David Vs. Goliath: Playing Against Maturity Matched or Un-Matched Opposition Results in Distinct Physical Performance and Spatial Exploration Behavior for Pre-Peak Height Velocity Basketball Athletes

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Abstract
This paper seeks to examine the impact of maturity matching upon physical performance and spatial exploration behaviour for pre-PHV basketball players. For this purpose, thirty-two under-14 to 16 basketball players are assigned to different teams according to maturity status (Pre-, Mid-, and Post-Peak Height Velocity [PHV]), and instructed to participate in basketball matches against matched (same maturity status), and un-matched (different maturity status) opposition. Maturity status is estimated considering the percentage of predicted adult height. Workload data has been collected via WIMU PRO Local Positioning System. Heart rate is recorded with individual HR monitors. Only data from pre-PHV players has been considered for further analysis. The Pre-PHV players cover greater distances when competing against post-PHV players than against matched opposition ($p < 0.05$, *large*) and Mid-PHV ($p < 0.01$, *very large*) teams. It bears to note that they perform more accelerations ($p < 0.05$, *large*) and decelerations ($p < 0.05$, *very large*) when competing against matched opposition than against the Mid-PHV teams. Furthermore, the Pre-PHV players present higher mean values for high-intensity accelerations (> 2 $m \cdot s^{-2}$; $p < 0.01$, *very large*), average speed ($p < 0.05$, *very large*), body impacts (> 5g; $p < 0.05$, *large*), and Player Load ($p < 0.01$, *very large*) when competing against post-PHV than against Mid-PHV players. It is also found that the pre-PHV explore more space (*large* effect) when competing in maturity matched games than when competing against un-matched opposition teams. Pre-PHV athletes seem to benefit from playing in maturity-matched situations, to reduce the physicality of the game and to have an optimized perception of spatial-temporal information.
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Introduction

Biological maturation refers to the process of progress toward the adult or mature state and is defined in terms of status, timing, and tempo (Malina et al., 2019). Maturational status refers to the stage of maturation that an individual has attained (e.g., pre-pubertal, pubertal, post-pubertal); whereas tempo refers to the rate at which maturation progresses (Malina et al., 2019). In contrast, the timing of maturity refers to the age at which specific maturational events (e.g., puberty, menarche, peak height velocity) occur. Children of the same chronological age can demonstrate marked variance in the timing of maturation with some individuals maturing well in advance or delay of their same age peers (Malina et al., 2019).

The timing of maturation has been shown to have a significant impact upon the athletic development, performance, and selection of young athletes (Cumming, Lloyd, Oliver, Eisenmann, & Malina, 2017; Malina et al., 2019). Maturity-associated differences in anthropometrical, physical and psychological differences have been documented in young basketball players (Carvalho, Gonçalves, Collins, & Paes, 2018). Though players of advanced maturity status do not demonstrate marked advantages in sport-specific skills, such as dribbling, passing, shooting, and defensive movements (Silva et al., 2010), they do outperform less mature players in tests of speed, jump, agility, aerobic fitness, and throwing level. These advantages are, however, likely to be transient in nature as maturity-associated

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differences in both size and function have shown to be attenuated, and in some cases reversed, in early adulthood (Ostojic et al., 2014).

Competition grouping strategies in team-sports like basketball, and soccer, have traditionally employed age-based criteria, using a "one-size-fits-all" approach, with limited consideration of individual differences in biological maturity. Bio-banding is an alternative athlete grouping strategy that proposes to help counter some of the challenges presented by individual differences in growth and maturation (Bradley et al., 2019; Cumming et al., 2018; Cumming et al., 2017; Malina et al., 2019). In its simplest sense, bio-banding is described as the practice of grouping athletes relative to attributes associated with the processes of maturation (i.e., maturity matching), rather than age (Cumming et al., 2017; Malina et al., 2019). As a strategy, bio-banding seeks to attenuate maturity-associated differences in size and function, encouraging players to emphasis and use their technical, tactical, and psychological attributes (Cumming et al., 2018; Johnson et al., 2020). As a strategy, bio-banding can exist alongside age group competition as part of a diverse and multifaceted games programme.

