

Article

Muscle Injuries in Elite Youth Football Academy: A Six-Year Longitudinal Study on the U15 Football Team

Jaksa Skomrlj ^{1,2} , Toni Modric ^{2,3} , Damir Sekulic ^{2,3} , Ognjen Uljevic ^{2,*} , Marijana Geets Kesic ², Ante Bandalovic ^{1,4}, Ante Turic ^{1,4}, Boris Becir ^{1,4} and Sime Versic ^{1,2,3} 

¹ HNK Hajduk Split, 21000 Split, Croatia; skomrlj@gmail.com (J.S.); ante.bandalovic@hajduk.hr (A.B.); ante.turic@hajduk.hr (A.T.); boris.becir@hajduk.hr (B.B.); sime.versic@kifst.eu (S.V.)

² Faculty of Kinesiology, University of Split, 21000 Split, Croatia; toni.modric@kifst.eu (T.M.); dado@kifst.hr (D.S.); markes@kifst.hr (M.G.K.)

³ High Performance Sport Center, Croatian Olympic Committee, 10000 Zagreb, Croatia

⁴ Surgery Clinic, Department of Orthopedics and Traumatology, University Hospital Split, 21000 Split, Croatia

* Correspondence: ognjen.uljevic@kifst.eu

Abstract: To develop specific preventive strategies, it is necessary to investigate in detail the occurrence of injuries in young football players. This study aimed to provide details about the type, location, severity, and contact nature of muscle injuries in elite U15 Croatian football players. A total number of 130 muscle injuries occurred during the six competitive seasons, of which 88 were DOMS injuries and 42 were rupture injuries. Specifically, 87% of all muscle injuries belonged to the four major groups, with only 15 injuries to the other muscle groups: hamstrings (43), quadriceps (41), adductors (25), calves (6). The muscle injury incidence was stable during the observed period as the injury incidence rate ratio (IRR) was 1.01 (95%CI: 0.99–1.03), with 3.13 (95%CI: 3.09–3.17) muscle injuries per 1000 h of exposure in the first season and 3.06 (95%CI: 3.02–3.1) in the sixth season. A significantly higher risk for muscle injuries was discovered in the competition as the incidence for the whole observed period was 7.38 (95%CI: 7.29–7.47) compared to 2.25 (95%CI: 2.24–2.26) in the training period. Despite the relatively stable number of sustained muscle injuries, the relative proportion of muscular injuries increased over the years due to a severe decrease in the total number of injuries. Regarding the proportion of players who had sustained a muscle injury, our results suggest that approximately two out of five players can expect a muscular injury over the one-season period. Relatively high injury expectancy rates, as well as reinjury rates, require specific preventive interventions that will reduce the number and severity of new and recurred injuries. Future studies should include a wide set of predictor variables in order to establish the most important injury risk factors.

Keywords: academy; football; elite; muscle; injury



Citation: Skomrlj, J.; Modric, T.; Sekulic, D.; Uljevic, O.; Kesic, M.G.; Bandalovic, A.; Turic, A.; Becir, B.; Versic, S. Muscle Injuries in Elite Youth Football Academy: A Six-Year Longitudinal Study on the U15 Football Team. *Appl. Sci.* **2024**, *14*, 4422. <https://doi.org/10.3390/app14114422>

Academic Editors: Joohyung Lee and Sae Yong Lee

Received: 25 April 2024

Revised: 20 May 2024

Accepted: 21 May 2024

Published: 23 May 2024



Copyright: © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Football is one of the most demanding sports in terms of injuries [1]. Highly intensive and repetitive changes in directions, accelerations, decelerations, jumps, kicks, and tackles present a significant risk of sustaining injury. This is also present in youth football as young players train intensively while going through different phases of growth and development [2]. Clubs all around the world have organized football academies where children from the age of 8 to 19 train and are being prepared for the demands of senior-level football. For young players to develop properly and progress in all aspects of football, regular exposure to training and match loads is essential. The occurrence of an injury sidelines the player from training for a specific amount of time, which leads to a decline in their fitness abilities and disrupts the process of the player's football development [3]. This can also affect young player's well-being and mental health as their ambitions and sports goals are being interrupted [4]. For this reason, it is necessary to investigate in detail

the occurrence of injuries in young football players in order to develop specific preventive strategies. The first step in that process is to determine the characteristics of youth football injuries by type, location, mechanism, and severity [1].

While this topic is well covered among senior football players, it is not the case in the population of young players, where there is a lack of systematic prospective studies on individual age categories [1]. This is particularly important to identify players in the pubertal phase, between 13 and 16 years of age. This period corresponds with the highest annual gains in body height and body mass or the appearance of the peak high velocity (PHV) [5,6]. Adolescent awkwardness is a known phenomenon used to describe this period when the muscles are not still fully developed in terms of size and strength, while the trunk and extremities already increased significantly [7]. This disproportion can potentially cause an imbalance in strength and flexibility features and can lead to bad movement mechanics, compensations, and even a decline in motor performance [7,8]. Finally, this drop in motor abilities and skills, and the inability to withstand the high intensity to which the tissues of young soccer players are exposed, represent a significant risk factor for injury [7]. This is supported by recent studies, for example, one study on young Dutch football players showed that athletes had significantly more traumatic and overuse injuries in the year of PHV than in the year before PHV [7]. Studies showed that youth football players of pubertal age have 5.3 injuries/1000 h of football exposure which is significantly higher than players of prepubertal age (1.6 injuries/1000 h) [1]. Also, a study on six English professional football academies indicated that the highest rate of severe injuries among young players occurs in the U15 categories [2]. This increased likelihood of injuries is explained by maturation effects and increasing demands of training and competition [1].

