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Predictors of Speed and Agility in Youth Male Basketball Players

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Abstract: Player performance in an intense sport such as basketball is known to be related to attributes such as speed, agility, and power. This study presents a comparative analysis of associations between anthropometric assessment and physical performance in different age groups of elite youth basketball players, while simultaneously identifying the predictors for speed and agility in these players. U14 (n = 44), U15 (n = 45), and U16 (n = 51) players were tested for anthropometry, lower-body power, speed, and agility. U16 players were found to be taller, heavier, more muscular than U14 and U15 players. In addition, the U16 group showed better performance in all performance tests. Age had a significant positive correlation with countermovement (CMJ) and drop jump (DJ) performance in U14 players, and a significant negative correlation with 15m and 20m sprint times in the U15 group. CMJ and DJ emerged as the most significant predictors for sprint and agility variables, respectively. Body fat percentage was found to be a significant predictor for the speed and agility tests in all age groups, but a negative lower-body power predictor. Therefore, besides all sport-specific and fitness tests, it is essential to place emphasis on the percentage of body fat when designing players' individualized training programs, and during team selection.

Keywords: team sports; explosive strength; body composition; CMJ

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1. Introduction

Basketball is a dynamic and complex aerobic game that involves frequent interchange of high-intensity anaerobic activities such as jumping, accelerations and decelerations, changes of direction (COD), and sprinting [1]. Besides the player's technical skills, performance and success are related to lower-body physical components of multidirectional running, power, vertical jump, and agility [2–4].

Special research interest is directed towards physical fitness and its relation with high performance in young basketball players. In fact, speed, agility, and power are the most performance-related, evaluated, and tested abilities in basketball and tend to peak with attaining body height peak velocity (between 13 and 15 years of age) in male basketball players [5].

A well-known fact is that significant relations exist between jump performance, running speed, and agility in basketball players [3,4,6–8]. The aforementioned physical components have been shown to vary by gender and age [9], especially from 12–14 years of age [10]. Buchanan and Vardaxis (2003) reported that speed tends to be similar in the 11–13 age group but disparate for 15–17-year-olds [11]. Additionally, 14-year-olds have better speed and agility performance when compared to 12-year-olds [10]. How speed and agility in young players are affected by intense changes in the morphological structure that occur from 12 to 16 years [12] and which differences are present among age groups remain unclear. Such differences probably emerge due to morphological diversity in the muscle mass as well as muscle structure and differences in muscle fiber types. Variation in speed and agility is also affected by puberty, adolescent growth spurts, relative age, and maturation level [13–15].

The selection of highly talented basketball players is usually performed by anthropometric screening, emphasizing stature. Even though height is genetically predetermined, general and sports-specific fitness tests such as 5m, 10m and 20-meter sprint, countermovement jump (CMJ), drop jump (DJ), squat jump (SJ), as well as agility *t*-test, and Lane test are most commonly used for the assessment of players' physical potential related to basketball success [10,16], independent of training status and experience. As suggested by Cui et al. (2019), drafted NBA players outperformed undrafted players in body height, arm span, vertical jumps, and agility [17]. This is of special importance in relation to the player's position. Body dimensions such as height, limb length, body fat percentage, and BMI have a consequential influence on running speed, explosive strength, and agility [3,4,9,18–20]. Body fat percentage has been negatively associated with explosive actions, change of direction, and vertical jumps [21,22].

The available literature focusing on correlations between anthropometric assessment and physical performance in elite youth basketball players is highly limited. Moreover, it is important to comparatively analyze these relations in basketball players with different levels of play in order to accurately predict the lacking components to be improved in a player, thus enhancing the sport performance as well as facilitating early return to sports in case of an injury. Therefore, the aim of this research was to identify the anthropometric factors predicting speed and agility profiling in under 14 (U14), under 15 (U15), and under 16 (U16) basketball players. In addition, we aimed to investigate the correlation of physical performance tests with the players' anthropometric profiles. We hypothesize that a superior lower body explosive strength (CMJ, DJ) performance would be associated with a shorter sprint times and change of direction test times.

