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The effect of the maturity status on strength performance in young elite basketball players
El efecto del estado madurativo en el rendimiento físico de jóvenes jugadores de baloncesto de élite

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Abstract. The aim of this study was to examine the possible differences on anthropometrics and strength performance between young basketball players with different maturity status. Thirty-one male players (12-15 years) participated in the study. Their maturity status was estimated by the years from/to their peak height velocity (PHV) and players were categorized as pre-, mid- or post-PHV. The analysis of variance showed significant differences in players' body weight and height according to their maturity group. Players' strength performance (1RM, SJ and CMJ) was significantly different between the maturity groups. Pearson's correlation analysis showed a correlation between the PHV and the players' weight, height and performance in 1RM (r = 0.74 – 0.80; $p < .001$) but not with the performance in the SJ and the CMJ (r = 0.19; $p = .295$ and r = 0.35; $p = .055$, respectively). In addition, the linear regression analysis showed that the PHV predicted the players' weight, height and performance in 1RM ($\alpha = 0.74$-0.80; $p < .001$; $R^2 = 0.55$-0.65). The results of this study showed anthropometric and strength performance advantages for young basketball players with an advanced maturity status. These findings may have an impact on talent identification, selection and long-term development processes.
Keywords: maturation, peak height velocity, testing, performance.

Resumen. El objetivo de este estudio fue examinar las posibles diferencias antropométricas y de rendimiento de fuerza entre jóvenes jugadores de baloncesto con diferente estado madurativo. Treinta y un jóvenes (12-15 años) participaron en el estudio. Su estado madurativo fue estimado con los años desde/hasta su pico de velocidad de crecimiento (PHV) y se les categorizó como pre-, mid- o post-PHV. Los análisis de la varianza mostraron diferencias significativas en el peso y la altura de los jugadores de acuerdo con su grupo de maduración. El rendimiento en fuerza de los jugadores (1RM, SJ y CMJ) fue significativamente distinto entre los grupos madurativos. El análisis de correlación de Pearson mostró correlación entre el PHV y el peso, la altura y el rendimiento en fuerza de los jugadores en el 1RM (r = 0.74 – 0.80; $p < .001$), pero no en el SJ ni el CMJ (r = 0.19; $p = .295$ and r = 0.35; $p = .055$, respectivamente). Además, el análisis de regresión lineal mostró que el PHV predijo el peso, la altura y la fuerza de los jugadores en el 1RM ($\alpha = 0.74$-0.80; $p < .001$; $R^2 = 0.55$-0.65). Los resultados de este estudio muestran ventajas antropométricas y de rendimiento en tareas de fuerza para los jóvenes jugadores de baloncesto con estado madurativo avanzado. Estos hallazgos pueden ser relevantes en los procesos de identificación, selección y desarrollo a largo plazo.
Palabras clave: maduración, pico de velocidad de crecimiento, evaluación, rendimiento.

Introduction

Physical performance in basketball is characterized by short and high-intensity actions (i.e. jumping) which are decisive in the game (Abdelkrim et al., 2007, 2010). These kind of high intensity actions are dependent on a player´s strength, and higher levels of maximal and explosive strength have been related with a higher performance in these actions (Comfort et al., 2014). For this reason, strength-related measurements in basketball have been of great importance in recent years (Calle-Calle et al., 2020). The measurement of the maximal strength has been traditionally performed using the 1 repetition maximum test (1RM) (directly or indirectly) (González-Badillo & Sánchez-Medina, 2010). The lower-limb explosive strength (considering it as the application of the maximum strength in the less time possible) has been traditionally measured by the assessment of the jumping height (Young et al., 2011). The squat jump (SJ) and the countermovement jump (CMJ) are two of the most commonly used tests to measure the jumping height (Bosco et al., 1983). Through the assessment of the SJ it is possible to measure the capability of the player's muscles to contract rapidly while the CMJ assesses the players' ability to contract their muscles and to use the elastic energy of a previous countermovement (Komi, 2000).

