent social implications, as was previously explored in the results. Additionally, on specific occasions, the main gym of the club was not available, and the group was forced to practice in a smaller space which meant that the need to train separately, due to the randomization demands, might have reduced the practice quality. Finally, having two different plans to apply would have been easier to implement with a large coaching staff.

7. Conclusions

We recommend the careful planning of the learning process; however, a careful and sustainable planning process should be flexible and adaptable to multiple changes over time. Plans that are too detailed ignore intra- and inter-individual variability, inherent characteristics in any learning group. This adaptability of planning should not only be individualized to learners' necessities, but also flexible to external constraints. These adaptations over time in planning should be guided through ongoing assessments, and these can provide useful insights about learners' evolutions and diagnostic special needs to aid planning. A flexible plan is open to receiving information from assessment and can adapt in order to respond correctly to actual learners' needs. In the same way, the assessment tools should adapt to different constraints, issues, and contexts that the learner needs to solve over time. The assessment itself should be assessed (i.e., meta-assessment), as a result of reflection about the learning process, and for consideration of what the next steps are that coaches and teachers want their learners to undertake. Future research is recommended in this area of planning and assessment bidirectional interaction, especially during longer periods of time and in different contexts.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/children10010029/s1, Figure S1 "Periodized Planning", Figure S2 "Flexible Planning", Figure S3 "GPAI Version 1", Figure S4 "GPAI Version 2" and Figure S5 "GPAI Version 3"; Table S1: GPAI variables in Efficiency; Table S2: GPAI variables in Decision Making.

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References

1. Ennis, C.D. What goes around comes around ... or does it? Disrupting the cycle of traditional, sport-based physical education. *Kinesiol. Rev.* **2014**, *3*, 63–70. [CrossRef]
2. Herranen, J.; Vesterinen, V.-M.; Aksela, M. From learner-centered to learner-driven sustainability education. *Sustainability* **2018**, *10*, 2190. [CrossRef]
3. McQuilliam, S.J.; Clark, D.R.; Erskine, R.M.; Brownlee, T.E. Mind the gap! A survey comparing current strength training methods used in men's versus women's first team and academy soccer. *Sci. Med. Footb.* **2022**, *6*, 1–8. [CrossRef] [PubMed]
4. Emmonds, S.; Heyward, O.; Jones, B. The Challenge of Applying and Undertaking Research in Female Sport. *Sport. Med. Open* **2019**, *5*, 51. [CrossRef]
5. Roberts, W.M.; Newcombe, D.J.; Davids, K. Application of a constraints-led approach to pedagogy in schools: Embarking on a journey to nurture physical literacy in primary physical education. *Phys. Educ. Sport Pedagog.* **2019**, *24*, 162–175. [CrossRef]
6. Sullivan, M.O.; Woods, C.T.; Vaughan, J.; Davids, K. Towards a contemporary player learning in development framework for sports practitioners. *Int. J. Sport. Sci. Coach.* **2021**, *16*, 1214–1222. [CrossRef]
7. Jung, H.; Choi, E. The importance of indirect teaching behaviour and its educational effects in physical education. *Phys. Educ. Sport Pedagog.* **2016**, *21*, 121–136. [CrossRef]
8. Afonso, J.; Clemente, F.M.; Ribeiro, J.; Ferreira, M.; Fernandes, R.J. Towards a de facto nonlinear periodization: Extending nonlinearity from programming to periodizing. *Sports* **2020**, *8*, 110. [CrossRef] [PubMed]
9. Chow, J.Y.; Davids, K.; Button, C.; Renshaw, I. *Nonlinear Pedagogy in Skill Acquisition: An Introduction*; Routledge: London, UK, 2015.
10. Strogatz, S.H. *Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering*; CRC Press: Boca Raton, FL, USA, 2018.
11. Coutinho, P.; Afonso, J.; Ramos, A.; Bessa, C. Harmonizing the learning-assessment cycle. In *Learner-Oriented Teaching and Assessment in Youth Sport. Porto, Portugal*; Farias, C., Mesquita, I., Eds.; Routledge: Porto, Portugal, 2022.