In general, studies reported muscle strains, along with sprains as the most common injury type, while the thigh was the most frequently injured anatomical body part in youth football players [1,2]. In particular, hamstring and quadriceps muscle injuries have been regularly reported as the most common [9,10]. Muscle injuries represent one of the major problems in both senior and youth football, making up a proportion of up to 37% of all injuries [11]. Recent studies reported that the number of muscle injuries is not declining, despite advances in diagnostics, therapies, and training methodology, and has even increased in the last 20 years [12]. Muscle injuries are usually classified as either functional or structural, with functional being classified as fatigue-induced neurogenic injuries and structural being muscle tears of fibers or bundles [11]. Muscle injuries are mostly non-contact and are the focus of sports scientists and practitioners as they are caused by several controllable factors and can, therefore, be prevented to a certain extent [13–15]. Although this is a multifactorial health problem in which risk factors are often in cause-and-effect relationships, studies have highlighted several clear risk factors [16,17]. Some of these factors such as age, previous injuries, and surface conditions cannot be controlled [18,19]. On the other hand, a player's range of motion, muscle strength and flexibility, physical fitness, and mechanical load imposed on players are things that coaches can and must take care of [16,17].

Given that studies have shown that systematic strength and conditioning training, proper warm-up, and workload monitoring can reduce their incidence, it is necessary to determine in detail the profile of muscle injuries in young soccer players and to monitor their occurrence over a longer period [18]. Considering the limited body of knowledge in terms of muscle injury classification among elite young pubertal football players, particularly the absence of this kind of study on the sample of Croatian youth players, the main aim of this study was to identify the incidence of muscle injuries among U15 football players over a six-year period. The authors aimed to provide details about the type, location, severity, and contact nature of muscle injuries in order to give guidelines for the creation of specific preventive programs.

2. Materials and Methods

2.1. Study Design

This longitudinal study observed injury occurrence and characteristics in the U15 category of an elite Croatian football academy. The studied period included six competitive seasons, starting from the 2016/2017 season and lasting until the 2021/2022 season. The injury data were extracted from the academy database. All the players were notified about the purpose of this study. Written informed consent was obtained from the parents or legal guardians of all participants, considering they were underage. This study was performed in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the Faculty of Kinesiology (Ethical Approval Number: 2181-205-02-05-23-0007).

2.2. Participants

The sample of participants comprised 278 young male football players (age range = 13.6–15.6). The sample is considered elite as the players were part of a football academy competing at the highest level of the domestic championship. All playing positions, including goalkeepers, were analyzed in this study. In the observed period, this age category averaged 5.5 training sessions (e.g., team training, strength training, and individual training) and 1 match per week throughout the season, respectively, with at least one day during the week without organized football exposure. The warm-up strategies used in the academy are provided in the Supplementary Materials. The exposure accounted for the preparatory and competitive period, excluding the transition period without team training. Due to a regular fluctuation of the roster during winter break (e.g., dissatisfied players changing between the teams), and to avoid potential bias of the results, only the players that completed the full competitive season were included in the final sample. The confidentiality of the extracted injury data was preserved, as all the participants were given a code number known only to the authors.

2.3. Variables

Medical professionals recorded muscle injuries during the regular daily medical check-ups, occurring right before or after the training session or match. All injuries were reported to the internal database and were immediately shared among the different compartments of the club. Muscle injuries were recorded and classified either as (i) functional muscle injuries represented as delayed onset muscle soreness (DOMS) or (ii) structural injuries i.e., ruptures (a partial or complete tear of muscle fibers). The accuracy and the consistency of the clinical diagnosis were obtained with the use of ultrasound imaging. Permission for return to play was granted by the medical doctor once the ultrasound imaging showed a total healing of the tissue, with a pain-free contraction of the muscle and an appropriate overall fitness status evaluated by the whole medical and coaching staff. A reinjury was defined as an injury to the same location and categorized as the same type after the player had returned to full participation following the initial injury. Injury severity, expressed as a total number of days in absence from training, was presented separately for DOMS and rupture injuries, respectively. Football exposure was calculated for all the observed seasons and was reported as the number of training and match hours. The total player match exposure time in hours for a team was given by $(N_m * P_m * D_m / 60)$ where N_m is the number of team matches played, P_m is the number of players in the team, and D_m is the duration of the match in minutes. Similarly, the total training exposure time in hours is given by $(P_t * D_t / 60)$, where P_t is the number of players attending a training session and D_t is the duration of the training session in minutes. Exposure time was adjusted for the 2019/2020 season, where there was a complete cessation of training due to the COVID-19 lockdown. In particular, muscle injury incidence was calculated as the number of muscle injuries sustained per 1000 h of the training and match exposure, respectively. Also, injuries were classified as new one or a reinjury, according to the affected body region, contact nature of injuries, and training/game occurrence.

2.4. Statistics

Descriptive data were presented, including arithmetic means and standard deviations. The muscle injury incidence was calculated as the number of injuries sustained per 1000 h of exposure. The injury incidence rate ratio and the 95% confidence intervals were calculated between the first and the last observed season.

