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The Importance of Speed and Power in Elite Youth Soccer Depends on Maturation Status

THE IMPORTANCE OF SPEED AND POWER IN ELITE YOUTH SOCCER DEPENDS ON MATURATION STATUS

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ABSTRACT

Maturation status is a confounding factor when identifying talent in elite youth soccer players (ESP). By comparing performance of ESP and control participants (CON) matched for maturation status, the aims of our study were to establish the importance of acceleration, sprint, horizontal-forward jump and vertical jump capabilities for determining elite soccer playing status at different stages of maturation. ESP (n=213; age, 14.0±3.5 yrs) and CON (n=113; age, 15.0±4.4 yrs) were grouped using years from/to predicted peak height velocity (PHV) to determine maturation status (ESP: pre-PHV, n=100; mid-PHV, n=25; post-PHV, n=88; CON: pre-PHV, n=44; mid-PHV, n=15; post-PHV, n=54). Participants performed three reps of: 10 m and 20 m sprint, bilateral vertical countermovement jump (BV CMJ) and bilateral horizontal-forward countermovement jump (BH CMJ). ESP demonstrated faster 10 m ($P<0.001$) and 20 m sprint ($P<0.001$) performance than CON at all stages of maturation. Mid-PHV and post-PHV ESP achieved greater BV CMJ height ($P<0.001$) and BH CMJ distance (ESP vs. CON; mid-PHV: 164.32±12.75 vs. 136.53±21.96 cm; post-PHV: 197.57±17.05 vs. 168.06±18.50 cm; $P<0.001$) compared to CON but there was no difference in BV or BH CMJ between pre-PHV ESP and CON. While 10 and 20 m and sprint performance may be determinants of elite soccer playing status at all stages of maturation, horizontal-forward and vertical jumping capabilities only discriminate ESP from CON participants at mid- and post-PHV. Our data therefore suggests that soccer talent identification protocols should include sprint, but not jump assessments in pre-PHV players.

Key words: horizontal power; acceleration; sprint; maturation status; talent identification.

INTRODUCTION

Identifying predictors of long-term success is an extremely important process for elite soccer clubs competing at the highest level. A holistic multi-disciplinary approach has been recommended for identifying talented soccer players, with predictors of expertise including physiological, psychological, sociological, anthropometric and technical factors (24). From a physiological perspective, a specific physical quality can be indirectly considered important for determining high-level soccer playing status if elite players outperform non-elite players (3). Elite youth soccer players (ESP) have previously been shown have greater acceleration, speed and power capabilities than non-elite players at various youth age groups, including 14-17 yrs (6), U13-U15 (4) and U14 (28). However, significant morphological and neural changes occur during maturation (12) and cross sectional data consistently shows that from the age of ~13 years, boys that are advanced in physical maturity status (sexual and skeletal maturation) are better represented in elite youth soccer teams (13). As the adolescent growth spurt (the rapid increase in the height and weight of an individual during puberty) varies in timing and rate, and is closely associated with improvements in speed and power capabilities in youth soccer players (23), the difference in performance between elite and non-elite youth soccer players may be somewhat confounded by failure to account for differences in maturation status (27).

The maturation status of an individual can be estimated non-invasively from the predicted age at which peak height velocity (PHV) occurs (calculated using prediction equations based on the interaction between stature, sitting height, body mass and chronological age), with individuals subsequently classified as being pre-, mid- or post-PHV (15). The importance of certain speed and power characteristics throughout growth and maturation may depend on the developmental stage of the physiological determinants underpinning these specific traits. Of these specific traits, acceleration and sprint performance have been shown to be independent capabilities in ESP (10). While early acceleration is associated with longer ground contact times [(0.12-0.20 s] and relies on contractile force capabilities (14), sprinting is associated with shorter ground contact times [(0.09-0.12 s] and therefore relies more on the ability of the muscle-tendon unit to perform fast stretch-shortening cycle actions (29). Similarly, vertical and horizontal-forward CMJ capabilities are independent qualities (18) and are controlled by different co-ordination strategies (19), with horizontal-forward CMJs requiring significantly greater biceps femoris electromyographic activity compared to vertical CMJs (5, 18). Considering the biological changes that occur during growth and maturation (12), certain physical assessments may be better predictors of elite soccer playing status at different stages of maturation. However, no study to date has assessed and compared speed and power performance in cohorts of youth ESP and control participants (CON), grouped according to maturation status. Thus, the importance and relevance of acceleration, speed and power qualities at different stages of maturation in elite soccer remains unknown.

Considering the physiological changes that occur during growth and maturation, the talent identification process for any given sport needs to be dynamic and perhaps specific to the stage of biological development. Hence, the aim of the current cross sectional study was to compare acceleration, speed, vertical power and horizontal power capabilities, in pre-, mid- and post-PHV ESP and maturity matched CON, to establish which performance assessments may determine elite soccer playing status at specific stages of maturation.

METHODS

Experimental Approach to the Problem

In order to investigate which specific power and speed capabilities may determine elite soccer playing status, the current study examined BV CMJ, bilateral horizontal-forward CMJ (BH CMJ), 10 m acceleration and 20 m sprint performance in maturity matched pre-, mid- and post-PHV elite youth soccer players and non-elite control participants. Due to the 5 min rest period in between assessments, any fatigue from the previous assessment would have been minimal. However, to minimize potential systematic bias, the testing order for separate performance tests was randomized. Performance tests were completed either on the same day, or where logistical circumstances limited the time available (i.e. school commitments or soccer team training schedules didn't allow all assessments to be completed on the same day), on separate days within a 3-week period (i.e. jump tests on one day and sprint tests on another day). All tests were performed during the in-season period and testing sessions were scheduled > 48 h after competition or a high intensity training session to minimize the influence of prior exercise. Participants performed all tests in soccer shirt/t-shirt, shorts and soccer boots, except for the BV CMJ, for which participants removed their boots.

