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ORIGINAL ARTICLE

# Predictors of maximal short-term power outputs in basketball players 14–16 years

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**Abstract** Relationships between growth, maturation and maximal short-term power outputs were investigated in 94 youth basketball players aged 14–16 years. Data included chronological age (CA), skeletal age (SA), years of training; body dimensions, estimated thigh volume, a running based short-term exercise assessed by the line drill test (LDT), the Bangsbo sprint test (BST) and short-term muscle power outputs with the Wingate anaerobic test (WAnT). Multiple linear regression analyses were used to estimate the effects of CA, skeletal maturity (SA/CA), years of training experience, body size and lower-limb volume on short-term performance in the LDT, BST and WAnT, respectively. Explained variances differed between cycle-ergometry outputs (52–54%) and running test performances (23–46%). The independent effects of predictors were small in the fatigue scores of the WAnT (4%) and the BST (11%). Skeletal maturity, body mass and leg length were primary predictors for all maximal short-term power output measures. Leg length was more relevant as a predictor than stature in the WAnT outputs, while stature and body mass appeared in the model with the running tests as dependent variable. Maximal short-term running abilities were also sensitive to years of training. In summary, skeletal maturation, body size and thigh muscle mass explained moderate to large proportions of the variance on maximal short-term performances of adolescent basketball players. The results highlight the importance of considering maturity status in evaluating the maximal short-term power outputs of adolescent athletes.

**Keywords** Maturation · Growth · Lower-limb volume · Repeated-sprint ability · Wingate test

## Introduction

Movement patterns in basketball rely on short, intense and repeated episodes of activity that require rapid changes in direction (Ben Abdelkrim et al. 2007; McInnes et al. 1995). Although the majority of play time in basketball is devoted to aerobic activities (Ben Abdelkrim et al. 2007; Stone and Kilding 2009), the ability to produce maximal-intensity efforts is crucial given the intermittent nature of the sport (Ben Abdelkrim et al. 2007). Performance in 30-s all-out sprint tests was a significant predictor of playing time in youth (Hoffman et al. 1996) and adult (Sallet et al. 2005) basketball players. However, relatively little is known about short-term power output of male basketball players,

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especially during adolescent years (Drinkwater et al. 2008; Ziv and Lidor 2009).

Maximal short-term power output is defined as the highest mechanical power that can be produced during exercise of up to 30 s duration, with the time period depending on the force or load against which the individual has to work and organization of the acceleration (Van Praagh and Doré 2002). The ability to produce cycling- or running-based short-duration maximal sprints and the capacity to repeat maximal short-term efforts has potentially important physiological implications for many team-sports given the intermittent nature of activities during a competition (Castagna et al. 2007, 2008; Ziv and Lidor 2009).

The issue of maturity-associated variation in maximal short-term power output has not received much attention (Malina et al. 2004). There is also the need to consider de determinants of short-term power output, i.e., muscle quantity, quality, endurance and neuromuscular activation and musculoskeletal architecture, in young athletes in the context of changes associated with growth, maturation and perhaps training (Martin and Malina 1998). Maximal short-term power outputs during adolescence are related to body size (Van Praagh and Doré 2002). A combination of variables related to body size (stature, leg length, body mass, lean body mass, leg volume and total muscle mass) explained up to 92% of variance in peak power assessed by the Wingate anaerobic test (WAnT) in young males (Falk and Bar-Or 1993). Further, estimated lean leg volume was strongly associated with short-term power output in youth (Doré et al. 2000). Available data also suggest that factors of qualitative nature should be considered in determining short-term power output (Martin et al. 2003).

The preceding observations were largely based on males spanning late childhood through adolescence who were not regularly involved in organized competitive sport. Relationships between morphological factors and short-term maximal performance in young athletes engaged in sport-specific training programs merit more detailed consideration. Although elite adolescent athletes within a sport tend to be relatively homogeneous in training history, functional capacity and sport-specific skills, variation in size and maturity status may be considerable during adolescence (Malina 1994, Malina et al. 2004). Adolescent basketball players demonstrate this pattern in addition to potential variation by position within the sport (Coelho e Silva et al. 2010). As such, adolescent basketball players may provide a useful model for evaluating relationships among variation in body size, biological maturation and maximal short-term performances. The purpose of this study was, therefore, to examine the relationships between growth and maturation status, on one hand, and maximal short-term power outputs, on the other hand, in adolescent basketball players 14–16 years of age.