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The assessment of the maximal and explosive strength is commonly used by basketball academies as indicators of young players' physical performance to identify and select possible future talented players at early ages (Calle-Calle et al., 2020). In this way, these basketball academies try to select young basketball players with talent and programme their long-term training with the aim that these players reach the elite. Within these long-term training programs, players are grouped by age-categories, being the chronological age of the athlete the only grouping criteria. These age-categories usually hold players born in two consecutive years (i.e., 14-15 years old). The aim of this grouping system is that players train and compete in theoretically equal conditions, eliminating players' differences according to their growth or physical development. It is also assumed that players from a same category can learn and adapt to training stimulus in a similar way, and that they have the same opportunities to succeed (Cobley et al., 2009). However, it has been observed that players from a same age-category show differences in their maturity status which may suppose differences in their physical performance and their anthropometrics. (Meylan et al., 2014; Peña-González et al., 2019).

Biological maturation is the process that leads to adulthood in which structural and functional changes take place (such as the ossification of the cartilage or the appearance of pubic hair, among others) (Radnor et al., 2018). The assessment of the point of the maturation process at a given moment is known as the maturity status (Lloyd et al., 2014). Previous literature has shown that young athletes with similar ages may have differences in their maturity status and consequently, those players with an advanced maturity status will show a better physical performance (Asadi et al., 2018; Peña-González et al., 2019). These differences may mean a bias in the talent identification and selection process in young basketball players, since the anthropometrics and strength performance advantages of early-mature players may be mistaken as higher talent (Beunen & Malina, 2008). The most commonly used indicator of somatic maturity for the assessment of the maturity status is the years from/to the peak height velocity (PHV) (Mirwald et al., 2002). The PHV is a theoretical point of maximum growth in height during adolescence, which takes place around 14 years of age in boys and 12 years in girls (Malina & KozieB, 2014). The estimation of the years from/to the PHV is calculated by a formula which includes the age, weight, height and leg length of the young player.

Although the general physical performance has been linked to the young athletes' maturity status in several sports (i.e. football) (Meylan et al., 2014; Peña-González et al., 2019) including basketball (Torres-Unda et al., 2013), the maximal (1RM), explosive (SJ) and plyometric (CMJ) strength performance has not been associated to the young basketball players' maturity status. Thus, the aim of this study was to examine the possible differences in anthropometrics and strength performance between young basketball players with different maturity status, hypothesizing that those players with an advanced maturity status would have higher anthropometric values and higher strength performance than those players with a delayed maturity status.

Methods

Participants

Thirty-one elite young U13 (12 and 13 years of age) and U15 (14 and 15 years of age) basketball players took part in the study (age: 13.5 ± 0.81 years; weight: 58.6 ± 10.47 kg; height: 168.4 ± 10.28 cm). All players pertained to an elite Spanish basketball academy (*with licence in the Spanish Basketball Federation*), and they play at the maximum national competitive level. To participate in the study, the players should have a minimum of 5 years of experience in basketball training and competition, and they usually train 6 hours per week.participation in this study was voluntarily and the participants and their parents/guardians were informed of the aim of the study and its possible risks. The players and their parents/guardians signed an informed consent. This study was approved by the ethical committee of the hosting university according to the Declaration of Helsinki.

Design and Procedure

The testing session was carried out in a competitive period and all testing conditions were standardized. The timetable of the measurements, the order of the tests and the operators and devices were always the same. Body height and sitting height were measured using a fixed stadiometer (±0.1 cm, SECA LTD., Germany), and body weight was measured using a digital scale (±0.1 kg, Oregon scientific® GA101/GR101, USA). After the anthropometrical measurements and before the strength performance assessment, players carried out a standardized warm-up which consisted in 5-min of low-intensity running, 3-min of dynamic stretching and 3-min of high intensity actions, including jumping actions.