Research investigating the practice of bio-banding and its potential benefits is largely limited to soccer-playing youth (Abbott, Williams, Brickley, & Smeeton, 2019; Bradley et al., 2019; Cumming et al., 2018). To date, the results of these studies suggest that bio-banding strategies benefit both early and late maturing players and can result in changes to the physical and technical demands of the game (Bradley et al., 2019; Cumming et al., 2018). More recently, Abbott and colleagues (Abbott et al., 2019) investigate the effect of bio-bending over chronological competition upon physical and technical performance in young soccer athletes (85–90% of predicted adult stature). Results shows that bio-banded competition changes the technical demand placed upon athletes compared to the chronological competition, but no significant differences in physical performance are identified between competition formats (Abbott et al., 2019). In youth sports, bio-banding has most often been studied in football, but little is known about the effects and consequences of bio-banding in the context of young basketball players.

J Arede, Cumming, and Leite (2019) have been the first to examine differences in external and internal load between traditional (i.e., chronological age) and bio-banded competitions in youth basketball. The results confirm that the players cover more distance during traditional competition over bio-banding (J Arede et al., 2019). Also, a significantly lower number of body impacts (> 5g) and Player Load (J Arede et al., 2019) are observed in the bio-banded competition (J Arede et al., 2019). Nevertheless, further research is needed to extrapolate which variables, including external, and internal load, and individual exploration behaviour, are interchangeable in the bio-banding approach. This research study aims to analyse the effect of playing against biological matched and un-matched opposition, on physical performance and spatial exploration behaviour of young basketball players, in pre-PHV athletes.

Methods

Participants

Thirty under-14 to under-16 national level junior basketball players (age = 13.45±1.22 years; height = 164.52±11.85 cm; body mass = 55.90±12.84 kg; percentage of their predicted adult height [% PAH] = 90.75±5.40%) are recruited from a Portuguese Basketball Academy to participate in this study. Written informed assent and consent is obtained from all participants and their parents, respectively, before this investigation. The present study has been approved by the institutional research ethics committee and conforms to the recommendations of the Declaration of Helsinki.

Somatic maturation

Height is recorded using a commercial portable stadiometer (Tanita BF-522W, Japan, nearest 0.1 cm). Body mass has been estimated using the scales (Tanita BF-522W, Japan, nearest 0.1 kg). All measurements are taken following the guidelines outlined by the *International Society for the Advancement of Kinanthropometry* (ISAK) by the same researcher, who holds an ISAK Level 1 accreditation. Players' height, weight, chronological age, and mid-parent height are used to predict the adult height of each player (Khamis & Roche, 1994). The height of the biological parents of each player are self-reported and have been adjusted for over-estimation using the previously established equations (Epstein, Valoski, Kalarchian, & McCurley, 1995). The current height of each player is then expressed as a percentage of their predicted adult height (% PAH), which can then be used as an index of somatic maturation (Roche, Tyleshevski, & Rogers, 1983). Players are grouped into three maturity bands based on the percentage of predicted adult height attained at the time of the tournament (Cumming et al., 2017): <88% (Pre-PHV), 88-95% (Mid-PHV) and >95% (Post-PHV) of predicted adult stature.