## Methods

The sample included 94 male basketball players, aged 14.0–16.0 years. Players volunteered for the study and were of Portuguese ($n = 88$) and African ($n = 6$) ancestry. All participants were classified as under 16 (U16) by the Federação Portuguesa de Basquetebol (Portuguese Basketball Federation) and were engaged in formal training and competition for at least 2 years. The study was approved by the Scientific Committee of the Faculty of Sport Science and Physical Education of the University of Coimbra and registered in the Portuguese Foundation for Science and Technology [PTDC/DES/70918/2006]. Participants were informed about the nature of the study and were also informed that participation was voluntary and that they could withdraw at any time. Players and their parents or legal guardians provided informed written consent.

Participants were instructed not to eat for at least 3 h and not to drink coffee or beverages containing caffeine for at least 8 h before testing. Assessments were performed at the same hours of the day (6:00 to 7:00 PM for field tests, 3:00 to 6:00 PM for laboratory tests). Subjects wore similar clothing and the same footwear on each testing occasion. All testing procedures were completed within 30 days with at least 48 h between testing sessions.

Chronological age (CA) was calculated to the nearest 0.1 year by subtracting birth date from date of hand–wrist radiographs. The Fels method (Roche et al. 1988) was used to estimate skeletal maturity. This method utilizes specific criteria for each bone and ratios of linear measurements of epiphyseal and metaphyseal widths as observed/measured on a radiograph of the left hand and wrist. Ratings were entered into a program (Felshw 1.0 Software) to derive skeletal age (SA) and standard error of estimate. The assessments were made by a single observer (HMC) trained by an expert (RMM). Twenty-two radiographs (~20%) were assessed independently on two occasions to determine intra-observer reliability. The mean difference between replicate assessments of SA was 0.22 years with a technical error of measurement of 0.10 years. The estimates were similar with other studies with young athletes (Figueiredo et al. 2009; Malina et al. 2000, 2007). SA was divided by CA (SA/CA ratio) to provide an indicator of skeletal maturity at the time of the study. A ratio above one indicated SA was in advance of CA while a ratio below one indicated that SA lagged behind CA.

Years of training was obtained by interview and confirmed in the online database of the Federação Portuguesa de Basquetebol (FPB 2009). Anthropometric dimensions were taken by a single experienced observer following standard procedures (Lohman et al. 1988). Stature and sitting height were measured with a portable stadiometer

(Harpenden model 98.603, Holtain Ltd, Crosswell, UK) to the nearest 0.1 cm. Leg (subischial) length was estimated as stature minus sitting height. Body mass was measured with a portable balance (Seca model 770, Hanover, MD, USA) to the nearest 0.1 kg. Circumferences, measured at the gluteal furrow (the highest possible horizontal circumference), mid thigh (the largest possible mid thigh circumference) and minimum circumference above the knee; and partial lengths, between each circumference location, of the dominant leg were used to estimate total thigh volume (Jones and Pearson 1969). This method has often been used in studies with youth populations (Doré et al. 2000, 2001; Martin et al. 2003, 2004). Based on 18 participants measured twice within 1 week, intra-observer technical errors of measurement were 0.54 cm for stature, 0.74 for sitting height, 0.88 kg for body mass, 0.29–0.74 cm for limb circumferences and 0.16–0.46 cm for limb lengths. The estimates were within the range reported for intra- and inter-observer errors for youth (Malina 1995). A pilot study of the estimation of thigh volume indicated correlations ranging from 0.88 to 0.90 between the anthropometric protocol and dual-energy X-ray absorptiometry in 23 athletes (20.5 ± 1.2-year-old). There was no heteroscedasticity, but the anthropometric method tended to overestimate lower-limb volumes by 6.4–7.2% compared with estimates based on dual-energy X-ray absorptiometry (unpublished results).

After a standardized warm-up, athletes completed the 30-s WAnT on a friction-loaded cycle-ergometer (Monark 824E, Monark AB, Vargerg, Sweden) that was interfaced with a microcomputer and calibrated for pedal speed and applied resistance. Resistance was set at 0.075 kg (0.74 N) body mass. The WAnT began with minimal resistance (basket supported) at 60 rev $\text{min}^{-1}$. On the command "go", the resistance was abruptly applied and the computer was activated simultaneously. Athletes remained seated during the test and were verbally encouraged to give an all-out effort throughout the test. Measurements included peak power (PP, highest mechanical power generated any 5-s period, watts), mean power (MP, average for the 30-s period, watts) and fatigue index (FI, PP minus lowest power divided by PP) (Inbar et al. 1996). Coefficients of variation based on replicate tests in 20 subjects were 2.8, 3.2 and 8.7% for PP, MP and FI, respectively.