12. Schildkamp, K.; van der Kleij, F.M.; Heitink, M.C.; Kippers, W.B.; Veldkamp, B.P. Formative assessment: A systematic review of critical teacher prerequisites for classroom practice. *Int. J. Educ. Res.* **2020**, *103*, 101602. [CrossRef]

13. Loureiro, M.; Nakamura, F.Y.; Ramos, A.; Coutinho, P.; Ribeiro, J.; Clemente, F.M.; Mesquita, I.; Afonso, J. Ongoing Bidirectional Feedback between Planning and Assessment in Educational Contexts: A Narrative Review. *Int. J. Environ. Res. Public Health* **2022**, *19*, 12068. [CrossRef]
14. Kiely, J. Periodization paradigms in the 21st century: Evidence-led or tradition-driven? *Int. J. Sport. Physiol. Perform.* **2012**, *7*, 242–250. [CrossRef]
15. Kataoka, R.; Vasenina, E.; Loenneke, J.; Buckner, S.L. Periodization: Variation in the definition and discrepancies in study design. *Sport. Med.* **2021**, *51*, 625–651. [CrossRef] [PubMed]
16. Afonso, J.; Rocha, T.; Nikolaidis, P.T.; Clemente, F.M.; Rosemann, T.; Knechtle, B. A Systematic Review of Meta-Analyses Comparing Periodized and Non-periodized Exercise Programs: Why We Should Go Back to Original Research. *Front. Physiol.* **2019**, *10*, 1023. [CrossRef] [PubMed]
17. Gavanda, S.; Geisler, S.; Quittmann, O.J.; Schiffer, T. The effect of block versus daily undulating periodization on strength and performance in adolescent football players. *Int. J. Sport. Physiol. Perform.* **2019**, *14*, 814–821. [CrossRef] [PubMed]
18. Den Hartigh, R.J.; Niessen, A.S.M.; Frencken, W.G.; Meijer, R.R. Selection procedures in sports: Improving predictions of athletes' future performance. *Eur. J. Sport Sci.* **2018**, *18*, 1191–1198. [CrossRef] [PubMed]
19. Correia, V.; Carvalho, J.; Araújo, D.; Pereira, E.; Davids, K. Principles of nonlinear pedagogy in sport practice. *Phys. Educ. Sport Pedagog.* **2019**, *24*, 117–132. [CrossRef]
20. De Ribaupierre, A.; Lecerf, T. On the Importance of Intraindividual Variability in Cognitive Development. *J. Intell.* **2018**, *6*, 17. [CrossRef]
21. Afonso, J.; Mesquita, I. How do coaches from individual sports engage the interplay between longand short-term planning? *RPCD* **2018**, *18*, 85–98. [CrossRef]
22. Afonso, J.; Ramos, A.; Coutinho, P.; Mesquita, I.; Clemente, F.M.; Farias, C. Creative learning activities: Thinking and playing 'outside the box'. In *Sport Learner-Oriented Development and Assessment of Team Sports and Games in Children and Youth Sport: Teaching Creative, Meaningful, and Empowering Learning Activities*; Routledge: Porto, Portugal, 2022.
23. Fukuda, D.H. *Assessments for Sport and Sthletic Performance*; Human Kinetics: Champaign, IL, USA, 2018.
24. Atkinson, O.; Brunsdon, J.J. Changing the Score: Alternative Assessment Strategies and Tools for Sport in Middle School Physical Education. *Strategies* **2022**, *35*, 23–30. [CrossRef]
25. Mesquita, I.; Afonso, J.; Coutinho, P.; Ramos, A.; Farias, C. Implementing learner-oriented assessment strategies. In *Learner-Oriented Teaching and Assessment in Youth Sport*; Mesquita, C.F.I., Ed.; Routledge: Oxfordshire, UK, 2022.
26. Tomkinson, G.R.; Carver, K.D.; Atkinson, F.; Daniell, N.D.; Lewis, L.K.; Fitzgerald, J.S.; Lang, J.J.; Ortega, F.B. European normative values for physical fitness in children and adolescents aged 9–17 years: Results from 2 779 165 Eurofit performances representing 30 countries. *Br. J. Sport. Med.* **2018**, *52*, 1445–1456. [CrossRef]
27. Grgic, J. Test–retest reliability of the EUROFIT test battery: A review. *Sport Sci. Health* **2022**, *95*, 1–8. [CrossRef]
28. Lander, N.; Morgan, P.J.; Salmon, J.; Barnett, L.M. Teachers' perceptions of a fundamental movement skill (FMS) assessment battery in a school setting. *Meas. Phys. Educ. Exerc. Sci.* **2016**, *20*, 50–62. [CrossRef]
29. Fanelli, D.; Costas, R.; Ioannidis, J.P. Meta-assessment of bias in science. *Proc. Natl. Acad. Sci. USA* **2017**, *114*, 3714–3719. [CrossRef] [PubMed]
30. Ramos, A.; Afonso, J.; Coutinho, P.; Bessa, C.; Farias, C.; Mesquita, I. Appropriateness-based learning activities: Reaching out to every learner. In *Learner-Oriented Teaching and Assessment in Youth Sport*; Mesquita, C.F.I., Ed.; Routledge: Porto, Portugal, 2022.