The order of the strength performance assessment was SJ, CMJ and 1RM. For the SJ and the CMJ, players performed 3 attempts and the best one of each of the tests was recorded for further analysis. For the correct performance of the jump, the researcher ensured a 90º knee flexion and the players had to keep their hands on their hips during the whole jump. The flight time during the jump was measured using a contact platform connected to a digital software (Globus Ergotester®, Italy) that calculated the jumping height in cm. The 1RM in the half-squat exercise was estimated indirectly (González-Badillo & Sánchez-Medina, 2010) using a Smith Machine (Technogym Trading, Gambettola, Italy) and recorded with a linear encoder (T-Force System, Ergotech, Murcia, Spain). Participants were verbally encouraged to perform the tests at their maximal effort.

The players' maturity status was estimated by the equation proposed by Mirwald et al., (2002) for boys: *PHV = -9.232 + 0.0002708 (leg length * sitting height) - 0.001663 (decimal age * leg length) + 0.007216 (decimal age * sitting height) + 0.02292 (weight / height).* Decimal age was calculated as the birthdate minus the date of the measurement.

Statistical Analysis

The participants were grouped for the data analysis according to their maturity status. This grouping was carried out as in Peña-Gonzalez et al., (2019): Pre-PHV (players who had not reached their PHV; n = 13; PHV < -0.5), Mid-PHV (players who were close to their PHV; n = 10; PHV between -0.5 and 0.5) and Post-PHV (players that passed their PHV; n = 8; PHV > 0.5). A one-way analysis of variance (ANOVA) with a post-hoc analysis (Bonferroni) was carried out to compare the anthropometrics and strength performance between players with different maturity status. The effect size was calculated as the partial η^2 and it was interpreted as: small ($\eta^2 < 0.59$), moderate ($\eta^2 >= 0.59$ and < 0.138) and large ($\eta^2 >= 0.138$) (García et al., 2016). A Pearson's correlation coefficient and a linear regression analysis were performed to test the relationship between the PHV and the anthropometrics and strength performance. The Pearson's correlation coefficient (r) was interpreted as: trivial (< 0.09), small (0.10–0.29), moderate (0.30–0.49), large (0.50–0.69), very large (0.70–0.89) and almost perfect (> 0.90) (Hopkins et al., 2009). The significance level was set at $p < .05$ and all statistical analyses were performed using Microsoft Excel (Microsoft, Seattle, Washington, USA) and SPSS Statistics® (Statistical Package for the Social Sciences, Version 27.0).

Table 1.
Descriptive data and comparison between maturity groups for anthropometric and strength performance variables.

	Pre-PHV (n = 13)	Mid-PHV (n = 10)	Post-PHV (n = 8)	F	*p*	η^2
Weight (kg)	51.96 ± 10.17†	58.84 ± 6.07†	68.95 ± 6.39	10.77	< .001	0.44
Height (cm)	158.98 ± 5.41*†	171.72 ± 6.82†	179.71 ± 4.01	36.30	< .001	0.72
1RM (kg)	44.69 ± 6.76*†	76.30 ± 9.72	79.75 ± 11.11	51.63	< .001	0.79
SJ (cm)	22.82 ± 6.76*	29.55 ± 3.74	26.80 ± 4.93	4.36	.022	0.24
CMJ (cm)	24.70 ± 6.41*†	32.55 ± 3.68	30.94 ± 5.04	6.99	.003	0.33

1RM: 1 repetition maximum test; SJ: Squat jump test; CMJ: Countermovement jump test
* Statistically different from Mid-PHV; † Statistically different from Post-PHV

Table 2.
Pearson's correlation coefficients between players' PHV and their anthropometrics and strength performance.