Running-based maximal short-term performance in field conditions was measured by line drill test (LDT) and Bangsbo sprint test (BST). In the LDT protocol, subjects ran 140 m as fast as possible in the form of four consecutive shuttle sprints of 5.8, 14.0, 22.2 and 28.0 m on a regular basketball court. Details and reliability of the LDT have been reported (Carvalho et al. 2010). The BST (Bangsbo 1994) included seven consecutive sprints (about 35-m sprint with a slalom) with a recovery period of 25 s between sprints during which the subject ran/walked from the end line back to the starting line. Time was measured using photoelectric cells (Globus Ergo Timer Timing System, Codogné, Italy). Test scores included the fastest sprint (i.e., speed), total time for the seven sprints (total sprint time, seconds) and percentage decrement among sprints. The percent sprint decrement was calculated as follows:

$$(\text{Total sprint time}/\text{ideal sprint time}) \times 100 - 100$$

where ideal sprint time is the best sprint time, usually the first or second sprint, multiplied by seven (Bishop et al. 2001; Glaister et al. 2008). It has been recommended that participants who failed to achieve at least 95% of the time of the best sprint in the first run be excluded in order to avoid pacing during the test (Bishop et al. 2001; Meckel et al. 2009). All players met the inclusion criterion. The protocol is highly reliable (Wragg et al. 2000). Coefficients of variation for the BST based on replicate tests in 15 subjects were 1.5, 1.2 and 22.2% for the best sprint, total sprint time, and percent sprint decrement, respectively.

Descriptive statistics (means and standard deviation) for CA, SA, SA/CA ratio, anthropometric dimensions, thigh volumes and performance variables were calculated for the sample. The assumption of normality was checked by the Kolmogorov–Smirnov test with Lilliefors' significance correction and by visual inspection of normality plots. When assumptions were violated, log-transformations were performed to reduce non-uniformity of error. Multiple linear regression (backward method with the stepping criteria for removal of $P < 0.10$) was used to estimate the relative contributions of CA, skeletal maturity status (SA/CA ratio), years of formal training, stature, body mass, leg length and thigh volume to variation in maximal short-term performance measures. The method reduces collinearity among the independent variables making them more stable predictors.

## Results

Characteristics of the total sample are summarized in Table 1. The sample of basketball players was, on average, advanced in SA compared with CA. Estimates of the relative contribution of CA, skeletal maturity status, years of formal training, stature, body mass, leg length and thigh volume to maximal short-term tests performance are given in Table 2.

The independent variables explained approximately 23% of variance in the LDT and 44 and 46% of the best sprint time and total sprint time in the BST. Advanced skeletal maturity ($P < 0.001$), training experience ($P < 0.05$) and stature ($P < 0.05$) were positive predictors

**Table 1** Descriptive statistics for the total sample ($n = 94$)

| | Mean | Standard deviation | Range |
|---|---|---|---|
| Chronological age (years) | 15.12 | 0.53 | 13.91–15.96 |
| Skeletal age (years) | 16.75 | 1.00 | 13.58–18.00 |
| SA/CA ratio (#) | 1.11 | 0.06 | 0.92–1.21 |
| Years of training (years) | 5.8 | 2.4 | 2–11 |
| Stature (cm) | 177.0 | 10.9 | 150.1–206.9 |
| Mass (kg) | 67.4 | 12.9 | 44.6–127.3 |
| Sitting height (cm) | 93.1 | 5.6 | 75.4–103.2 |
| Leg length (cm) | 88.6 | 6.6 | 61.8–104.7 |
| Thigh volume (L) | 5.11 | 1.14 | 3.04–9.58 |
| Line drill test (s) | 31.75 | 2.09 | 28.43–41.68 |
| BST best sprint time (s) | 6.92 | 0.49 | 6.14–8.25 |
| BST total sprint time (s) | 50.16 | 3.86 | 43.87–61.17 |
| BST percent sprint decrement (%) | 3.5 | 1.9 | 0.8–9.9 |
| WAnT peak power (W) | 603 | 118 | 357–978 |
| WAnT mean power (W) | 517 | 96 | 312–799 |
| WAnT fatigue index (%) | 29.7 | 5.7 | 17.0–43.0 |