MedCalc Statistical Software (version 19.2.6), Microsoft Excel 2019 (Microsoft, Redmond, WA, USA) and SPSS software (IBM, Armonk, NY, USA, SPSS, version 25.0) were used for the analysis. The level of statistical significance was set at $p < 0.05$.

3. Results

A total of 130 muscle injuries were recorded during the six-year period with 42 of them defined as ruptures and 88 as DOMS (Table 1). Structural muscle injuries (i.e., ruptures) sidelined players from team training and competition for 25.8 days on average, while DOMS resulted in 7.5 days of average absence. Approximately every fifth muscle injury was re-injury, and the vast majority were described as non-contact.

Table 1. Descriptive data.

	Number of Injuries	Days Out	Reinjury	Training	Match	Unknown	Contact	Non-Contact	IRR 1–6 Years (95%CI)
Rupture	42	25.8	9	28	11	3	6	36	
DOMS	88	7.5	20	71	16	1	7	81	1.01
Total	130	13.5	29	99	27	4	13	117	(0.99–1.03)

Injury incidence was stable during the observed period as the injury incidence rate ratio (IRR) was 1.01 (95%CI: 0.99–1.03), with 3.13 (95%CI: 3.09–3.17) muscle injuries per 1000 h of exposure in the first season and 3.06 (95%CI: 3.02–3.1) in the sixth season (Tables 1 and 2, and Figure 1). A significantly higher risk for muscle injuries was present in the games as the incidence for the whole observed period was 7.38 (95%CI: 7.29–7.47) compared to 2.25 (95%CI: 2.24–2.26) in the training.

Table 2. Muscle injuries/1000 h of exposure.

Season	Overall	Muscle Injuries Training	Match	All Injuries
2016/2017	3.13 (3.09–3.17)	2.73 (2.69–2.77)	6.56 (6.34–6.76)	11.92 (11.84–11.99)
2017/2018	2.51 (2.47–2.54)	1.93 (1.9–1.96)	9.84 (9.59–10.1)	6.33 (6.27–6.38)
2018/2019	2.86 (2.82–2.89)	2.15 (2.12–2.18)	8.20 (7.97–8.43)	6.83 (6.78–6.89)
2019/2020	2.11 (2.07–2.14)	1.69 (1.66–1.72)	6.90 (6.68–7.11)	5.06 (5.01–5.11)
2020/2021	2.66 (2.62–2.69)	2.22 (2.18–2.25)	6.45 (6.25–6.65)	5.31 (5.26–5.36)
2021/2022	3.06 (3.02–3.1)	2.90 (2.86–2.94)	4.92 (4.74–5.09)	6.65 (6.59–6.71)
All	2.73 (2.71–2.74)	2.25 (2.24–2.26)	7.38 (7.29–7.47)	7.02 (6.96–7.08)

The majority of the injuries occurred in the lower body, with hamstrings ($N = 43$) and quadriceps ($N = 41$) being injured most frequently. Besides these two groups, U15 players suffered significant amounts of adductor injuries ($N = 25$), while only six calf injuries were reported in the observed period (Figure 2).

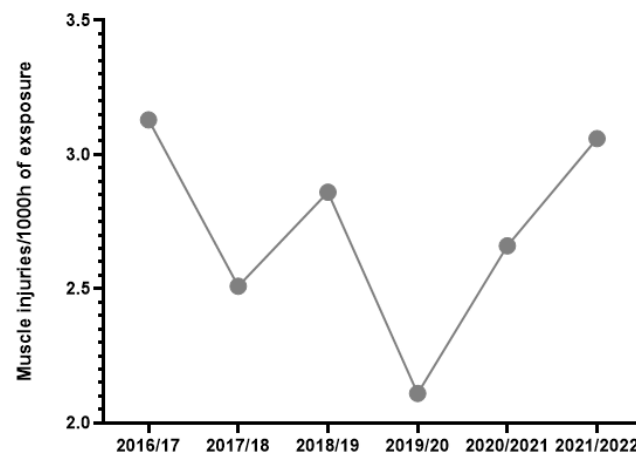


Figure 1. Muscle injuries/1000 h of exposure. These circles are a visual presentation of the injury data from the Table 1. Circle 1—3.13. Circle 2—2.51. Circle 3—2.86. Circle 4—2.11. Circle 5—2.66. Circle 6—3.06.

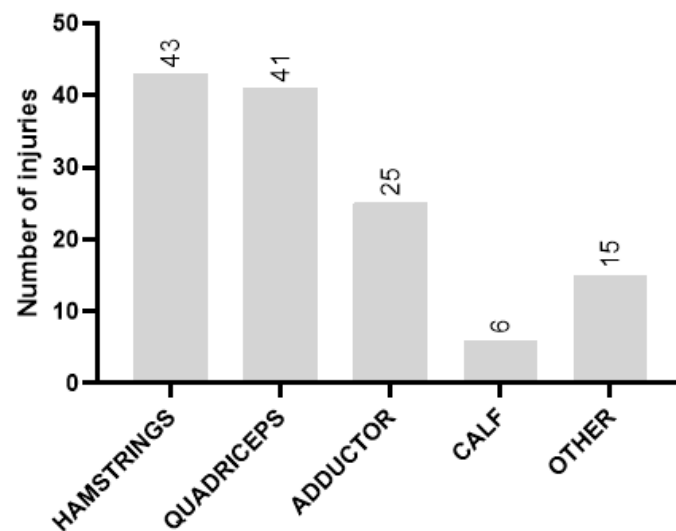


Figure 2. Muscle injuries by injured region.

