Sprint performance according to the maturation status of U-13 and U-14 players from a professional club

Rendimiento en sprint según el estado madurativo de futbolistas sub- 13 y sub-14 de un club profesional

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Como citar en APA

Zapata Bastías, J., Cortés Roco, G., Salinas González, C., Aguirre Ramírez, F., Muñoz Ortiz, J., & Yañez Sepúlveda, R. (2025). Sprint performance according to the maturation status of U-13 and U-14 players from a professional club. *Retos*, *68*, 1441–1450. https://doi.org/10.47197/retos.v68.116539

Abstract

Introduction: In youth football, maturity-related changes in physical performance vary significantly between players. Aim: To compare sprint performance between U-13 and U-14 players of a professional club according to maturity level.

Methodology: Non-experimental study with a quantitative, descriptive and comparative approach. The sample consisted of 47 U-13 and U-14 players from a professional club. Maximum height velocity (HPV) was estimated: pre-HPV (<-1.0 years, n=21), mid-HPV (-0.99 to 0.5 years, n=21) and post-HPV (>0.5 years, n=5). A 30-m sprint test was performed using a linear encoder, and results were obtained for force-velocity, maximal force (F0), velocity (V0) and power (Pmax) profiles.

Results: V0 was higher in mid-versus pre-PHV (7.76± 0.74 vs 7.34± 0.7; Pb = 0. 015; ES=0.91); Pmax was higher in mid versus pre-PHV (813.84±211.79 vs 619.08± 123.8; Pb = 0.004; ES=1.05); Fmax was greater in mid- (440.96± 43.14 vs 351.07± 49. 16; Pb = < .001; ES=1.54); and 30-meter sprint time was lower in mid versus pre-PHV (4.78± 0.19 vs 5.12± 0.33; Pb=0.014; TE=0.91) and lower (Pb=0.085; TE=1.12) than PHV post (5.20± 0.91).

Discussion: These findings indicate that biological age affects maximal velocity, maximum power, maximum strength, and sprint time in U-13 and U-14 players of a professional club.

Conclusion: The results indicate differences in sprint performance among young soccer players, primarily between pre-PHV and mid-PHV stages.

Keywords

Biological age; biological maturity; maturity; speed; peak height; youth football; acceleration.

Resumen

Introducción: En el fútbol juvenil, los cambios relacionados con la madurez en el rendimiento físico varían significativamente entre jugadores.

Objetivo: comparar el rendimiento en sprint entre jugadores sub-13 y sub-14 de un club profesional según el nivel de madurez.

Metodología: Estudio no experimental con enfoque cuantitativo, descriptivo y comparativo. La muestra consistió en 47 jugadores sub-13 y sub-14 de un club profesional. Se estimó la velocidad de altura máxima (VPH): pre-PHV (<-1,0 años, n=21), med-PHV (-0,99 a 0,5 años, n=21) y post-PHV (>0,5 años, n=5). Se realizó una prueba de sprint de 30 metros utilizando un codificador lineal, y se obtuvieron los resultados de los perfiles de fuerza-velocidad, fuerza máxima (F0), velocidad (V0) y potencia (Pmax). Se aplicó una prueba ANOVA para comparar los perfiles en función del PHV.

Resultados: La velocidad máxima (7,76± 0,74 vs 7,34± 0,7; Pb = 0,015; TE=0,91), la Pmax (813,84±211,79 vs 619,08± 123,8; Pb = 0,004; TE=1,05) y la Fmax (440,96± 43,14 vs 351,07± 49,16; Pb = < 0,001; TE=1,54) fueron significativamente mayores en med-PHV vs pre-PHV. Mientras que la velocidad en los 5-10 m. (2,19± 0,11 vs 2,08± 0,07; Pb= 0,004; TE=1,28), 10-15 m. (2,95± 0,16 vs 2,79± 0,10; Pb= 0,004; TE=0,75), 20-25 m. (4,40± 0,26 frente a 4,12± 0,16; Pb= 0,012; TE=1,14) y 25-30 m. (5,12± 0,33 frente a 4,78± 0,19; Pb= 0,014; TE=0,95) fueron significativamente inferiores en med-PHV.