	1	2	3	4	5
1.PHV	-				
1.Weight	0.740** (<.001)	-			
1.Height	0.804** (<.001)	0.717** (<.001)	-		
1.1RM	0.781** (<.001)	0.545** (.002)	0.668** (<.001)	-	
1.SJ	0.194 (.295)	-0.166 (.371)	0.169 (.363)	0.363* (.045)	-
1.CMJ	0.347 (.055)	0.010 (.956)	0.309 (.090)	0.483** (.006)	0.953** (<.001)

1RM: 1 repetition maximum test; SJ: Squat jump test; CMJ: Countermovement jump test
* $p < .05$; ** $p < .01$

Table 3.
Linear regression analysis for anthropometric and strength performance variables according to players' PHV.

	B	Error Estándar	β	*p*	R^2
Peso (kg)	8.31	1.40	0.74**	(<.001)	0.55
Altura (cm)	8.87	1.22	0.80**	(<.001)	0.65
1RM (kg)	15.76	2.34	0.78**	(<.001)	0.61
SJ (cm)	1.27	1.19	0.19	.295	0.04
CMJ (cm)	2.35	1.18	0.35	.055	0.12

1RM: 1 repetition maximum test; SJ: Squat jump test; CMJ: Countermovement jump test
* $p < .05$; ** $p < .01$

Results

Descriptive data for Pre-, Mid- and Post-PHV are presented as Mean ± Standard deviation in table 1. Mid- and Post-PHV players were significantly taller and heavier and showed higher values of maximal (1RM) and explosive (SJ and CMJ) strength than Pre-PHV players (Table 1). However, Post-PHV players showed higher values of weight, height and 1RM than Mid-PHV players, but they did not show higher values for the SJ and CMJ.

Pearson's correlational analysis showed a positive and significant correlation between players' PHV and their weight, height and 1RM, while there was no correlation between the PHV and the SJ and the CMJ (Table 2). Although there were no significant values, the relationship between the PHV and the CMJ was moderate (r = 0.35). The relationship between the 1RM, the SJ and the CMJ tests (r = 0.36 – 0.95; $p = .045$ – .001) can also be seen in table 2. Similarly, the linear regression analysis showed that players' PHV predicts the players' weight ($\beta = 0.74$; $p = <.001$; $R^2 = 55\%$), height ($\beta = 0.80$; $p = <.001$; $R^2 = 65\%$) and 1RM ($\beta = 0.78$; $p = <.001$; $R^2 = 61\%$). However, the PHV did not predict players' performance in the SJ and CMJ (β

= 0.19 and 0.35; p = .295 and .055; R^2 = 4% and 12%, respectively).

Discussion

The aim of this study was to examine the possible differences in anthropometrics and strength performance between young basketball players with different maturity status, hypothesizing that those players with an advanced maturity status would have higher anthropometric values and higher strength performance than players with a delayed maturity status. The main finding of the study suggests that young elite basketball players who are advanced in their maturation process have anthropometric and strength performance advantages, mainly in maximal strength rather than explosive strength, when compared with their peers with a delayed maturation.

The results of this study showed that players with an advanced maturity status had higher values of body weight and height (Pre-PHV < Mid-PHV < Post-PHV). These findings are in line with previous literature that examined the physical differences between young people (young athletes and non-athlete population) with different maturity status (Cripps et al., 2016; Meylan et al., 2014; Peña-González et al., 2019). Regarding the strength performance, Pre-PHV players had the lower values of 1RM, SJ and CMJ in comparison to Mid- and Post-PHV, while there were no statistical differences between Mid- and Post-PHV for these strength performance variables. These physical performance advantages from Mid- and Post-PHV in comparison to Pre-PHV have been previously reported in young non-athlete individuals (Meylan et al., 2014), the same as in other sports as soccer (Peña-González et al., 2019), Australian football (Cripps et al., 2016) or hockey (Moran et al., 2017), in which physical performance differences between players with advanced and delayed maturity status were observed. Specifically in basketball, differences were observed between players with different maturity status in the isokinetic strength (Carvalho et al., 2012). The main reasons that the literature provides for the higher strength performance of young players with advanced maturation are a higher muscular structure (hypertrophy), a different fibre type composition and/or higher motor-unit recruitment (Radnor et al., 2018). These differences may play a crucial role in the talent identification and selection process in basketball, since there exists a higher probability of selecting players who show an advanced maturity status (Arede et al., 2019), which implies a bias in this process.