2. Materials and Methods

2.1. Participants

Overall, 140 male basketball players from under 14 (U14), under 15 (U15), and under 16 (U16) age groups participated in this study: 44 players were U14 (age = 13.41 $\pm$ 0.54 years, height = 175.14 $\pm$ 8.58 cm, body mass = 63.46 $\pm$ 13.70 kg); 45 players were U15 (age = 14.71 $\pm$ 0.29 years, height = 183.60 $\pm$ 7.91 cm, body mass = 75.20 $\pm$ 11.87 kg); and 51 players were U16 (age = 15.64 $\pm$ 0.32 years, height = 185.99 $\pm$ 5.83 cm, body mass = 76.25 $\pm$ 10.29 kg). All participants had a minimum three years of playing experience. All players were registered in basketball clubs in Sarajevo Canton and were enrolled in a top-level regional competition in Bosnia and Herzegovina. All players had a minimum of 5 training sessions per week along with 1 game on the weekend.

2.2. Measurement Procedure

All the measurements were performed by experienced personnel at the Institute of Sport at Faculty of Sport and Physical Education, University of Sarajevo. Specifically for this study, an appropriate testing sessions lasting two days (in a row) was planned and designed in a specific order. The testing sessions took place between 09:00 and 12:00 in the morning, during the end of the preparation period a few days before the start of the season. On the first day, body height, body mass, and body fat percentage (PBF) measurements were performed. Body height was measured to one decimal place (0.1 cm) by digital stadiometer (InBody BSM 370; Biospace Co., Ltd., Seoul, Republic of Korea). Body mass and PBF were estimated using a direct segmental high-frequency bioelectrical impedance scale (InBody 720; Biospace Co., Ltd., Seoul, Republic of Korea). Prior to testing of lower-body power (CMJ and DJ), players were instructed to complete a standard warm-up consisting of three minutes of jogging, three minutes of dynamic stretching, and three minutes of acceleration–deceleration. The following day, all speed and agility tests were performed, including 15 m and 20 m sprint tests, *t*-test, and lane agility test. Prior to the tests, all players performed a standard warm-up protocol. All tests were conducted on a wooden basketball court. The study was approved by the Ethics Committee (No: 01-2603/22; 7 January 2022) of the Faculty of Sports and Physical Education, University of Sarajevo, and was carried out in accordance with the Declaration of Helsinki. Informed consent was obtained from the participants' parents or legal guardians, prior to enrolment into the study.

2.3. Lower-Body Power

For assessment of the lower-body power, countermovement jump (CMJ) and drop jump (DJ) from a height of 40 cm were performed [23]. Both protocols included two trials that were measured by using Optojump Next system (Microgate, Bolzano, Italy). For CMJ, players started from an upright standing position (with feet shoulder-width apart and hands fixed on hips throughout the jump to eliminate the use of arm swing), made a preliminary downward countermovement position to a self-selected depth by flexing the hips and knees. Players then immediately extend their hips and knees to make a vertical jump. The player returned to the starting position after the jump. The best of the two trials was used for analysis. The trial was considered invalid in case of knee flexion at landing, or if arm swing was detected.

The DJ was performed from a 40 cm wooden box, as recommended by previous study [24]. The DJ protocol began with the athlete standing on the box with hands fixed on the hips for the entire protocol to eliminate the arm swing influence. They were then instructed to step off the box one foot at the time (self-chosen order of limbs) and then after contact with the ground, to jump as fast and high as possible. The jump was invalid if hands were removed from the hips at any point or if athlete jumped off the box. After each jump, the athlete returned to the starting position, and the procedure was repeated two times. The best of the two trials was used for analysis.

2.4. Sprint Tests

As part of the running speed testing, the participants ran a 20 m maximal sprint starting from a stationary standing position, with their lead foot on the additional line placed 20 cm behind the photocell to prevent premature time start. Three photocells of 1.2 m height and 1.5 m wide gates (Microgate, Bolzano, Italy) were used to measure 15 m and 20 m sprint times with precision of 0.01 s. Two valid trials were performed by each player, with a 3 minute rest in between, and the best result was used for analysis.

2.5. Agility

Agility was evaluated by using the *t*-test and Lane agility drills, as used in previous studies [25,26]. For the *t*-test, athletes started the test from the standing position with their lead foot placed 20 cm behind the first photocell. Players were asked to sprint forwards 9.14 m to the center cone and touch it with right hand tip, then shuffle 4.57 m to the left to touch the second cone, then 9.50 m to the right to the third cone and then shuffle back 4.75 m to touch the center cone with left hand before finally running backwards to the starting point. Test time was recorded in seconds (to 0.01 s) with a photocell placed at the starting line (Microgate, Bolzano, Italy). Two trials were performed for the *t*-test, with a rest period of 3 minutes in between.