Discusión: Estos resultados indican que la edad biológica afecta a la velocidad máxima, la potencia máxima, la fuerza máxima y el tiempo de sprint en jugadores sub-13 y sub-14 de un club profesional.

Conclusiones: Los resultados indican diferencias en el rendimiento en sprint entre los jóvenes futbolistas, principalmente entre las etapas pre-PHV y mid-PHV.

Palabras clave

Futbol joven; maduración; velocidad; pico de altura; edad biológica; aceleración.

Introduction

The assessment of the linear force-velocity relationship has been used to identify the maximal mechanical capacities of the muscles involved to generate a high level of force (through the theoretical maximal force, F0), to generate force at very high velocity (through the theoretical maximal velocity, V0), and to produce maximal power (Pmax) (Jimenez-Reyes et al., 2018). The force-velocity profile (FVP) is a method that describes the relationship between force and velocity during muscle contraction for a given motor task, relating to the capabilities of the neuromuscular system (Cormie et al., 2011). Strength and conditioning professionals can currently use field methods to assess the sprint FVP profile (Romero-Franco et al., 2017). The sprint FVP profile (horizontal profile) provides information on the ability to produce effective force for a specific sprint task, such as horizontal force (Jimenez-Reyes et al., 2018). This approach provides a personalized diagnosis of the mechanical factors related to force generation and, second, an intervention plan that targets individual performance limits (Nieder-Draeing & Zentgraf, 2025). Assessing the horizontal force-velocity relationship during the acceleration phase of sprinting, known as the horizontal F-V relationship, enables the determination of mechanical efficiency in linear sprint performance. This is because the displacement of the body's centre of mass in space over time facilitates the calculation of ground reactive forces, which vary with increasing velocity, like the increase in loads in the vertical profile (Morin et al., 2016). The individual FV relationship can be modelled from a horizontal sprint of maximum intention, including split times (Haugen et al., 2020).

Biological maturation can be defined as the timing and rate of progress toward reaching a mature state (Towlson et al., 2021). Maturation in young athletes often affects physical performance, providing an interesting challenge to optimize performance (Gonzalo-Skok & Bishop, 2025). The timing and rate of growth is highly individual and asynchronous with decimal age throughout adolescence (Philippaerts et al., 2006), with young football players undergoing an estimated phase of accelerated growth (approximately 7.5-9.7 cm/year) between the ages of 10.7 and 15.2 years (Towlson et al., 2018). This enhanced growth rate is called maximum height velocity (PHV) (Malina et al., 2012). The predicted maturity lag, defined as the time before maximum height velocity (PHV) [Moore et al., 2015], and estimated age at PHV, i.e. chronological age minus the predicted-to lag, are widely used as estimates of maturity status (state of maturation at the time of observation) and/or timing (age at which a specific maturational event occurs) in studies of young athletes and, to a lesser extent, in studies of youth physical activity and fitness (Malina, 2014; Towlson et al., 2021).

Philippaerts et al. (2006) assessed longitudinal changes in young football players regarding peak height velocity (PHV). They revealed that balance, explosive strength, speed, and agility demonstrated maximal development around PHV, while flexibility exhibited the most significant development during the post-PHV stage. Furthermore, growth-related musculoskeletal adaptations (e.g., tendon and fascicle lengths, penetration angles, and motor unit recruitment patterns) stabilize after puberty and more closely resemble adult characteristics, predispose athletes to a greater magnitude and rate of potential strength development (Radnor et al., 2018). Moreover, about the growth phase, in circa PHV, children experience rapid growth in stature, which can influence both their performance in speed and other physical abilities, as growth in height and leg length can improve speed due to the increased stride but can also lead to a temporary decrease in coordination and motor control (Lloyd & Oliver, 2012).