Game formats

Subjects are included in one of two teams per maturity band. Participants compete in maturity matched (i.e., bio-banded) and non-matched (i.e., different bio-bands) formats against opposition that has also been grouped in one of the three equivalent maturity bands. Each team competes twice against each maturity band. In total, each participant completes a total of 6 games. Games are played in 5 vs. 5 formats, with 8-min duration, and conform to standard officiating and rule procedures. Matches are played on a full-sized standard basketball court (28 × 15 m), with full-sized baskets (3.05 m), with a size 7-ball. The physical and tactical data has been collected using previously validated WIMU PRO Local Positioning System (*Realtrack Systems, Almeria, Spain*) which integrates multiple sensors (3-axis accelerometer, gyroscope, magnetometer, and barometer) registering at different sample frequencies (Jorge Arede, Ferreira, Esteves, Gonzalo-Skok, & Leite, 2020). The following variables are calculated per minute: (a) distance covered (DC; $m{\cdot}min^{-1}$), (b) accelerations (Acc; $n{\cdot}min^{-1}$) and decelerations (Dec; $n{\cdot}min^{-1}$), (c) Body impacts (BI >5G; $n{\cdot}min^{-1}$), and (d) Player load (PL, a.u./min.), (e) average speed ($km{\cdot}h^{-1}$) are calculated (Jorge Arede et al., 2020). The $> 2\ m{\cdot}s^{-2}$ and $> -2\ m{\cdot}s^{-2}$ is the criteria to detect high-intensity accelerations (HIAcc) and decelerations (HIDec), respectively (Osgnach, Poser, Bernardini, Rinaldo, & Di Prampero, 2010). Body impacts correspond to the number of jumps and impacts that exceed 5G forces, measured with the inertial accelerometer in the z, x, and y axes (McLellan, Lovell, & Gass, 2011). The heart rate (HR) data has been recorded continuously with individual HR monitors (*Garmin, Soft Strap Premium, USA*). The HR peak zones are defined as: zone 1 (50-60%); zone 2 (60–70%); zone 3 (70–80%); zone 4 (80-90%), and zone 5 (90-100%). The Edward's training impulses (TRIMP) is calculated based on the following formula and presented in arbitrary unit (a.u.) (Fox, Stanton, & Scanlan, 2018): TRIMP = (time spent in zone 1 * 1) + (time spent in zone 2 * 2) + (time spent in zone 3 * 3) + (time spent in zone 4 * 4) + (time spent in zone 5 * 5). All data has been analysed using the commercially available software *(WIMU SPRO Software; Realtrack Systems SL*). Spatial exploration index (SEI) is obtained for each player by calculating his mean pitch position, computing the distance from each positioning time-series to the mean position and, finally, computing the mean value from all the obtained distances (Gonçalves et al., 2017).

Statistical analyses

Data are presented as mean ± SD. All data is found to be normally distributed using the Shapiro-Wilk test. The parametric related samples t-test has been used to analyze within-group changes. Effect sizes (ES) of the within-group changes. are evaluated using the Cohen's "*d*". The level of statistical significance is set at $p \leq 0.05$. All statistical analyses have been performed using JASP software (version 0.13*, University of Amsterdam, Netherlands*).

Results

The Pre-PHV players cover greater distances when competing against post-PHV players than against matched opposition ($p < 0.05$, *large*) and Mid-PHV ($p < 0.01$, *very large*) teams (Figure 1). Also, they perform more accelerations ($p < 0.05$, *large*) and decelerations ($p < 0.05$, *very large)* when competing against matched opposition than against the Mid-PHV teams (Figure 1). Furthermore, the Pre-PHV players present higher mean values for HIAcc ($p < 0.01$, *very large*), AS ($p < 0.05$, *very large*), BI ($p < 0.05$, *large*), and PL ($p < 0.01$, *very large*) when competing against post-PHV than against Mid-PHV players (Figure 1). The Pre-PHV obtained higher mean values for SEI (*large* effect) when competing in maturity matched games than when competing against un-matched opposition teams (Figure 1).

Discussion

The purpose of this investigation has been to study the impact of maturity matching upon physical performance and spatial exploration behaviour of young basketball players. Consistent with previous research, the results of the current study suggest that physical, technical, and tactical demands of competitive game vary relative to the maturity status of the opposing team. Further, the results of the current study suggest that the process of maturity matching encourages a style of play that is more conducive to technical and tactical development, and reliant on physical aptitude.

The Pre-PHV players in the current study appear to benefit the most when competing against maturity matched opponents. When paired against maturity matched opponents, Pre-PHV players present higher mean values for individual spatial exploration behaviour (i.e. SEI), engage in longer passing sequences, complete more passes, and have greater displacements in lateral and longitudinal directions (Folgado, Duarte, Fernandes, & Sampaio, 2014) to find a solution to complete the offensive phase. Further, Pre-PHV players are found to cover less distance during maturity matched games; suggesting that they spent less time on deference and/or 'chasing the game'. Collectively, these observations suggest that Pre-PHV players are more involved and have a greater opportunity to explore and utilise court space when matched against opponents of a similar maturational status (Figueira, Gonçalves, Masiulis, & Sampaio, 2018). In addition to optimising challenge and learning opportunities, greater competitive equity affords more opportunity for pre-PHV players to both, use and develop their technical and tactical skill sets, which ultimately benefits the long-term development of these players.