31. Rocha, A.C.R.; Laporta, L.; Andre Barbosa de Lira, C.; Modenesi, H.; Figueiredo, L.S.; Costa, G.D.C.T. Complex I in male elite volleyball: An interactional analysis according to reception location. *Int. J. Perform. Anal. Sport* **2022**, *22*, 77–89. [CrossRef]
32. Hileno, R.; Arasanz, M.; García-de-Alcaraz, A. The sequencing of game complexes in women's volleyball. *Front. Psychol.* **2020**, *11*, 739. [CrossRef]
33. Sgrò, F.; Coppola, R.; Schembri, R.; Lipoma, M. The effects of a tactical games model unit on students' volleyball performances in elementary school. *Eur. Phys. Educ. Rev.* **2021**, *27*, 1000–1013. [CrossRef]
34. Boichuk, R.; Iermakov, S. Pedagogical conditions of motor training of junior volleyball players during the initial stage. *J. Phys. Educ. Sport* **2017**, *17*, 327–334. [CrossRef]
35. Cuschieri, S. The CONSORT statement. *Saudi J. Anaesth.* **2019**, *13*, S27. [CrossRef]
36. Etikan, I.; Musa, S.A.; Alkassim, R.S. Comparison of convenience sampling and purposive sampling. *Am. J. Theor. Appl. Stat.* **2016**, *5*, 1–4. [CrossRef]
37. Coghlan, D. *Doing Action Research in Your Own Organization*; Sage: London, UK, 2019.
38. Guilherme, J. Conhecimento Específico em Futebol: Contributos para a Definição de Uma Matriz Dinâmica do Processo Ensino Aprendizagemtreino do Jogo. Porto: FCDEF-UP. Ph.D Thesis, University of Porto, Porto, Portugal, 2004.
39. Castelo, J. *Futebol: Modelo Técnico-Táctico do Jogo: Identificação e Caracterização das Grandes Tendências Evolutivas das Equipas de Rendimento Superior*; Faculdade de Motricidade Humana: Lisbon, Portugal, 1994.
40. Afonso, J.; Mesquita, I.; Marcelino, R.; Da Silva, J.A. Analysis of the Setter's Tactical Action in High-Performance Women's Volleyball. *Kinesiology* **2010**, *42*, 82–89.
41. Oslin, J.L.; Mitchell, S.A.; Griffin, L.L. The game performance assessment instrument (GPAI): Development and preliminary validation. *J. Teach. Phys. Educ.* **1998**, *17*, 231–243. [CrossRef]

42. Maia, J.A.R.; Barreira, D.; Coutinho, P.; Dias, C.; Tavares, F.; Sousa, F.; Silva, A.; Fernandes, R.J. A estrutura operativa do INEX. *RPCD* **2021**, *2021*, 25–44. [CrossRef]
43. Palao, J.; Manzanares, P.; Ortega, E. Techniques used and efficacy of volleyball skills in relation to gender. *Int. J. Perform. Anal. Sport* **2009**, *9*, 281–293. [CrossRef]
44. Pass, J.; Nelson, L.; Doncaster, G. Real world complexities of periodization in a youth soccer academy: An explanatory sequential mixed methods approach. *J. Sport. Sci.* **2022**, *40*, 1290–1298. [CrossRef] [PubMed]
45. Hader, K.; Rumpf, M.C.; Hertzog, M.; Kilduff, L.P.; Girard, O.; Silva, J.R. Monitoring the athlete match response: Can external load variables predict post-match acute and residual fatigue in soccer? A systematic review with meta-analysis. *Sport. Med. Open* **2019**, *5*, 1–19. [CrossRef] [PubMed]
46. Van de Ruit, M.; Grey, M.J. Interindividual variability in use-dependent plasticity following visuomotor learning: The effect of handedness and muscle trained. *J. Mot. Behav.* **2019**, *51*, 171–184. [CrossRef]
47. Jovanovic, M.; Jukic, I. Optimal vs. Robust: Applications to Planning Strategies. Insights from a simulation study. *SportRxiv* **2019**. [CrossRef]
48. Atkinson, G.; Batterham, A.M.; Hopkins, W.G. Sports Performance Research under the Spotlight. *Int. J. Sport. Med.* **2012**, *33*, 949. [CrossRef]