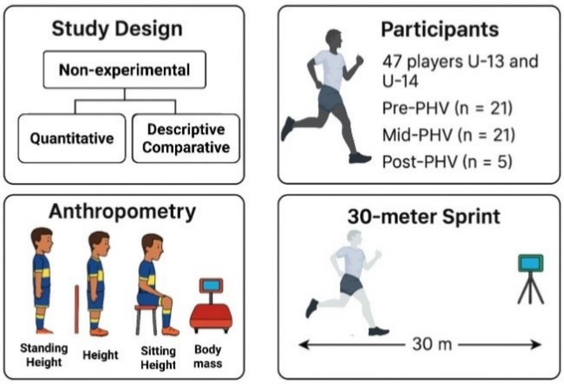
Based on speed performance, several studies have shown that children experience significant improvements in speed after reaching PHV (Asadi et al., 2018; Fernandez et al.,2022). However, the relationship is not linear, as some children may experience decreased performance due to the temporal incoordination that accompanies rapid growth (Vescovi & McGuigan, 2008). Nowadays, football is characterized by an intense rhythm game, where speed has become a fundamental aspect for gaining an advantage over the opponent and attracting fans with a dynamic game (Ortiz, 2004). Therefore, understanding the effects of different types of training on each phase of speed is essential for coaches, as it allows them to design more effective training programs tailored to the individual needs of athletes (Romero et al., 2017; Cetin et al., 2018). A recent meta-analysis conducted in young male athletes revealed that velocity training demonstrated greater adaptive responses in the circa-PHV and post-PHV groups compared to the pre-PHV groups (Moran et al., 2015). However, football-related research has revealed that improvements in speed and strength can still be achieved in the pre-PHV with 6-8 weeks of relatively low volume strength training (Chaabene & Negra, 2017; Rodriguez-Rosell et al., 2016). Therefore, previous literature suggests that these periods of accelerated gains may exist in youth football, and practitioners can potentially adjust athlete development programs accordingly (Towlson et al., 2021). Therefore, this study aims to compare sprint performance between U13 and U14 children, categorized by pre-, mid-, and post-PHV maturational level, belonging to the youth football team of a professional club.

Method

Type of study and design

The design of this study is non-experimental, employing a quantitative, descriptive, and comparative approach.

Figure 1. Study methodology



Participants

The non-probabilistic sample consisted of 47 U-13 and U-14 players selected for convenience. Peak height velocity (PHV) was estimated as pre-PHV (<-1.0 years, n=21), mid-PHV (-0.99 to 0.5 years, n=21), and post-PHV (>0.5 years, n=5). Inclusion criteria required that participants belonged to the U-13 and U-14 categories, were enrolled in a professional club's youth football program, had obtained informed consent from their parents and their respective assent, and did not present any injuries that would prevent them from participating in the 30-meter test. Conversely, exclusion criteria included players under 13 years or over 14, players not registered in a professional club's youth football program, players lacking informed consent from their parents and assent from the assessed children, or injured players. Additionally, this research was conducted according to the Helsinki Declaration, and the privacy and rights of those evaluated were always respected.

Assessments

Anthropometry

The date of birth and anthropometric measurements were collected, including height and sitting height (using the SECA 203 portable measuring rod) and body mass (measured on the SECA 874 mobile floor scale). Chronological age was established based on the date of birth and the date of assessment; all anthropometric tests were conducted by the same examiner following the protocols of Lohman et al. (1988).

PHV

The maturity estimation was carried out following the protocol proposed by Mirwald et al. (2002). The PHV protocol has been successfully validated against the gold standard method (hand-wrist radiographs) with a correlation coefficient of 0.83. Participants were divided into three maturity groups based on biological age: pre-PHV (<-1.0 years, n = 21), mid-PHV (-0.99 to 0.5 years, n = 21), and post-

PHV (>0.5 years, n = 5) for analysis (Meylan et al., 2014). This method was selected due to its non-invasive nature and satisfactory levels of measurement precision, with a standard error estimate of 0.59 years and a 95% inter-value confidence interval (CI) of ±1.18 years. This methodology is recommended for application in adolescents aged between 10 and 18 (14 ± 4 years) (Fernández-Galván et al., 2024). The equation used is sex-specific and calculates the maturity gap based on chronological age, body weight (in kilograms), height (in centimetres), sitting height (in centimetres), and estimated leg length (in centimetres).