**Table 2** Predictors of anaerobic performance estimated $R^2$ in adolescent basketball players

| | $R^2$ | Adjusted $R^2$ | $P$ | Predictors | Standardized $\beta$ coefficient | $P$ |
|---|---|---|---|---|---|---|
| Line drill[a] | 0.28 | 0.23 | <0.001 | Years of training | 0.23* | <0.05 |
| | | | | Maturity | 0.46** | <0.001 |
| | | | | Stature | 0.33* | <0.05 |
| | | | | Body mass | −0.60** | <0.001 |
| BST best sprint time[a] | 0.47 | 0.44 | <0.001 | Age | 0.22* | =0.01 |
| | | | | Maturity | 0.48** | <0.001 |
| | | | | Years of training | 0.24** | <0.01 |
| | | | | Leg length | 0.25 | =0.06 |
| | | | | Stature | 0.33* | <0.05 |
| | | | | Body mass | −0.78** | <0.001 |
| BST total sprint time[a] | 0.49 | 0.46 | <0.001 | Age | 0.24** | <0.01 |
| | | | | Maturity | 0.45** | <0.001 |
| | | | | Years of training | 0.24** | <0.01 |
| | | | | Leg length | 0.34* | =0.01 |
| | | | | Stature | 0.30* | =0.05 |
| | | | | Body mass | −0.79** | <0.001 |
| BST percent sprint decrement[a] | 0.15 | 0.11 | <0.01 | Age | 0.18 | =0.09 |
| | | | | Leg length | 0.39** | =0.01 |
| | | | | Thigh volume | −0.23* | <0.05 |
| WAnT peak power | 0.53 | 0.52 | <0.001 | Maturity | 0.20* | <0.05 |
| | | | | Leg length | 0.23* | =0.01 |
| | | | | Body mass | 0.45** | <0.001 |
| WAnT mean power | 0.56 | 0.54 | <0.001 | Maturity | 0.23** | <0.01 |
| | | | | Leg length | 0.25** | <0.01 |
| | | | | Body mass | 0.43** | <0.001 |
| WAnT fatigue index | 0.05 | 0.04 | <0.05 | Maturity | −0.21* | <0.05 |

[a] Signs are reversed since a lower time on the running tests indicates a better performance

** $P < 0.01$, * $P < 0.05$

while body mass ($P < 0.001$) had a negative influence on LDT performance. Predictors were the same for the two components of BST: CA, advanced skeletal maturity status, years of training, leg length and height had a positive influence on sprint performance, while body mass had a negative influence. In contrast, only 11% of variance in the percentage sprint decrement was explained. CA, leg length and thigh volume were significant predictors of percentage sprint decrement.

The independent variables explained 52 and 54% of the variation in peak and mean power, respectively. Advanced skeletal maturity, leg length and body mass were significant predictors of the two cycle-ergometry indicators of maximal short-term performance. On the other hand, only 4% of the variance in the WAnT FI was explained. Delayed skeletal maturity explained a small but significant ($P < 0.05$) portion of the variance in the FI.

## Discussion

The contribution of years of sport-specific training, CA, skeletal maturity status (SA/CA ratio), body size and estimated leg length and thigh volume to concurrent assessments of maximal short-term performance among adolescent basketball players was considered. Advanced skeletal maturity status (SA in advance of CA), estimated leg length and body mass were among significant predictors for four of the seven indicators of short-term high-intensity exercise—best sprint time and total sprint time with the BST as well as peak and MP in the WAnT (Table 2). Advanced skeletal maturity and stature were positively related with LDT. Chronological age, years of training and stature were significant predictors for three of the short-term high-intensity exercise indicators, while estimated thigh volume appeared as a significant predictor for only one variable: percentage of sprint decrement score in the BST. Leg length was more relevant than total stature in the cycle-ergometer power outputs, while stature and body mass were included in the final models that explain variance in the running tests (which required displacement of the body through space).