For the Lane agility test, athletes started the test from a standing position with their lead foot placed 20 cm behind first photocell. Players sprinted 5.79 m forward towards the cone on the top right, then side shuffled 4.87 m to the cone on the top left, backstepped 5.79 m to the cone on the bottom left, then side shuffled 4.87 m to the cone on the bottom right. Then, athletes returned to the starting point, around the cones in a reverse order (shuffle left, run forward, shuffle left, run backward). Two trials were completed, with three minute rest intervals between trials. Test time was recorded in seconds with photocells placed at the starting line (Microgate, Bolzano, Italy).

2.6. Statistical Analysis

Descriptive statistics were expressed as means ± standard deviations. The normality of data distribution was checked for all variables using the Kolmogorov–Smirnov test, while Levene's test was used to check the homogeneity of variance. Two-way analysis of variance (ANOVA) was carried out to investigate the differences in body composition and physical performance test results between three age-groups (U14, U15, U16). Pairwise comparisons were performed by using Bonferroni post-hoc test. The relationship between physical performance and body composition variables was assessed using Pearson's *r* product-moment correlation coefficient. The size of correlations was evaluated using the following criteria [27,28]: trivial (0.0), small (0.1), medium (0.3), large (0.5), very large (0.7), nearly perfect (0.9), and perfect (1.0). A hierarchical model of multiple regression analysis was conducted to investigate the amount of variance in speed and agility tests explained by CMJ and DJ (Step 3), after adjusting for chronological age (Step 1) and body composition variables (Step 2). The regression analysis was performed to investigate whether the superior performance in lower body power tasks (CMJ, DJ) would correspond to lower sprinting and agility time scores. All analyses were performed using IBM SPSS Statistics software 22.0 (SPSS Inc., Chicago, IL, USA). The significance level was set at $p \leq 0.05$.

3. Results

Table 1 summarizes the body composition, speed, and agility characteristics for the three age categories of basketball players. The U16 players were significantly taller and heavier than their peers from other age groups. Overall, the U16 group showed better performance in all physical fitness tests.

Table 1. Descriptive statistics and post-hoc comparisons for body composition and physical fitness tests.

Variables	U14		U15		U16		ANOVA		
	Mean	SD	Mean	SD	Mean	SD	ηp^2	F	*p*-Value
Chronological age (years)	13.41	0.54	14.71	0.29	15.64	0.32	/	304.879	≤0.01
Height (cm)	175.14 €	8.58	183.60	7.91	185.99 £	5.83	0.28	26.888	≤0.01
Body mass (kg)	63.46 €	13.70	75.20	11.87	76.25 £	10.29	0.19	16.044	≤0.01
PBF (%)	12.88	5.98	13.92	5.62	12.92	5.74	0.07	0.477	0.62
CMJ (cm)	28.83	4.36	30.39	5.62	31.44 £	4.88	0.04	3.255	0.04
DJ (cm)	27.68	4.63	29.89	5.28	31.68 £	5.49	0.09	7.039	≤0.01
15 m sprint (s)	2.69	0.19	2.64 $	0.18	2.53 £	0.14	0.12	9.345	≤0.01
20 m sprint (s)	3.40	0.24	3.35 $	0.23	3.20 £	0.19	0.13	10.254	≤0.01
t-test (s)	11.45	0.87	11.21 $	0.78	10.77 £	0.85	0.10	8.129	≤0.01
Lane agility (s)	13.48	0.98	13.13	0.85	12.77 £	0.89	0.09	7.215	≤0.01

SD = standard deviation; PBF = body fat percentage; CMJ = countermovement jump; DJ = drop jump; $\eta_p{}^2$ = partial eta squared; € = sig. difference U14 vs. U15 $p < 0.01$; $ = sig. difference U15 vs. U16 $p < 0.01$; £ = sig. difference U14 vs. U16 $p < 0.01$.