PHV=- 9.236 + (0.0002708 x [leg length x sitting height]) - (0.001663 x [age x leg length]) + (0.007216 x [age x sitting height]) + 0.02292 x (mass/height).

Procedures

After anthropometric measurements, participants underwent a standardised 10-minute warm-up procedure consisting of 5 minutes of dynamic movements (e.g., high knees, jumping, and lungs). Each player wore football shoes, and the test was conducted on the natural grass training pitch.

30-metre sprint

Each player performed two 30-meter sprints on the training field. Players started standing, with the front foot 0.5 m from the first timing gate. Instantaneous velocity in 30 m sprints was measured using a Race Analyzer friction encoder (Chronojump, Barcelona, Spain), with a distance accuracy of 3 cm and a time accuracy of 4 microseconds. The device was mounted on a 1-meter-high tripod behind the participants. Participants were then secured to a belt connected to the friction encoder and verbally encouraged during the test to ensure they exerted maximum effort. The cable was attached to a waist belt and set with a 1-kg load to avoid fluctuations, ensuring the thread is in tension. Before starting the capture, the type of race was selected. The configuration was requested in Chronojump v2.1.2- 2 software (Chronojump, Barcelona, Spain), considering the distance travelled, 30 metres, and the ambient temperature to calculate the air density. The encoder was operated remotely via connection to a laptop to negate the possibility of variability introduced through direct manual operation. Data were analysed post hoc using Chronojump v2.1.2-2 software (Chronojump, Barcelona, Spain) to calculate sprint F-V spectra using the validated method described in detail elsewhere (Samozino et al., 2016). Individual linear F-V relationships were then extrapolated to calculate theoretical maximum velocity (V0), maximum acceleration (Acc. max), maximum strength (F0), maximum power (Pmax), velocity at maximum power (VPmax), and sprint times (0-5m, 5-10m, 10-15 m,10-25 m, and 25-30m).

Ethical considerations

The present study was conducted according to the principles outlined in the Declaration of Helsinki for human studies. Before the evaluations, guardians and students signed an informed consent/assent form indicating the objective, procedure, and evaluations to be carried out during the study. Participation was voluntary, and participants could withdraw from the research project anytime. In case of doubts about the procedures, the research team was available to answer questions. Participants' data were coded to mask their identities, and the collected databases were stored on the principal investigator's laptop, accessible only with a password and fingerprint.

Data analysis

The analysis plan utilized jamovi 2.3.17 statistical software. Data are presented as means ± SD. The distribution of each variable was examined using the Shapiro-Wilk test for normality, and homogeneity of variance was checked with Levene's test. The ANOVA test and the Bonferroni correction were compared between groups (pre-, mid-, and post-PHV). An alpha level of $p<0.05$ was used to determine statistical significance. Effect sizes (ES) were estimated using partial eta squared (ηp^2), with values interpreted as small (≥ 0.01), medium (≥ 0.06), or large (≥ 0.14), as described by Richardson (2011). Cohen's effect sizes were categorized according to Hopkins et al. (2009): <0.2 = trivial, 0.2-0.6 = small, 0.6-1.2 = moderate, 1.2-2.0 = large, 2.0-4.0 = very large, and >4.0 = extremely large. In addition, 95% confidence intervals (95% CI) were calculated, and the significance level was set at .05.