49. Pliauga, V.; Lukonaitiene, I.; Kamandulis, S.; Skurvydas, A.; Sakalauskas, R.; Scanlan, A.T.; Stanislovaitiene, J.; Conte, D. The effect of block and traditional periodization training models on jump and sprint performance in collegiate basketball players. *Biol. Sport* **2018**, *35*, 373–382. [CrossRef]
50. Niemi, K. 'The best guess for the future?'Teachers' adaptation to open and flexible learning environments in Finland. *Educ. Inq.* **2021**, *12*, 282–300. [CrossRef]
51. Henriksen, K.; Storm, L.K.; Kuettel, A.; Linnér, L.; Stambulova, N. A holistic ecological approach to sport and study: The case of an athlete friendly university in Denmark. *Psychol. Sport Exerc.* **2020**, *47*, 101637. [CrossRef]
52. Neupert, E.; Gupta, L.; Holder, T.; Jobson, S.A. Athlete monitoring practices in elite sport in the United Kingdom. *J. Sport. Sci.* **2022**, *40*, 1450–1457. [CrossRef] [PubMed]
53. Jorge Rodrigues, M.C.; Rodrigues Rocha, A.C.; Barbosa Lira, C.A.; Figueiredo, L.S.; Vilela Lima, C.O.; Laporta, L.; De Conti Teixeira Costa, G. How small-sided games' court dimensions affect tactical-technical behavior in beginner volleyball athletes. *Int. J. Sport. Sci. Coach.* **2022**, *17*, 1385–1395. [CrossRef]
54. Siedentop, D.; Hastie, P.; Van der Mars, H. *Complete Guide to Sport Education*; Human Kinetics: Champaign, IL, USA, 2019.
55. López-Pastor, V.M.; Kirk, D.; Lorente-Catalán, E.; MacPhail, A.; Macdonald, D. Alternative assessment in physical education: A review of international literature. *Sport Educ. Soc.* **2013**, *18*, 57–76. [CrossRef]
56. Dixson, D.D.; Worrell, F.C. Formative and summative assessment in the classroom. *Theory Into Pract.* **2016**, *55*, 153–159. [CrossRef]
57. Leenknecht, M.; Wijnia, L.; Köhlen, M.; Fryer, L.; Rikers, R.; Loyens, S. Formative assessment as practice: The role of students' motivation. *Assess. Eval. High. Educ.* **2021**, *46*, 236–255. [CrossRef]
58. Andrade, H.L. A critical review of research on student self-assessment. *Front. Educ.* **2019**, *2019*, 87. [CrossRef]
59. Afonso, J.; Farias, C.; Ramos, A.; Coutinho, P.; Mesquita, I. Empowering self-assessment, peer-assessment, and sport learning through technology. In *Sport Learner-Oriented Development and Assessment of Team Sports and Games in Children and Youth Sport: Teaching Creative, Meaningful, and Empowering Learning Activities*; Routledge: Porto, Portugal, 2022.
60. Shepard, L.A.; Penuel, W.R.; Pellegrino, J.W. Using learning and motivation theories to coherently link formative assessment, grading practices, and large-scale assessment. *Educ. Meas. Issues Pract.* **2018**, *37*, 21–34. [CrossRef]
61. Whitley, M.A.; Massey, W.V.; Camiré, M.; Boutet, M.; Borbee, A. Sport-based youth development interventions in the United States: A systematic review. *BMC Public Health* **2019**, *19*, 1–20. [CrossRef]
62. Silva, M.; Lacerda, D.; João, P.V. Match analysis of discrimination skills according to the setter attack zone position in high level volleyball. *Int. J. Perform. Anal. Sport* **2013**, *13*, 452–460. [CrossRef]
63. Hepburn, L.-A.; Borthwick, M.; Kerr, J.; Vasnev, A. A strategic framework for delivering ongoing feedback at scale. *Assess. Eval. High. Educ.* **2022**, *47*, 742–754. [CrossRef]
64. Ben-Eliyahu, A. Sustainable learning in education. *Sustainability* **2021**, *13*, 4250. [CrossRef]
65. Booysen, R.M. The perspectives of secondary school teachers regarding the flexible implementation of the Curriculum Assessment Policy Statement. Ph.D. Thesis, North-West University, Potchefstroom, South Africa, 2018.