The growth characteristics of this sample of Portuguese adolescent basketball players were consistent with other reports with heterogeneous samples of young male athletes (Malina 1994, 1998). Variation in body size was considerable (Table 1), but mean statures and body masses exceeded age-specific 75th percentiles of US reference data (Kuczmarski et al. 2000). The current sample of basketball players was, on average, advanced in skeletal maturity expressed as the ratio of SA and CA (Table 1), although inter-individual variation was considerable. The data were consistent with observations on adolescent basketball players based on assessment of pubic hair (Coelho e Silva et al. 2010). The literature about skeletal maturation of youth basketball players is limited. However, the presence of a significant number of players advanced in skeletal maturation among 14- to 15-year-old players in the present study may reflect selective criteria of the sport (selection or exclusion) in developmental programs (Malina 1994), as already noted in basketball (Drinkwater et al. 2008) and soccer (Malina et al. 2000).

The independent variables in the regression model explained 52 and 54% of variance for peak and MP from the WAnT, respectively, emphasizing the importance of body size and muscle mass (quantitative factors) to variance in maximal power in the 30-s cycle-ergometer test. However, the explained variances in the present study were lower than previously reported for the WAnT (Armstrong et al. 2000; Falgairette et al. 1991; Falk and Bar-Or 1993; Martin and Malina 1998; Mercier et al. 1992) or force–velocity test (Doré et al. 2000). These studies, however, largely considered children and adolescents not training for sport; they had, on average, statures and body masses comparable to age-specific reference medians. The results would seem to suggest, therefore, that other factors (i.e., training, genotype) may interact in the expression of short-term power outputs in young athletes, specifically adolescent basketball players. The metabolic profile of WAnT is highly anaerobic (Beneke et al. 2002; Micklewright et al. 2006); it has been demonstrated that energy is supplied mostly by glycolysis (~50%) and phosphorylcreatine (PCr) breakdown (~30%) with a minor aerobic component (~20%) (Beneke et al. 2002). However, neither the availability of anaerobic energy nor the rate of anaerobic energy release seems to limit performance during the WAnT, indicating that the rate of ATP utilization may be the performance-limiting factor during the 30-s all-out cycling performance (Calbet et al. 2003). Short-term maximum intensity performance, absolute and relative to body mass, is lower in children than adolescents and adults. It has been suggested that limitations of glycolysis, PCr breakdown and oxidative re-phosphorylisation confine short-term maximum performances throughout pubertal development (Beneke et al. 2007).

The limitations of ratio standards (e.g., $\mathrm{W\ kg^{-1}}$ body mass, $\mathrm{W\ L^{-1}}$ lean leg volume) to remove potentially spurious effects associated with body size have been noted for some time (Tanner 1949). Body mass has been the most used size variable when modeling power outputs, but it has been argued that other dimensions can serve as alternatives when using allometric scaling to compare individuals (Nevill et al. 2005; Tolfrey et al. 2006; Vanderburgh and Katch 1996). The results of the backward regression analysis (Table 2) indicate that body mass, leg length and skeletal maturity status are the most relevant variables to partition the effects of body dimensions on cycling power outputs among adolescent basketball players.

There is a lack of valid, reliable and standardized methods of assessing maximal short-term power outputs in children and adolescents (Van Praagh and Doré 2002). The WAnT has been used extensively and in a variety of settings in children and adolescents and was highly reliable and sensitive (Bar-Or 1987). Meanwhile, the specificity of the WAnT for athletes in non-cycling sports has not been yet established. In an effort to more closely match short-term maximal-intensity efforts related to the demands of basketball performance, the experimental approach included a basketball-specific short-term maximal running protocol. The LDT is considered a valid and reliable measure of all-out exercise with changes of direction during approximately 30 s in 14- to 16-year-old basketball players and showed a moderate association with WAnT (Carvalho et al. 2010; Hoffman et al. 2000). This suggests that the running field protocol may measure, to some extent, the same anaerobic properties as the all-out 30-s cycling test. In fact, it has been reported that the 30-s maximal effort shuttle run was a strenuous effort for 10 to 14-year-old boys and girls; no differences were observed in peak blood lactate after the shuttle run protocol and WAnT (Falgairette et al. 1994; Van Praagh et al. 1990). The results of the regression analysis indicate that maximal short-term exercise with changes of direction with an approximate duration of 30 s was related to training experience, skeletal maturity status, stature and body mass; however, only a moderate portion of variance is explained by the independent variables (23%). Performance in this basketball-specific test may be limited largely by the rate of ATP utilization, given the cost of generating force or alterations in the storage and recoil of elastic energy imposed by 180° directional changes that require deceleration and acceleration.