Results

Table 1 presents the overall results for formative football players based on their level of maturation (pre-, mid-, and post-PHV). The chronological age of the pre-PHV group was 13.62 ± 0.44 years, while the predicted APHV was 14.41 ± 0.52 years, showing a difference of -0.805. In contrast, the mid-PHV group had a chronological age of 23 ± 0.46 years and a predicted PHV age of 13.79 ± 0.47 years, resulting in a difference of 0.448. The post-PHV group had a chronological age of 14.56 ± 0.27 years, with a predicted PHV of 13.26 ± 0.54 years (+1.2). All variables exhibited significant differences between the pre-PHV and mid-PHV periods and between the pre-PHV and post-PHV periods.

Table 1. Descriptive statistics of parameter metrics

	Pre-PHV Mid-PHV Post-PHV (N=21) (N=21) (N=5)		
Variables	M/SD	M/SD	M/SD p
Weigth	50.13± 6.18	62.8± 6.59	66.76 ± 4.39 <0.001[a, b]
Size	159.78± 7.99	169.08± 6.88	177.02± 4.32 <0.001[a, b]
Sitting height	79.17± 3.90	86.27±2.64	90.64± 2.04 <0.001[a, b]
Chronological age	13.62± 0.44	14.23± 0.46	14.56±0.27 <0.001[a, b]
Predicted APHV	14.41± 0.52	13.79± 0.47	13.26± 0.54 <0.001[a, b]
Maturational lag (years)	-0.80± 0.51	0.44± 0.35	12.00± 0.27 <0.001[a, b]

[a] significant difference between pre- and mid-PHV; [b] significant difference between mid- and post-PHV

Table 2 presents the inferential results of the comparisons between pre-, mid- and post-PHV maturation groups. Maximum velocity (V0) increased from pre- to post-PHV, showing significant differences between pre- and mid-PHV (Pb = 0.091), with a small effect size (0.91). Peak Power (Pmax, W) increased from pre- to mid-PHV (Pb = 0.004), with a moderate difference and effect size (1.05). Maximal Force (F0) increased significantly from pre- to mid-PHV (Pb < .001) with a moderate effect size (1.54), and Velocity at Pmax (VPmax, km/h) increased from pre- to mid-PHV, with a significant difference (Pb= 0.001), and a moderate effect size (1.24). In the comparison of sprint times by lengths between the maturation groups (pre-, mid- and post-PHV), it is observed that the mid-PHV group consistently presents better times in most intervals, especially between 0-5 m, 5-10 m, and up to 25-30 m. Although not all results reach statistical significance, several stretches show significant differences, particularly between pre- and mid-PHV and mid- and post-PHV.

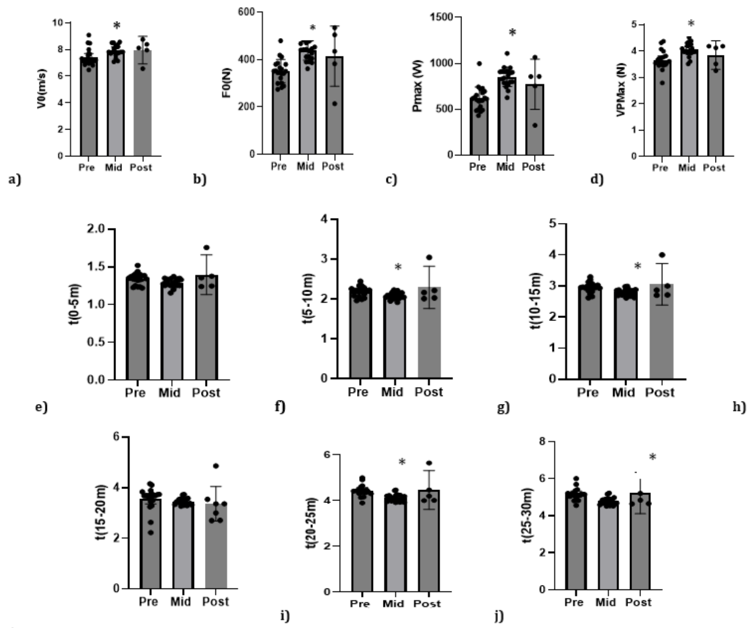
Table 2. Results of the comparisons between maturation groups (PHV)