The proportion of muscle injuries had an increased trend during the six-year period, with 26% and 46% of all injuries classified as muscle ones in the first and the last season, respectively (Table 3 and Figure 3). However, the absolute number of muscle injuries remained relatively stable.

Table 3. Number of players, total and muscle injuries, and incidence rate.

Season	Registered Players	Players with Muscle Injuries	Incidence Rate	Total Injuries	Total Muscle Injuries
2016/2017	45	21	0.47	99	26
2017/2018	52	19	0.37	53	21
2018/2019	47	16	0.34	55	23
2019/2020	46	13	0.28	36	15
2020/2021	45	14	0.31	44	22
2021/2022	43	18	0.42	50	23

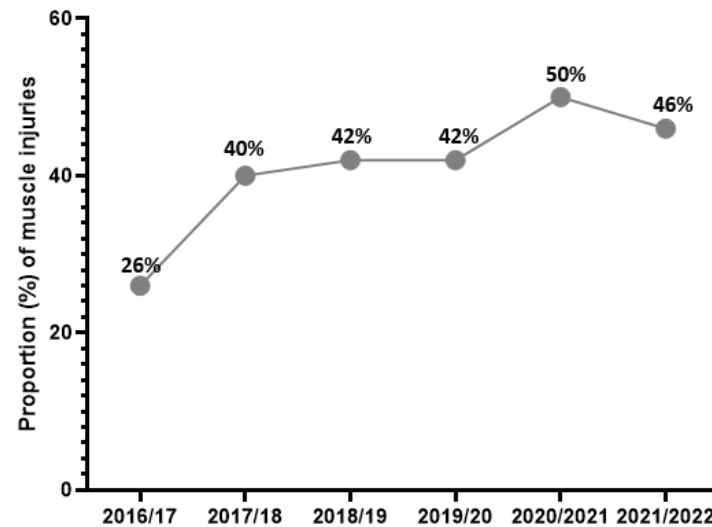


Figure 3. Proportion of muscle injuries.

Figure 4 shows that the incidence rate of players suffering a muscle injury had a downward trend until the 2019/2020 season (i.e., from 46.7% to 28.3% of players with muscle injuries), with that trend being altered and rising up to 41.9% in the last season. This implies that in the U15 team of 20 players, approximately 8 of them can expect muscle injury over the one-season period.

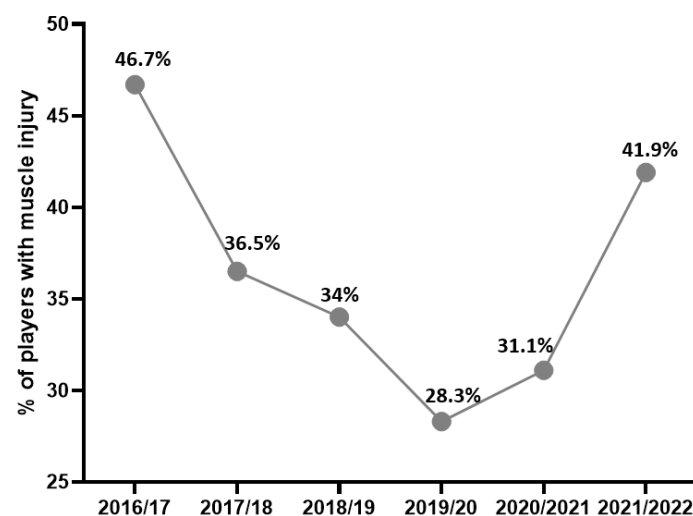


Figure 4. Proportion of players with muscle injuries.

4. Discussion

There are several important findings of this study. First, the results suggest a relatively stable muscle injury incidence throughout the study period. Second, the hamstrings and quadriceps muscles are the most injured body parts. Lastly, the evidence indicates that 40% of players in this category are expected to sustain a muscle injury during the season.

4.1. Injury Incidence

The results of this study have shown a slightly higher overall injury incidence compared to the recent meta-analysis on a similar sample (i.e., U13–U16 players) (7.02/1000 h vs. 5.3/1000 h, respectively) [1]. However, when compared to the Swedish players of the same age, our players displayed almost the same injury rates (7.02/1000 h vs. 6.8/1000 h) [20]. More specifically, the mean muscle injury incidence in our study is found to be 2.73/1000 h. Similarly, investigators reported a muscle injury rate of 3.2/1000 h in a group of U13–U18

Middle Eastern football players [21]. Interestingly, the number of muscle injuries remains quite stable throughout the six competitive seasons, as there is no significant difference between the years, which is reflected in the IRR of 1.01 between year one and year six. Regarding the injury time trends, a major 18-year prospective cohort study revealed a gradual decrease in training and match injury rates of professional football players [22]. However, as far as muscle injury trends are concerned, the situation is quite the opposite. For example, the number and severity of hamstring injuries doubled in the last 21 seasons, with muscle injuries increasing by 6.7% annually over the last 8 seasons [12]. This increment is explained through a continuous increase in both intensity (i.e., higher volume of running at higher velocities) and total amount of international team travel and matches.