The results of Pearson product-moment correlations according to age groups are presented in Table 2. In the U14 group, chronological age presented significant positive correlations with CMJ (r = 0.50, $p \leq 0.01$) and DJ (r = 0.43, $p \leq 0.01$). In the U15 group, chronological age showed significant correlation with 10m speed (r = −0.30, $p \leq 0.05$) and 20 m speed (r = −0.34, $p \leq 0.05$). In the U16 group, chronological age did not correlate with any of analyzed variables. PBF correlated significantly and positively with speed and agility tests in all age groups, but was, in contrast, a negative predictor of lower-body power in all groups (CMJ from r = −0.39 to r = −0.63, $p \leq 0.01$; DJ from r = −0.42 to r = −0.56, $p \leq 0.01$). Generally, speed and agility tests were strongly and negatively correlated with lower-body power across all groups. A significant and positive correlation was observed between sprint time and agility performance in all age groups.

Table 2. Correlations between anthropometric measures, power, sprint and agility performance for basketball players U14 (*n* = 44), U15 (*n* = 45), and U16 (*n* = 51).

	Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
U14	1. Chronological age (yrs.)	1	0.284	0.178	−0.203	0.495 **	0.434 **	−0.459 **	−0.536 **	−0.571 **	−0.370 *
	2. Height (cm)		1	0.769 **	−0.001	0.074	−0.050	−0.348 *	−0.343 *	−0.264	−0.250
	3. Body mass (kg)			1	0.515 **	−0.082	−0.147	−0.022	−0.017	−0.130	−0.163
	4. PBF (%)				1	−0.493 **	−0.421 **	0.632 **	0.661 **	0.405 **	0.301 *
	5. CMJ (cm)					1	0.898 **	−0.711 **	−0.739 **	−0.719 **	−0.486 **
	6. DJ (cm)						1	−0.635 **	−0.650 **	−0.690 **	−0.530 **
	7. 15 m sprint (s)							1	0.962 **	0.702 **	0.480 **
	8. 20 m sprint (s)								1	0.726 **	0.509 **
	9. *t*-test (s)									1	0.772 **
	10. Lane agility (s)										1
U15	1. Chronological age (yrs.)	1	0.276	0.096	−0.121	0.180	0.209	−0.349 *	−0.343 *	−0.194	−0.231
	2. Height (cm)		1	0.564 **	−0.208	0.350 *	0.285	−0.278	−0.349 *	−0.308 *	−0.159
	3. Body mass (kg)			1	0.400 **	0.011	−0.009	−0.058	−0.068	0.012	0.241
	4. PBF (%)				1	−0.629 **	−0.560 **	0.506 **	0.566 **	0.573 **	0.551 **
	5. CMJ (cm)					1	0.898 **	−0.652 **	−0.719 **	−0.629 **	−0.555 **
	6. DJ (cm)						1	−0.549 **	−0.621 **	−0.587 **	−0.550 **
	7. 15 m sprint (s)							1	0.969 **	0.588 **	0.543 **
	8. 20 m sprint (s)								1	0.662 **	0.600 **
	9. *t*-test (s)									1	0.844 **
	10. Lane agility (s)										1
U16	1. Chronological age (yrs.)	1	−0.229	−0.059	0.017	−0.079	−0.050	−0.119	−0.126	−0.181	−0.036
	2. Height (cm)		1	0.433 **	−0.329 *	0.163	0.057	−0.079	−0.120	−0.021	−0.066
	3. Body mass (kg)			1	0.259	0.053	0.031	0.032	0.031	0.039	0.063
	4. PBF (%)				1	−0.394 **	−0.446 **	0.544 **	0.531 **	0.469 **	0.426 **
	5. CMJ (cm)					1	0.861 **	−0.659 **	−0.658 **	−0.516 **	−0.475 **
	6. DJ (cm)						1	−0.718 **	−0.702 **	−0.634 **	−0.595 **
	7. 15 m sprint (s)							1	0.967 **	0.690 **	0.658 **
	8. 20 m sprint (s)								1	0.679 **	0.693 **
	9. *t*-test (s)									1	0.873 **
	10. Lane agility (s)										1

PBF = body fat percentage; CMJ = countermovement jump; DJ = drop jump; * = $p \leq 0.05$; ** = $p \leq 0.01$.