	Pre-PHV Mid-PHV Post-PHV							
Variables	M/DS	M/DS	M/DS	P	Δ	η_p^2	Pb	ES
V0 (m/s)	7.34±0.7	7.76±0.74	7.92± 0.78	0.013[a]	-0.42[a]	0.180	0.015[c]	0.91
Amax(m/s^2)	6.76± 0.57	6.86± 0.53	5.97± 1.71	0.057	-0.89	0.12	0.059	1.20
Pmax(W)	619.08± 123.8	813.84± 211.79	772.63 ± 274.23	0.005[a]	+194.76[a]	0.21	0.004[c]	1.05
F0 (N)	351.07± 49.16	440.96± 43.14	413.87 ± 126.70	< .00[a]	+89.89[a]	0.21	< .001[c]	1.54
VPmax (Km/h)	3.65± 0.34	4.04± 0.24	3.85± 0.43	0.001[a]	-1.41[a]	0.26	< .001[c]	1.24
Sprint time (0-5 m)	1.34± 0.07	1.29± 0.05	1.39± 0.21	0.067 (ns)	-0.05[a]	0.13	0.033[c]	1.22
Sprint time (5-10 m)	2.19± 0.11	2.08± 0.07	2.29± 0.43	0.021[a]	-2.14[a]	0.16	0.004[c]	1.28
Sprint time (10-15 m)	2.95± 0.16	2.79± 0.10	3.05± 0.54	0.013[a]	-0.16[a]	0.12	0.055	0.75
Sprint time (15-20 m)	3.63± 0.31	3.45 ±0.13	3.77± 0.62	0.127 (ns)	0.18	0.12	0.170	1.20
Sprint time (20-25 m)	4.40± 0.26	4.12± 0.16	4.46± 0.68	0.009[a]	-0.28[a]	0.20	0.012[c]	1.14
Sprint time (25-30 m)	5.12± 0.33	4.78± 0.19	5.20± 0.91	0.008[a]	0.34[a]	0.19	0.014[c]	0.917

V0: Maximum velocity; Amax: Maximum acceleration; Pmax: maximum power; F0: maximum force; VP max: velocity at maximum power. Pb: Bonferroni post hoc test, ES: Effect size.

[a:] significant difference between pre and mid PHV; [b:] significant difference between mid and post-PHV; [c:] significant difference in Bonferroni post hoc test between Pre and Mid PHV.

Figure 1. Results of force-velocity profile comparison between biological maturation groups (PHV).



* Mean difference between Pre and Mid PHV.

Discussion

The results of our study indicate differences in the variables of maximum velocity, maximum strength, maximum power, and velocity at maximum power (VPmax), as well as in sprint times (5-10, 10-25, and 25-30), between pre- and mid-PHV, in young soccer players. This demonstrates that biological age influences players' strength-velocity profile and sprint time within a professional club's under-13 and under-14 categories. Regarding the results of the 30-meter sprint, performance was significantly different between pre- and mid-PHV, with shorter mid-PHV times in most speed sections. This could indicate that variables related to strength (exemplified in the 5 m sprint) and velocity (reflected in the 30 m sprint and the maximum 20-30 m velocity) develop more substantially from pre- to mid-PHV and from mid- to post-PHV stages, respectively (Fernández-Galvan et al., 2024). This finding enhances our understanding that the mechanical variables of the sprint strength-velocity profile related to the ability to reach and maintain maximum sprint velocity (i.e., maximum velocity) develop more significantly from the PHV (Fernández-Galván et al., 2022). However, the low number of players in the post-PHV group does not allow us to analyse the evaluated variables' results accurately.