Although minimal, an evident annual decrease in injuries was present up until the 2019/20 season, from which the number of injuries rose again. This trend change coincides with the emergence of the COVID-19 pandemic. The pre-pandemic injury drop can be explained by the current use of scientifically proven training methodologies that have been shown to reduce the risk of injury [23]. These include better preventive measures, more developed training methods and player and coach education, all of which were being applied in the here-stated academy. Since the start of the global pandemic, there has been a lack of studies as there are only a few of them that have examined the effect of the COVID-19 disease on injury occurrence in football, and especially in youth players [24,25]. The interruption-related training maladaptation, lack of medical evaluation, inadequate re-training period, congested competition schedule, and the negative effect of the disease itself are all associated with the rise in injuries following the comeback to sport [26].

In line with the existing data, a much higher match than training incidence was observed in this study (7.38/1000 h vs. 2.25/1000 h, respectively). For example, a 10-year study on the elite French U13-U16 football players revealed an injury incidence of 11.2/1000 h and 3.8/1000 h, for match and training, respectively [27]. Among other factors, underlying explanations include greater playing demands and intensities in competition, number of contacts and collisions, and fatigue accumulation during the match [9,21,28]. Also, match-induced psychological arousal, observed mainly through higher competitiveness and more aggressive play, results in elevated injury risk [23].

4.2. Location and Type of Injuries

The results suggest the thigh as the most commonly injured body area, with hamstrings being slightly more injured than the quadriceps muscle. In accordance with our results, the upper leg (i.e., anterior and posterior thigh) has been considered to be the most common injury location in youth football players [9,29,30]. Generally, previous epidemiologic studies in adult football players have shown that the hamstring group is the single most injured muscle [12,31]. It is important to highlight the architectural specifics of the muscle, as the hamstrings are a multi-joint muscle group with dual innervation and a great proportion of fast-twitch fibers [32]. These anatomic characteristics can, in some cases, result in a disruption of running coordination patterns and increase injury risk, as it is known that hamstring injuries mostly occur during running, especially at higher velocities [33,34]. The injury to the hamstrings typically happens during the active lengthening of the muscle (i.e., eccentric muscle contraction), with the late swing phase of the running gate cycle responsible for 81% of strains [35]. With almost the same injury occurrence as hamstrings, the quadricep muscle also seems to be a vulnerable area and is sometimes regarded as the most injured muscle in the youth population [36]. For example, Pietsch et al. recently reported that previous quadricep injuries, recent hamstring injury, the dominant kicking leg, and competitive match play were all strongly associated with quadricep injuries [37]. Regarding the quadriceps injury mechanism, the kicking action is identified as the most common, due to a high volume of passing and shooting, with quadriceps being the main agonist in these movements [17]. Further, adductor muscles are also common injury sites in football, with highly intense and repetitive movements such as kicking, change in direction, and inside passing [38]. The hip–groin–pelvis region is highly affected in the PHV period

when muscles and tendons adapt slowly to changes in limb length and body mass and have, therefore, reduced capacity for producing and sustaining force [39,40]. It is interesting to note that 87% of all muscle injuries included four big muscle groups in the lower limb. Comparably, Ekstrand et al. reported that 92% of all muscle injuries affect the hamstrings, quadriceps, adductors, and calves in professional footballers [11].

A considerably higher number of DOMS injuries was noticed, in contrast to muscle ruptures (88 vs. 42, respectively). Moderate severity (i.e., injury lasting shorter than 28 days) was observed for both types of injuries, with DOMS resulting in 7.5 days lost from training, compared to 25.8 days of time loss due to muscle rupture. As previously mentioned, this result is not surprising because, unlike ruptures, DOMS is not characterized by structural fiber damage. Similarly, a 4-year prospective study revealed a median of 4.2 and 22.5 days of time loss, for DOMS and muscle tears, respectively [41]. The re-injury rate was the same for DOMS and muscle ruptures, with every fifth injury being a re-injury. The same is reported in a study by Hawkins et al., where 22% of injuries are relapses of a previous injury [42]. Such a high re-injury rate may be explained by a premature attempt to return to unrestricted activity, with the injured tissue not being fully reorganized and healed [36].

4.3. Proportion of Muscle Injuries

In general, there is an evident increase in the proportion of muscle injuries throughout the 6-year period. As the total number of other injuries (e.g., bone and joint injuries) decreased over the years, a relative increase in muscle injury incidence occurred due to a relatively stable absolute number of muscle injuries. On average, 41% of all injuries incurred are related to the muscular system. This is in agreement with previous studies, where 37% and 45% of injuries at elite senior and youth levels were observed, respectively [11,43].

The proportion of players that had sustained a muscle injury gradually decreased until the 2019/20 season, when this trend was altered, presumably because of the negative effects caused by the COVID-19 pandemic mentioned earlier. Since the authors of this study are coaches at the observed football academy, we assume that preventive measures, including regular and supervised strength, balance, and coordination training, combined with a regular medical examination, may be the crucial factor responsible for the reduction in the number of injured players. However, the results suggest that approximately two out of five players in the U15 sustained an injury, regardless of the advanced training methodology employed. As discussed above, the circa-PHV players, especially those in the U15 age category, are predisposed to higher muscular injury risk due to disruption in motor control and anthropometric discrepancies [7,44].