Table 3 summarizes the results (whole sample) of a hierarchical multiple regression conducted on chronological age (Step 1), body composition (Step 2), and lower-body power (Step 3) on speed and agility performance. Chronological age and body composition variables explained 49% and 53% of variance observed in 10 m and 20 m sprint time. By adding lower-body power variables, an additional 11% and 13% of variance was explained. Along with PBF (β = 0.39; $p \leq 0.01$), DJ (β = −0.33; $p \leq 0.05$) remained the most powerful predictor in the predictive model. Regarding the agility tests, chronological age and body composition variables explained 42% (*t*-test) and 36% (Lane agility) of variance observed. By adding lower-body power variables, an additional 13% and 10% of variance was explained. DJ (β = −0.51; $p \leq 0.01$) remained the most significant predictor of the whole agility model.

Table 3. Multiple regression analysis.

	15 m Sprint			**20 m Sprint**			***t*-test**			**Lane Agility**		
	Model I β	**Model II β**	**Model III β**	**Model I β**	**Model II β**	**Model III β**	**Model I β**	**Model II B**	**Model III β**	**Model I β**	**Model II β**	**Model III β**
1. Chronological age (yrs.)	−0.43 **	−0.34 **	−0.23 **	−0.46 **	−0.35 **	−0.26 **	−0.43 **	−0.36 **	−0.23 *	−0.37 **	−0.30 **	−0.16
2. Height (cm)		0.11	0.06		0.08	0.01		0.19	0.08		0.03	−0.09
3. Body mass (kg)		−0.33 *	−0.19		0.30 *	−0.16		−0.36 *	−0.19		−0.17 *	−0.05
4. PBF (%)		0.65 **	0.39 **		0.66 **	0.38 **		0.59 **	0.32 **		0.44 **	0.18
5. CMJ (cm)			−0.35 *			−0.38 **			−0.10			0.07
6. DJ (cm)			−0.09			−0.07			−0.36 *			−0.51 **
R^2	0.19	0.49	0.61	0.21	0.53	0.66	0.18	0.42	0.55	0.14	0.36	0.46
F for change in R^2	31.939 **	32.764 **	34.564 **	36.010 **	38.614 **	43.502 **	30.988 **	23.984 **	26.646 **	21.519 **	13.661 **	15.921 **

Model I: chronological age, Model II: chronological age, height, body mass, and PBF; Model III: chronological age, height, body mass, PBF, CMJ height, and DJ height; PBF = body fat percentage; CMJ = countermovement jump; DJ = drop jump; * = $p \leq 0.05$; ** = $p \leq 0.01$.

4. Discussion

This research aimed to identify the anthropometric factors predicting the speed and agility profiling in under 14 (U14), under 15 (U15), and under 16 (U16) basketball players. In addition, we aimed to investigate the correlation of physical performance tests with the players' anthropometric profiles. As we omitted biological age, the study may have overlooked potential variations in physical development within the age groups studied, which limits the understanding of how maturation influences the observed performance differences and correlations. The relative age effect also could confound the results, as a player's competitive advantage may be due to their relative maturity within the cohort. This would allow for the identification of age-related patterns, potential maturation effects, and the influence of biological age on performance outcomes. Moreover, considering biological age in talent identification and training program design can aid in the appropriate placement and development of young athletes, accounting for individual differences in growth and maturation.

Besides obvious differences in anthropometric variables, we found significant between age group differences in all performance variables. Interestingly, no PBF differences were found between age groups. Further, although the U14 and U16 groups differed in all the measured variables, the U14 and U15 groups differed in only two variables (height and body mass), and the U15 and U16 groups differed in three variables (10 and 20 m sprints and *t*-test). This is understandable considering the fact that great biological and morphological transformations and variations occur in adolescence [29]. In fact, similar inconsistencies have been found in numerous earlier studies. For example, Jakovljević et al. (2012) [10] found similar trends in mixed young basketball and football players aged 12–15 years. In their study, they divided participants according to their chronological age (12, 13, 14, and 15 years). No differences in speed and agility test results were found between 12 and 13, and 14 and 15, whilst 13 and 14 differed in all performance variables.

Within age group correlation showed that chronological age correlated with all performance variables in U14 and sprint performance in the U15 group. No significant correlations were found in the U16 group, implying that the phenomenon known as relative age effect [30] is present in U15 and younger age groups. This implies that a specific biological development stabilization takes place, and it is crucial to take this stabilization into account during testing and scouting.