As noted earlier, the pre-PHV athletes in the current study cover greater distances when competing in non-matched games and especially so when competing against post-PHV athletes. The greater distances covered in these games may result from the more marked differences in physical, technical and tactical aptitude, (Lago, Casais, Dominguez, & Sampaio, 2010). Previous research demonstrates that players generally cover greater distance when competing against better quality teams (Lago et al., 2010). This means that players are more likely to spend more time 'chasing the game' when competing against superior opposition. Specifically, in youth basketball, the quality of the teams is strongly dependent on the maturity status of their team members (Torres-Unda et al., 2016). As a rule, the elements of the best teams are significantly more mature, which has a decisive impact on critical aspects of the game such as the number of points scored (Torres-Unda et al., 2013; Torres-Unda et al., 2016). Thus, it seems evident that in the present study, pre-PHV have to run long distances to cope up with the competitive disadvantages induced by physical differences. However, this long-distance exposure can be problematic for athletes whose biological development is not yet complete. In fact, a total distance covered in training and competition significantly predicted overuse injury incidence rates (Bacon & Mauger, 2017). Competitions based on chronological age often involve athletes with different maturity status (Jorge Arede, Ferreira, Gonzalo-Skok, & Leite, 2019; Torres-Unda et al., 2016), which leads to situations like those observed during the course of this study such as higher distance covered (J Arede et al., 2019). Considering that injuries can significantly limit the appropriate development of young athletes (Johnson et al., 2020), practitioners should take this scenario into account and promote competitive scenarios tailored to the practitioners' capabilities, and thus reducing the likelihood of injury (Bradley et al., 2019; Cumming et al., 2018)

Player Load has been frequently used to quantify the external training load in basketball (J Arede et al., 2019; Pino-Ortega et al., 2019). According to the present findings, the pre-PHV athletes show higher values of Player Load and body impacts against post-PHV athletes. This means that the physical disadvantage caused by maturational differences imposes an external load that can affect the performance of less mature athletes. Previous results have shown that the Player Load is constant despite the differences in the quality of the teams and the anthropometric aspects (e.g., height and weight) (Pino-Ortega et al., 2019). However, the data has been collected from athletes whose biological maturation process is already complete and where all differences derived from timing and status are practically attenuated (Ostojic et al., 2014). In fact, the present results and those of previous studies suggest that contexts where there is a maturity un-matching result in higher values of Player Load (J Arede et al., 2019; Pino-Ortega et al., 2019), which seems to be indicative of the fact that this type of settings allows athletes with more advanced status to use the between status-differences (Carvalho et al., 2018; Silva et al., 2010), favouring physicality of the game and thus be able to take advantage on technical-tactical aspects of game. In this regard, Pre-PHV may benefit playing against maturity matched opposition to reduce match physicality, to be less likely to induce contact injuries, but also to promote a higher level of enjoyment, pleasantly; and physical and technical challenge (Bradley et al., 2019)

Limitations for interpreting the data of this study include the relatively small sample size, and future studies should aim to consider the impact of maturity matching on a larger sample (Abbott et al., 2019; Bradley et al., 2019; Cumming et al., 2018). Similarly, it is important to note that each athlete only completes short-duration bio-banded game formats. Further research with a larger sample, longer game durations, and players of different anthropometric attributes (height, body weight, and wingspan) should be conducted before the applicability of the current results can be generalized.

Conclusions

Playing against different maturity status results in different challenges, and changes vis-a-vis environment, which lead to distinct physical demands and individual spatial exploration behaviour, according to the game format (i.e., maturity matched and un-matched). Pre-PHV athletes seem to benefit from playing in maturity-matched situations or similar (e.g., playing against mid-PHV), to reduce the physicality of the game and to have an optimized perception of spatial-temporal information. Thus, the practice of grouping athletes relative to attributes associated with the processes of maturation (e.g., bio-banding) may be especially useful for pre-PHV athletes, who may be more susceptible to maturation bias during chronological-age competition, involving athletes from distinct maturity status (e.g., post-PHV). Finally, our findings can potentially help practitioners to individualize the prescription of training and competitive situations, considering physical and tactical development needs, and consequently encouraging the long-term developmental perspective.