4.4. Strengths and Limitations

This study has some limitations that need to be considered. First, the sample included only the players from one category of one football academy. However, as there is an evident lack of data on the specific age groups, this study may enable comparisons with football academies from other geographic regions. Further, it is possible that for various reasons (e.g., players refusing to report musculoskeletal problems, coaches forcing players to train), some injuries were not reported, thereby biasing the data set. Nevertheless, medical staff meticulously gathered and classified all the injuries according to consensus statements, thus validating all the reported data in terms of injury surveillance in football [45]. Also, a lack of follow-up for the released players is one of the study limitations, as these players could have possibly been the ones that were injured the most, thereby biasing the dataset. Regarding the main strengths of this study, the elite sample of players analyzed over the course of six years are two of the most significant. Additionally, detailed and specified information about muscle injuries, based on the mentioned consensus statement, is provided.

5. Conclusions

A total number of 130 muscle injuries was reported during the six seasons, with a much higher number of DOMS injuries compared to rupture injuries (88 vs. 42, respectively)

in the elite U15 Croatian football players. The occurrence of muscle injuries decreased during pre-pandemic, with a slight change in injury trend observed at the start of the COVID-19 pandemic. The hamstrings, quadriceps, adductors, and calves are the most injured muscles, contributing to 87% of all muscle injuries. Finally, muscle injuries account for approximately 40% of all injuries, with two out of five players expected to sustain a muscle injury during the competitive season.

Detailed injury information provided in this study may enable the creation of specific training interventions aimed at reducing the number of muscle injuries. Specifically, preventive measures targeting the most affected lower body regions should be carried out regularly in this age category, focusing on muscle strength, endurance, flexibility, and balance between the dominant and non-dominant side. Moreover, with the reinjury expectancy rate being approximately 20%, special attention to the previously injured players is needed to reduce this relatively high reinjury rate.

Guidelines for future studies include the incorporation of a broad set of predictor variables and the investigation of their influence on muscle injury occurrence.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/app14114422/s1>, Table S1: The RAMP method characteristics.

Author Contributions: Conceptualization, A.B. and B.B.; Methodology, T.M.; Investigation, O.U.; Data curation, M.G.K.; Writing—original draft, J.S. and A.T.; Writing—review & editing, S.V.; Supervision, D.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: This 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 Approval Number: 2181-205-02-05-23-0007, approved on 3 March 2023).

Informed Consent Statement: Written informed consent was obtained from the parents or legal guardians of all participants.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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

References

1. Robles-Palazón, F.J.; López-Valenciano, A.; Croix, M.D.S.; Oliver, J.L.; Garcia-Gómez, A.; de Baranda, P.S.; Ayala, F. Epidemiology of injuries in male and female youth football players: A systematic review and meta-analysis. *J. Sport Health Sci.* **2022**, *11*, 681–695. [\[CrossRef\]](#)
2. Read, P.J.; Oliver, J.L.; De Ste Croix, M.B.; Myer, G.D.; Lloyd, R.S. An audit of injuries in six English professional soccer academies. *J. Sports Sci.* **2018**, *36*, 1542–1548. [\[CrossRef\]](#) [\[PubMed\]](#)
3. Barguerias-Martínez, J.; Espada, M.C.; Perdomo-Alonso, A.; Gomez-Carrero, S.; Costa, A.M.; Hernández-Beltrán, V.; Gamonales, J.M. Incidence of Injuries in Elite Spanish Male Youth Football Players: A Season-Long Study with Under-10 to Under-18 Athletes. *Appl. Sci.* **2023**, *13*, 9084. [\[CrossRef\]](#)
4. Jones, S.; Almousa, S.; Gibb, A.; Allamby, N.; Mullen, R.; Andersen, T.E.; Williams, M. Injury incidence, prevalence and severity in high-level male youth football: A systematic review. *Sports Med.* **2019**, *49*, 1879–1899. [\[CrossRef\]](#) [\[PubMed\]](#)
5. Kyprianou, E.; Di Salvo, V.; Lolli, L.; Al Haddad, H.; Villanueva, A.M.; Gregson, W.; Weston, M. To measure peak velocity in soccer, let the players sprint. *J. Strength Cond. Res.* **2022**, *36*, 273–276. [\[CrossRef\]](#) [\[PubMed\]](#)
6. Van der Sluis, A.; Elferink-Gemser, M.; Brink, M.; Visscher, C. Importance of peak height velocity timing in terms of injuries in talented soccer players. *Int. J. Sports Med.* **2015**, *36*, 327–332.
7. Van Der Sluis, A.; Elferink-Gemser, M.; Coelho-e-Silva, M.; Nijboer, J.; Brink, M.; Visscher, C. Sport injuries aligned to peak height velocity in talented pubertal soccer players. *Int. J. Sports Med.* **2013**, *35*, 351–355. [\[CrossRef\]](#) [\[PubMed\]](#)
8. Beunen, G.; Malina, R.M. Growth and physical performance relative to the timing of the adolescent spurt. *Exerc. Sport Sci. Rev.* **1988**, *16*, 503–540. [\[CrossRef\]](#) [\[PubMed\]](#)
9. Price, R.; Hawkins, R.; Hulse, M.; Hodson, A. The Football Association medical research programme: An audit of injuries in academy youth football. *Br. J. Sports Med.* **2004**, *38*, 466–471. [\[CrossRef\]](#)
10. Raya-González, J.; Suarez-Arrones, L.; Larruskain, J.; de Villarreal, E.S. Muscle injuries in the academy of a Spanish professional football club: A one-year prospective study. *Apunts. Med. L'esport* **2018**, *53*, 3–9. [\[CrossRef\]](#)