In this respect, Marinho et al. (2020) found differences in sprint times between pre- and mid-PHV; however, the pre-PHV group had a lower time than the mid-PHV group, while Matta et al. (2014) obtained similar results to ours with a group of U-15 soccer players at different stages of maturation, where significant differences were observed in sprint speed over 30 meters. Additionally, it has been observed that subjects in the post-PHV stage have higher acceleration capacities and faster split times compared to those in pre- or mid-PHV. In our study, acceleration was higher in mid-PHV than in pre-PHV and post-PHV; however, the results were not significant. Itoh & Hirose (2020) and Meyers et al. (2015) also found no difference in acceleration between maturation levels. A possible explanation could relate to the supposed lack of adaptation to strength training in late-maturing subjects (i.e., those in the pre-PHV group) (Fernandez-Galvan et al., 2024). This phenomenon was documented by Behringer et al. (2010), who showed that the capacity to generate muscle strength appears to increase with the maturational stage, indicating that strength training may be especially beneficial at later stages of maturation. However, in our study this finding was not demonstrated.

Previous studies highlight the importance of sprint speed as an essential component of physical fitness for playing football (Murthagh et al., 2018). In addition, the most crucial moments of the soccer game, such as winning ball possession, scoring, assisting or preventing goals depend on the ability of the players to perform high-speed tasks and power production (Söhnlein et al., 2014; Faude et al., 2012). Furthermore, sprint performance may determine elite football playing status, as reported by Murtagh et al. (2018) in a study comparing acceleration, sprinting, horizontal-forward jumping, and vertical jumping abilities to establish elite football playing status at different stages of maturation. This suggests that talent identification protocols should include sprint assessments for pre-PHV players. This is supported by the fact that during the maturation stage of adolescence, accelerated growth in limb length may contribute to the transient increase in acceleration and sprinting abilities from Pre-PHV to Post-PHV (Matta et al., 2015).

Therefore, based on the results, we can conclude that maturation impacts the sporting performance of adolescents and professional footballers (Caccese et al., 2018; O'Brien-Smith et al., 2020). Previous evidence indicates that the development of physical characteristics shows non-linear behaviour among maturation groups. Additionally, a decrease in relative strength can be observed around peak growth velocity, leading to alterations in physical qualities such as speed, change of direction, and jumping power (Slimani & Nikolaidis, 2019). In our study, peak strength was higher in the mid-PHV group (440.96± 43.14) compared to pre-PHP (351.07± 49.16); peak power was also greater in mid-PHV (813.84± 211.79) than pre-PHP (619.08± 123.8).

Practical applications

These findings have important practical implications for coaches. Grouping players solely by chronological age may disadvantage less mature players, who struggle to compete with their more physically developed peers. In contrast, an approach based on maturation level facilitates more personalised training that respects individual differences and optimises each player's development (Malina et al., 2004). For example, pre-PHP players may benefit from training focused on technique and coordination, while post-PHP players may prioritise strength and power development. In addition, consideration could be given to adjusting training and competition loads for pre-PHV players, reducing demands on speed or power that exceed their capabilities, considering that a lower maturity may imply a higher risk of injury due to overload or mechanical stress. Finally, as a practical recommendation, periodic evaluations of the strength-speed profile and PHV can be implemented to monitor physical progression and detect talents or adjustment needs, monitoring over time that would allow us to understand whether performance improvements are the product of natural maturation or training.

Limitations

As a limitation of the study, the low number of the post-PHV group limited the possibility of obtaining representative results for the evaluated variables. While the present data should be used within talent development programmes, other components—such as sport-specific skills, tactical variables, and psychological and social factors, unfortunately not analysed in the present study—may be important for success in football (Marinho et al., 2020). Furthermore, the study design was observational rather than experimental, which implies that the observed results on performance variables are due to the natural processes of growth and maturation of the subjects rather than adaptations derived from specific training methods.

Conclusions

In conclusion, our results prove that maximum speed, maximum strength, and 30m sprint times vary across different stages of maturation, indicating that biological age and maturation level should be considered in talent detection and training programming.

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