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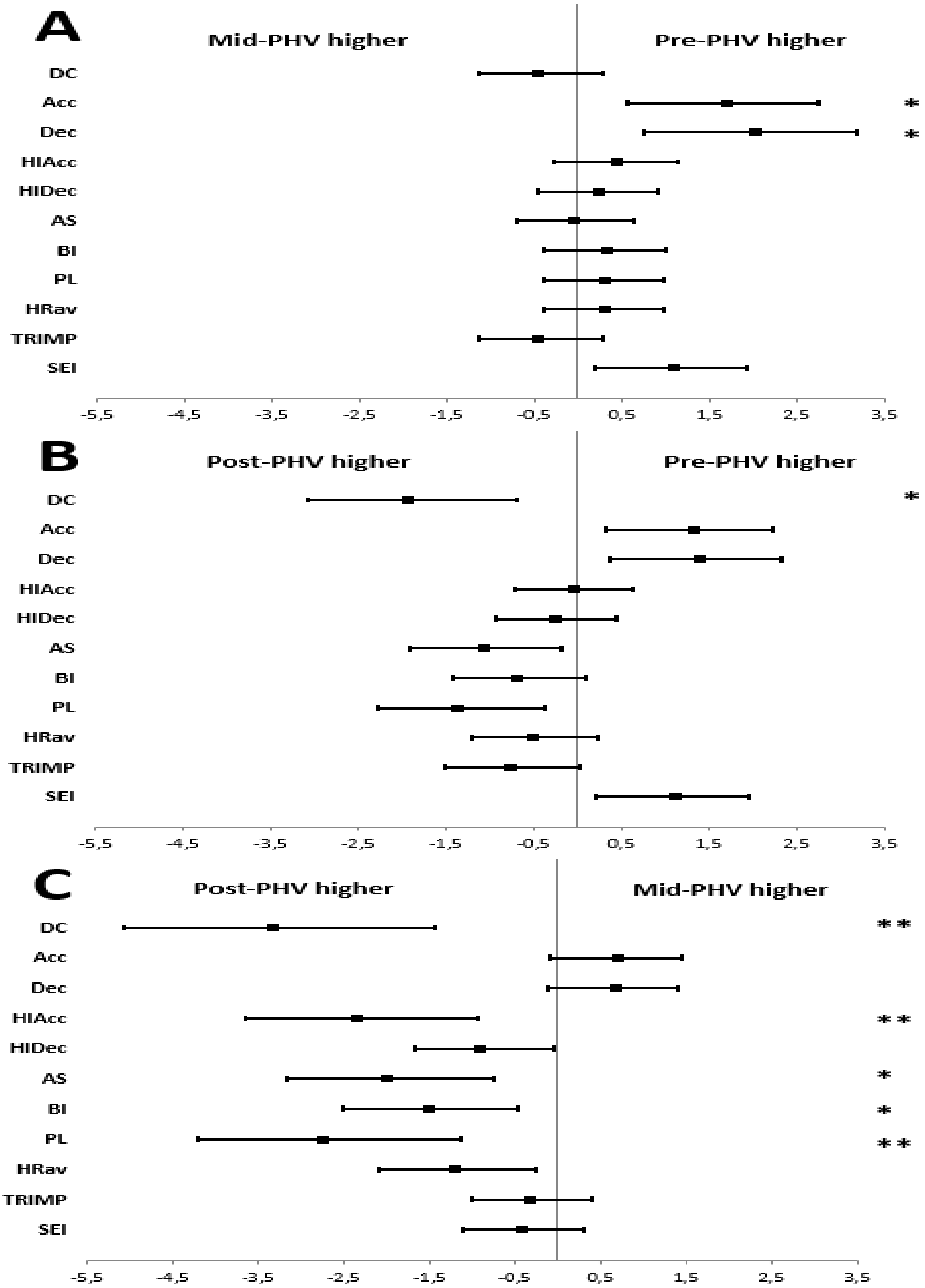

Figure 1. Physical and tactical performance produced by pre-PHV athletes during game formats (Standardized differences at 90% confidence limits). Note: * Significant difference ($p < 0.05$); ** Significant difference ($p < 0.01$). Legend: A = Matched vs. Non-Matched (Mid-PHV); B = Matched vs. Non-Matched (Post-PHV); C = Non-Matched (Mid-PHV) vs. Non-Matched (Post-PHV). Abbreviations: DC = Distance covered; Acc = Accelerations; Dec = Decelerations; HIAcc = High-intensity accelerations; HIDec = High-intensity decelerations; AS = Average Speed; BI = number of Body Impacts; PL = Player Load; HR_{av}= Average heart rate; TRIMP = Training impulse; SEI = Spatial Exploration Index.