11. Ekstrand, J.; Hägglund, M.; Waldén, M. Epidemiology of muscle injuries in professional football (soccer). *Am. J. Sports Med.* **2011**, *39*, 1226–1232. [[CrossRef](#)] [[PubMed](#)]
12. Ekstrand, J.; Bengtsson, H.; Waldén, M.; Davison, M.; Khan, K.M.; Hägglund, M. Hamstring injury rates have increased during recent seasons and now constitute 24% of all injuries in men's professional football: The UEFA Elite Club Injury Study from 2001/02 to 2021/22. *Br. J. Sports Med.* **2023**, *57*, 292–298. [[CrossRef](#)] [[PubMed](#)]
13. van der Horst, N. Preventing hamstring injuries in football through enhanced exercise and RTP strategies. *Br. J. Sports Med.* **2018**, *52*, 684–685. [[CrossRef](#)] [[PubMed](#)]
14. Almeida, M.O.; Maher, C.G.; Saragiotto, B.T. Prevention programmes including Nordic exercises to prevent hamstring injuries in football players (PEDro synthesis). *Br. J. Sports Med.* **2018**, *52*, 877–878. [[CrossRef](#)] [[PubMed](#)]
15. Sintès, P.; Caparrós, T. Proposal of a protocol for the primary prevention of hamstring strains in football players. *Apunts. Med. L'esport* **2019**, *54*, 19–26. [[CrossRef](#)]
16. Arnason, A.; Sigurdsson, S.B.; Gudmundsson, A.; Holme, I.; Engebretsen, L.; Bahr, R. Risk factors for injuries in football. *Am. J. Sports Med.* **2004**, *32*, 5–16. [[CrossRef](#)] [[PubMed](#)]
17. Hägglund, M.; Waldén, M.; Ekstrand, J. Risk factors for lower extremity muscle injury in professional soccer: The UEFA Injury Study. *Am. J. Sports Med.* **2013**, *41*, 327–335. [[CrossRef](#)]
18. Cardoso-Marinho, B.; Barbosa, A.; Bolling, C.; Marques, J.P.; Figueiredo, P.; Brito, J. The perception of injury risk and prevention among football players: A systematic review. *Front. Sports Act. Living* **2022**, *4*, 1018752. [[CrossRef](#)] [[PubMed](#)]
19. Svensson, K.; Alricsson, M.; Olausson, M.; Werner, S. Physical performance tests—A relationship of risk factors for muscle injuries in elite level male football players. *J. Exerc. Rehabil.* **2018**, *14*, 282. [[CrossRef](#)]
20. Timpka, T.; Risto, O.; Björnsjö, M. Boys soccer league injuries: A community-based study of time-loss from sports participation and long-term sequelae. *Eur. J. Public Health* **2008**, *18*, 19–24. [[CrossRef](#)]
21. Wik, E.H.; Lolli, L.; Chamari, K.; Materne, O.; Di Salvo, V.; Gregson, W.; Bahr, R. Injury patterns differ with age in male youth football: A four-season prospective study of 1111 time-loss injuries in an elite national academy. *Br. J. Sports Med.* **2021**, *55*, 794–800. [[CrossRef](#)] [[PubMed](#)]
22. Ekstrand, J.; Spreco, A.; Bengtsson, H.; Bahr, R. Injury rates decreased in men's professional football: An 18-year prospective cohort study of almost 12,000 injuries sustained during 1.8 million hours of play. *Br. J. Sports Med.* **2021**, *55*, 1084–1092. [[CrossRef](#)] [[PubMed](#)]
23. Le Gall, F.; Carling, C.; Reilly, T. Injuries in young elite female soccer players: An 8-season prospective study. *Am. J. Sports Med.* **2008**, *36*, 276–284. [[CrossRef](#)] [[PubMed](#)]
24. Mannino, B.J.; Yedikian, T.; Mojica, E.S.; Bi, A.; Alaia, M.; Gonzalez-Lomas, G. The COVID lockdown and its effects on soft tissue injuries in Premier League Athletes. *Physician Sportsmed.* **2023**, *51*, 40–44. [[CrossRef](#)] [[PubMed](#)]
25. Martens, G.; Delvaux, F.; Forthomme, B.; Kaux, J.-F.; Urhausen, A.; Bieuzen, F.; Leclerc, S.; Winkler, L.; Brocherie, F.; Nedelec, M. Exercise-based injury prevention in high-level and professional athletes: Narrative review and proposed standard operating procedure for future lockdown-like contexts after COVID-19. *Front. Sports Act. Living* **2021**, *3*, 745765. [[CrossRef](#)] [[PubMed](#)]
26. Škomrlj, J.; Modrić, T.; Sekulić, D.; Bandalović, A.; Turić, A.; Bećir, B.; Veršić, Š. Longitudinal analysis of the incidence rate of injury in elite youth football: Trends over six years including the COVID-19 pandemic period. *Phys. Ther. Sport* **2024**, *66*, 85–92. [[CrossRef](#)]
27. Le Gall, F.; Carling, C.; Reilly, T.; Vandewalle, H.; Church, J.; Rochcongar, P. Incidence of injuries in elite French youth soccer players: A 10-season study. *Am. J. Sports Med.* **2006**, *34*, 928–938. [[CrossRef](#)] [[PubMed](#)]
28. Bangsbo, J.; Mohr, M.; Krstrup, P. Physical and metabolic demands of training and match-play in the elite football player. *J. Sports Sci.* **2006**, *24*, 665–674. [[CrossRef](#)] [[PubMed](#)]
29. Ergun, M.; Denerel, H.N.; Mehmet, S.; Ertat, K.A. Injuries in elite youth football players: A prospective three-year study. *Acta Orthop. Traumatol. Turc.* **2013**, *47*, 339–346. [[CrossRef](#)]
30. Bourogiannis, G.; Hatzimanouil, D.; Semanlianou, E.; Georgiadis, I.; Sykaras, E. Reintegration Program for Professional Football Players after Grade 2 Hamstring Injuries. *Montenegrin J. Sports Sci. Med.* **2023**, *12*, 35–42. [[CrossRef](#)]
31. Jones, A.; Jones, G.; Greig, N.; Bower, P.; Brown, J.; Hind, K.; Francis, P. Epidemiology of injury in English Professional Football players: A cohort study. *Phys. Ther. Sport* **2019**, *35*, 18–22. [[CrossRef](#)] [[PubMed](#)]
32. Raya-González, J.; de Ste Croix, M.; Read, P.; Castillo, D. A Longitudinal Investigation of muscle injuries in an elite spanish male academy soccer club: A hamstring injuries approach. *Appl. Sci.* **2020**, *10*, 1610. [[CrossRef](#)]
33. Huygaerts, S.; Cos, F.; Cohen, D.D.; Calleja-González, J.; Guitart, M.; Blazevich, A.J.; Alcaraz, P.E. Mechanisms of hamstring strain injury: Interactions between fatigue, muscle activation and function. *Sports* **2020**, *8*, 65. [[CrossRef](#)] [[PubMed](#)]
34. Schache, A.G.; Dorn, T.W.; Blanch, P.D.; Brown, N.A.; Pandy, M.G. Mechanics of the human hamstring muscles during sprinting. *Med. Sci. Sports Exerc.* **2012**, *44*, 647–658. [[CrossRef](#)] [[PubMed](#)]
35. Danielsson, A.; Horvath, A.; Senorski, C.; Alentorn-Geli, E.; Garrett, W.E.; Cugat, R.; Samuelsson, K.; Hamrin Senorski, E. The mechanism of hamstring injuries—A systematic review. *BMC Musculoskelet. Disord.* **2020**, *21*, 641. [[CrossRef](#)] [[PubMed](#)]
36. Cloke, D.; Moore, O.; Shab, T.; Rushton, S.; Shirley, M.D.; Deehan, D.J. Thigh muscle injuries in youth soccer: Predictors of recovery. *Am. J. Sports Med.* **2012**, *40*, 433–439. [[CrossRef](#)] [[PubMed](#)]
37. Pietsch, S.; Pizzari, T. Risk factors for quadriceps muscle strain injuries in sport: A systematic review. *J. Orthop. Sports Phys. Ther.* **2022**, *52*, 389–400. [[CrossRef](#)] [[PubMed](#)]