Further, body height and weight correlation with performance tasks was found to be weak and insignificant (<0.35), whereas PBF showed large and constant correlation with power and sprint tests. In each age group, sprint and power performance exhibited a large to nearly perfect correlation, with correlation coefficients ranging 0.475–0.969 (irrespective of the direction). Similar results were found previously in young [10,31] and professional basketball players [6].

The results indicate that CMJ and DJ are significantly correlated with sprint and agility performance in all groups; however, while CMJ showed a stronger correlation with these results than DJ in U14 and U15, it was opposite in the U16 age category. A potential reason could be the difference in biological age, which could give more comprehensive understanding of the relationships between the maturity of anthropometric factors, physical performance, and CNS developmental processes that are more related to success in DJ. Additionally, more mature players have higher hormonal levels, stronger muscle structure, and possess rapid force development that could be advantageous during DJ [32,33]

It is possible that the findings could be influenced by several factors, including the age and maturity of the participants, as well as the specific training methods used. It was previously reported that power performance may be mediated by biological maturation [34]; agility performance tends to improve naturally with age, but there are significant increases from childhood to early adolescence, followed by a near-plateau in mid-adolescence [35]. Further, training regimens designed to increase lower-body power and strength, which have the potential to improve agility performance [36,37], are commonly introduced after peak height velocity age (13–15 years for boys) [12] because strength training is generally less effective before the growth spurt [38]. Therefore, training adaptations (in agility performance) are not solely attributable to the impacts of exposed training stimuli but also to the natural developmental processes of the young athlete [39,40]. Additionally, DJ is a measure of reactive muscular strength and may be more closely associated with agility, requiring rapid changes in direction, compared to CMJ, which provides information on lower limb power development during both the eccentric and concentric phase under the influence of the stretch–shortening cycle (SSC) [41,42].

The multiple regression analysis supported the aforementioned findings. CMJ and DJ both emerged as significant predictors for the sprint and agility variables, respectively, showing that lower limb power and SSC utilization ability are crucial components of high-quality sports performance. Additionally, PBF with its moderate but constant correlation coefficients with performance tasks was shown to be a significant predictor for the majority speed and agility capacities. This is understandable since excess body fat can negatively affect the ability to move quickly and efficiently. Additionally, carrying excess body fat can increase the energy cost of movement [43], thus leading to decreased speed and endurance. Therefore, athletes with lower body fat percentages are typically able to move more quickly and efficiently, leading to improved speed performance.

Given that talent identification refers to the process of recognizing current participants with the potential to become elite players [44], it is reasonable to assume that these tests could be utilized for appropriate talent selection and evaluation of both player development and training programs in young basketball players.

Practical recommendations from study outcomes can be directed to enhance talent identification, player development, and training programs in young basketball players. Performance tests such as countermovement jump (CMJ) and drop jump (DJ) (with initial jump height lowered to 25 cm) can be used for effective talent identification, focusing on lower limb power as essential for speed and agility performance. Additionally, players that have and maintain lower percentages of body fat are more likely to optimize movement efficiency, speed, and endurance. Specific training regimens to accommodate the variations in age and biological maturation among players should be introduced, such as strength training programs after the growth spurt for optimal effectiveness.

Possible limitations could be the non-inclusion of specific basketball ball dribbling tests and between-playing position comparisons since players specialize in their positions and develop more specific skills related to those positions. Moreover, peak height velocity (PHV), as a relatively easy assessment to make [45], should be incorporated in future research to better understand the growth spurt and its influence on speed and agility.

5. Conclusions

Significant age group differences were found in all performance variables, with no differences in percentage body fat between age groups. Within age group correlation showed interesting results, with the relative age effect present in U15 and younger age groups. Lower-body explosive strength was linked to essential attributes of high-quality sports performance such as speed and agility, with CMJ and DJ emerging as the most significant predictors for sprint and agility variables, respectively. Additionally, PBF showed moderate but constant correlation coefficients with performance tasks and emerged as a significant predictor for most speed and agility capacities, highlighting the importance of maintaining lower percentages of body fat for improved performance. When interpreting the results, it is crucial to consider potential variations in age, biological maturation, and training specificity among basketball players.

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