The correlational analysis showed the direct and significant relationship between the PHV and players' weight, height and 1RM. In addition, the PHV had moderate correlation to the CMJ (0.35) although without significant values. Similarly, the linear regression analysis showed that the PHV predicted the 1RM performance of young basketball players but not of the SJ and the CMJ. Both, the results observed from the maturity groups comparison (no significance between Mid- and Post-PHV groups) and those observed in Pearson's correlation and linear regression analyses suggest that physical performance in explosive actions may be related to the maturation until the young players are near their PHV, while the maximal strength performance is still linked to the maturation process once players pass their PHV. This is in accordance to a previous research with young soccer players which showed no statistical differences between Mid- and Post-PHV for linear velocity and change of direction ability, while both maturity groups were statistically better than the Pre-PHV in 1RM and peak power output in half-squat with the 60% of the 1RM (Peña-González et al., 2018). In this study, it was also reported that a plyometric-based strength training was more effective to improve strength performance of Pre-PHV than Mid- and Post-PHV players, suggesting that once young players are near to reaching their PHV, they need higher specific stimulus to improve the explosive actions that are related to sports performance. Without this specific stimulus, the physical improvements related to the maturation process between players who are around their PHV (Mid-PHV) and players who passed it (Post-PHV) do not seem to be different, while the consistent differences between Pre- and Mid-PHV in the literature indicate that just because they reach their PHV, young players show an increase in their physical performance, mainly through an increase in their strength output (Radnor et al., 2018).

The results from the present study can be related to the talent identification, selection and development processes in young basketball players. Coaches and scouts could mistake the physical advantages produced by an advanced maturity status as talent, when these advantages are just temporal advantages that will even out in the future (Beunen & Malina, 1988). This bias has an impact specially with Pre-PHV players who are less likely to be selected for the teams and development programs, and who are more likely to drop out of sports because they have less opportunities (Delorme et al., 2010). It is in accordance with Parr et al., (2020), who recently showed that the chronological age and the maturity status are two independent variables that should be treated separately in talent identification and selection processes (Parr et al., 2020). For these reasons, basketball academies should include a systematic evaluation of the players' maturity status and relate it to their physical performance for a better overview of their athlete's promotion opportunities.

This study presents some limitations that should be considered for the interpretation of the results, as well as for future research. First, the coaches and physical trainers of the participants ensured that their players were familiarized with the squat movement and jumping protocols, so a familiarization session was not carried out. The method to estimate maturity status used in this study is the most commonly used but this equation has been recently questioned by the error associated with the estimation in early and late mature players (KozieB & Malina, 2018). The statistically significant differences in anthropometric and physical performance between maturity groups as well as a small standard deviation of these variables in the three maturity groups may indicate that the error in the estimation of the maturity status was partially controlled. Moreover, the criteria used in this study to group the participants according to their PHV was < -0.5 to the Pre-PHV and > 0.5 to the Post-PHV, following the method used in Peña-González et al., (2019). However, other studies included in the discussion used the value of ± 1.0 to group their participants in the Pre-, Mid- and Post-PHV groups.Finally, this study included anthropometric and physical performance variables according to the players' maturity status but not technical and tactical performance or other variables (i.e. time of play) that could be included in the talent identification and selection process, thus this study only shows a part of a holistic selection process according to players' maturity status.

Conclusion

In accordance with the results of the present study, young basketball players (from 12 to 15 years) with an advanced maturity status have anthropometric (weight and height) and strength performance (1RM, SJ and CMJ) advantages. The systematically measure of the maturity status of young basketball players in youth academies and clubs may help to create fairer talent identification and player selection processes. In this way, it is possible to reduce the bias when selecting a player at early ages which usually favours those players who are advanced in their maturation process.

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