Several sport-specific protocols have been proposed for the evaluation of maximal-intensity performance, in particular dealing with repeated-sprint ability, for team sports such as basketball (Impellizzeri et al. 2008; Spencer et al. 2006; Wragg et al. 2000). Considering the movement patterns and intermittent nature of basketball, the assessment of the ability to perform maximal short-sprints repeatedly has logical validity and may be amenable to specific physiological interpretation. Anaerobic ATP production during a single short-duration sprinting (<10 s) is provided by PCr degradation and anaerobic glycolysis (Dawson et al. 1997), but the relative contribution of anaerobic glycogenolysis to performance in subsequent sprints throughout the test is reduced, which is partially explained by an increase in aerobic metabolism (Spencer et al. 2005). However, metabolic profiles of repeated-sprint ability tests are strongly dependent of sprint and recovery duration (Balsom et al. 1992a, b). Sport-specific training adaptations may also contribute to the physiological responses to repeated-sprint ability. It has been recently shown that performance of 10 sprints of 15 m with 30 s of recovery was independent of maximal oxygen consumption in 16 to 17-year-old basketball players (Castagna et al. 2007).

The regression models explained 44 and 46% of variance for best sprint time and total sprint time in the BST, respectively, in the present study of adolescent basketball players. The positive standardized coefficients of skeletal maturity status and stature and negative coefficient of body mass suggested that players who were advanced in maturity and were taller with less body mass attained better performances in the repeated-sprints test. It has been suggested that repeated-sprint ability improves during maturation of highly trained youth football players (Mujika et al. 2009). However, analyses of the effects of age on repeated-sprint ability controlling for maturity status are lacking. Years of training contributed positively to performance in repeated maximal short-term efforts, suggesting that intermittent maximal performances may be sensible to the accumulation of basketball-specific training stimulus. Of interest, older CA was significant predictor in only the fastest sprint and total sprint times in the BST.

The decline in performance from the best to worst, either in a continuous period of maximal effort or a repeated-sprint test, has been commonly labeled as a FI, although the usefulness of fatigue scores has been questioned (Oliver 2009; Spencer et al. 2006). Indices of fatigue on both the cycle-ergometer and repeated-sprint tests have moderate levels reliability (Bar-Or 1987; Glaister et al. 2007, 2008). Practical interpretation of fatigue scores is also problematic (Oliver 2009). Only small portions of variance in fatigue scores based on both the WAnT (4%) and BST (11%) were explained by the independent variables. The results add to concerns expressed about the utility of such scores.

Skeletal maturation probably influences maximal short-term performance through associated variation in somatic features including size per se and muscle mass and composition (Beunen and Malina 1996). Skeletal maturation, however, is not necessarily related to neuromuscular maturation. Nevertheless, boys show clearly defined adolescent spurts in an agility shuttle run, speed of plate tapping and vertical jump which may perhaps suggest neuromuscular maturation during adolescence (Beunen and Malina 1988). There are also adolescent changes in the cerebral cortex and neural pathways associated with motor function (Malina et al. 2004) which may influence neuromuscular characteristics and performance at these ages.

Potentially confounding factors in explaining the moderate to large relationship of maximal short-term outputs with training experience, growth characteristics, body size and lower-body morphology in adolescent basketball players include maturity-related variation in short-term muscle power outputs and sprinting ability, the non-linear improvement in anaerobic energy supply during the adolescent growth spurt, the trainability of muscle power during adolescence and the established relationship between body size and power. Given these considerations, is it problematic to extrapolate results from adolescent to adult athletes (Pearson et al. 2006).

In summary, using the same predictors, concurrent assessments of maximal short-term performance were explained by different models. Biological maturation entered almost all outputs derived from the three protocols with the exception of the decrement score in repeated-sprints. Consequently, future research on maximal short-term performance in adolescent athletes should consider variation related to maturation whether the protocol requires displacement of the body or cycling. Years of training experience was also a significant predictor of the running tests and failed to enter in models that explained peak and MP from the WAnT suggesting, perhaps, that 140-m shuttle run and sprints may be specific to basketball. Nevertheless, care should be exercised when interpreting or comparing the results of this study given the narrow range of variation in CA and skeletal maturity status, as well as the over-representation of subjects with extreme values for body size compared with the reference.

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**Conflict of interest** The authors declare that they have no conflict of interest.

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