38. Markovic, G.; Šarabon, N.; Pausic, J.; Hadžić, V. Adductor muscles strength and strength asymmetry as risk factors for groin injuries among professional soccer players: A prospective study. *Int. J. Environ. Res. Public Health* **2020**, *17*, 4946. [[CrossRef](#)] [[PubMed](#)]
39. Dupré, T.; Potthast, W. Groin injury risk of pubertal soccer players increases during peak height velocity due to changes in movement techniques. *J. Sports Sci.* **2020**, *38*, 2661–2669. [[CrossRef](#)]
40. Monasterio, X.; Gil, S.; Bidaurreazaga-Letona, I.; Lekue, J.; Santisteban, J.; Diaz-Beitia, G.; Martin-Garetxana, I.; Bikandi, E.; Larruskain, J. Injuries according to the percentage of adult height in an elite soccer academy. *J. Sci. Med. Sport* **2021**, *24*, 218–223. [[CrossRef](#)]
41. Mcnaughton, L.; Greig, M.; Materne, O.; Farooq, A.; Weir, A.; Bahr, R. Injury Incidence and Burden in a Youth Elite football (Soccer) Academy: A 4-Season Prospective Study of 551 players aged from under 9 to under 19 years. Injury and burden in elite young footballers. *Br. J. Sports Med.* **2020**, *55*, 493–500.
42. Hawkins, R.D.; Fuller, C.W. A prospective epidemiological study of injuries in four English professional football clubs. *Br. J. Sports Med.* **1999**, *33*, 196–203. [[CrossRef](#)] [[PubMed](#)]
43. Renshaw, A.; Goodwin, P.C. Injury incidence in a Premier League youth soccer academy using the consensus statement: A prospective cohort study. *BMJ Open Sport Exerc. Med.* **2016**, *2*, e000132. [[CrossRef](#)]
44. Bult, H.J.; Barendrecht, M.; Tak, I.J.R. Injury risk and injury burden are related to age group and peak height velocity among talented male youth soccer players. *Orthop. J. Sports Med.* **2018**, *6*, 2325967118811042. [[CrossRef](#)] [[PubMed](#)]
45. Fuller, C.W.; Ekstrand, J.; Junge, A.; Andersen, T.E.; Bahr, R.; Dvorak, J.; Hägglund, M.; McCrory, P.; Meeuwisse, W.H. Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. *Scand. J. Med. Sci. Sports* **2006**, *16*, 83–92. [[CrossRef](#)]

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.