66. Rieu, A.; Leuders, T.; Loibl, K. Teachers' diagnostic judgments on tasks as information processing–The role of pedagogical content knowledge for task diagnosis. *Teach. Teach. Educ.* **2022**, *111*, 103621. [CrossRef]
67. Clutterbuck, D. Coaching reflection: The liberated coach. *Coach. Int. J. Theory Res. Pract.* **2010**, *3*, 73–81. [CrossRef]
68. Downham, L.; Cushion, C. Reflection in a high-performance sport coach education program: A Foucauldian analysis of coach developers. *Int. Sport Coach. J.* **2020**, *7*, 347–359. [CrossRef]
69. Stiggins, R.; DuFour, R. Maximizing the power of formative assessments. *Phi. Delta Kappan.* **2009**, *90*, 640–644. [CrossRef]
70. Gikandi, J.W.; Morrow, D.; Davis, N.E. Online formative assessment in higher education: A review of the literature. *Comput. Educ.* **2011**, *57*, 2333–2351. [CrossRef]
71. Mesquita, I.; Afonso, J.; Coutinho, P.; Ramos, A.; Farias, C. Teaching creative, meaningful, and empowering learning activities. In *Learner-Oriented Teaching and Assessment in Youth Sport*; Routledge: Porto, Portugal, 2022.

72. Bonney, N.; Berry, J.; Ball, K.; Larkin, P. Australian football skill-based assessments: A proposed model for future research. *Front. Psychol.* **2019**, *10*, 429. [CrossRef]
73. Raviv, L.; Lupyan, G.; Green, S.C. How variability shapes learning and generalization. *Trends Cogn. Sci.* **2022**, *26*, 462–483. [CrossRef]
74. Carney, P.A.; Mejicano, G.C.; Bumsted, T.; Quirk, M. Assessing learning in the adaptive curriculum. *Med. Teach.* **2018**, *40*, 813–819. [CrossRef]
75. Black, P.; Wiliam, D. Classroom assessment and pedagogy. *Assess. Educ. Princ. Policy Pract.* **2018**, *25*, 551–575. [CrossRef]
76. Bompa, T.O.; Buzzichelli, C. *Periodization-: Theory and Methodology of Training*; Human Kinetics: Champaign, IL, USA, 2019.
77. Beni, S.; Chróinín, D.N.; Fletcher, T. A focus on the how of meaningful physical education in primary schools. *Sport Educ. Soc.* **2019**, *24*, 624–637. [CrossRef]
78. Krause, L.; Farrow, D.; Reid, M.; Buszard, T.; Pinder, R. Helping coaches apply the principles of representative learning design: Validation of a tennis specific practice assessment tool. *J. Sport. Sci.* **2018**, *36*, 1277–1286. [CrossRef]
79. Moore, D.E., Jr.; Green, J.S.; Gallis, H.A. Achieving desired results and improved outcomes: Integrating planning and assessment throughout learning activities. *J. Contin. Educ. Health Prof.* **2009**, *29*, 1–15. [CrossRef]
80. Leonardi, T.J.; Martins, M.C.S.; Gonçalves, C.E.d.B.; Paes, R.R.; Carvalho, H.J.G.M.d. Changes in tactical performance and self-efficacy on young female basketball players. *Rev. Bras. De Cineantropometria Desempenho Hum.* **2019**, *21*, e60180. [CrossRef]
81. Middaugh, M.F. Closing the loop: Linking planning and assessment. *Plan. High. Educ.* **2009**, *37*, 5.
82. Gill, D.L.; Gross, J.B.; Huddleston, S. Participation motivation in youth sports. *Int. J. Sport Psychol.* **1983**, *14*, 1–14.
83. Smith, A.L.; Ullrich-French, S.; Walker, E.; Hurley, K.S. Peer relationship profiles and motivation in youth sport. *J. Sport Exerc. Psychol.* **2006**, *28*, 362–382. [CrossRef]

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