Subjects

Three-hundred and twenty-six males volunteered to take part in this study, and formed two cohorts: ESP (n = 213) and CON (n = 113). The ESP were members of an English Premier League (EPL) football academy and regularly participated at U9 to U21 level. The CON participants had not previously played soccer at EPL academy or professional level. Participant characteristics are displayed in Table 1. The current study was approved by Liverpool John Moores University Ethics Committee and complied with the Declaration of Helsinki. All subjects were informed of the benefits and risks of the investigation prior to signing an institutionally approved informed consent document to participate in the study.

Parent/guardian consent was also obtained for all subjects that were under the age of 18 yrs (subject age range: 8.1 – 21.7 yrs).

Insert Table 1 here

Procedures

Anthropometric measurements. Standing height was measured with a fixed stadiometer (± 0.1 cm; Holtain Limited, Crosswell, UK), seated height with a fixed sitting height table (± 0.1 cm; Holtain Limited, Crosswell, UK), and body weight with a digital balance scales (± 0.1 kg; ADE Electronic Column Scales, Hamburg, Germany). Leg length was calculated by subtracting the seated height from the standing height. Pubertal timing was estimated according to the estimated biological age of each individual using calculations described by Mirwald et al. (17). The age at which peak linear growth in stature occurs (age at PHV) is an indicator of somatic maturity. The biological maturity age was calculated by subtracting the chronological age at the time of testing from the estimated chronological age at PHV. Participants were split into three maturity groups based on biological age: Pre-PHV (< -1.0 years), Mid-PHV (-0.99 to 0.5 years) and Post-PHV (> 0.51 years) (15, 25).

Warm up protocol. After anthropometric measurements were performed, the participants undertook a standardized 10-minute warm up procedure that consisted of 5 minutes of dynamic movements (e.g. high knees, skips, lunges). After this, CMJ, and sprint performance assessment procedures were demonstrated to the participants, after which, participants practiced each assessment (5 x BH CMJs, 5 x BV CMJs, and 3 x 20 m sprints).

Jump assessments. Participants performed a minimum of 3 trials of the BH CMJ and BV CMJ with approximately 30 seconds of recovery between trials and 5 minutes between jump types. If the third jump measurement (height or distance) was higher than the first or second, the participant performed a fourth trial. The highest or longest jump was selected for analysis. To isolate the lower limbs, and eliminate the contribution of technique and arm swing (8), participants were asked to keep their arms akimbo during all CMJs. Participants were instructed to jump as high, or as far as possible and no specific instructions were given regarding depth of countermovement. Upon landing, participants were required to remain in a position with both feet fixed on the ground, and if they lost balance, the jump was disqualified. The BH CMJ testing was performed on an artificial grass surface. Participants placed both feet behind a line and jumped as far as possible, while landing on two feet. The distance from the line to the player's closest heel was measured with a measuring tape. The BV CMJ assessment was carried out on a hard, flat surface according to previously described methods (21) and using a portable photoelectric cell system (Optojump, Microgate, Bolzano, Italy). This equipment has been shown as both reliable and valid when compared with the force plate for vertical jump assessment (7). It should also be noted that the inter-day test-retest reliability of BV and BH CMJ performance has previously been shown to be acceptable in pre (BV CMJ: CV = 5.8%, ICC = 0.93; BH CMJ: CV = 6.1%, ICC = 0.83), mid- (BV CMJ: CV = 5.4%, ICC = 0.97; BH CMJ: CV = 4.8%, ICC = 0.91) and post- (BV CMJ: CV = 5.1%, ICC = 0.95; BH CMJ: CV = 3.8%, ICC = 0.96) PHV male and female athletic children (16).

Speed assessments. A photocell timing system (Brower Timing System, Salt Lake City, UT, USA) was used to assess sprints to the nearest 0.001 s. Participants were required to perform three maximal sprints in which they were instructed to run 24 m as quickly as possible. The first, second and third timing gates were positioned 1 m, 11 m and 21 m from the start line, respectively. After assuming a split stance crouch position, with their front foot behind the start line, participants were instructed to sprint past the final marker which was situated 3 m from the third timing gate to ensure that participants did not slow down. The time taken for the participants to run between the first and second (10 m), and first and third (20 m) timing gates was recorded using a hand held wireless controller. The best 10 m and 20 m times of the three sprints were recorded and represented acceleration and sprint performance, respectively. Participants received verbal encouragement and were given feedback on performance throughout. Participants performed the speed tests on an artificial grass surface. The inter-day test-retest reliability of 10 m sprint time and maximal linear speed (fastest 10 m split time over 40 m) using timing gates has previously been shown to be acceptable in pre (10 m speed: CV = 2.2%, ICC = 0.48; maximal speed: CV = 1.6%, ICC = 0.90), mid- (10 m speed: CV = 2.2%, ICC = 0.76; maximal speed: CV = 1.4%, ICC = 0.96) and post- (10 m speed: CV = 2.2%, ICC = 0.70; maximal speed: CV = 1.2%, ICC = 0.97) PHV male soccer players (1).

Statistical Analyses

Sample size power calculations were performed using the freely available software: G*Power (Version 3.0). The sample size was associated with a power value of 0.95 (alpha = 0.05).

The mean and standard deviation (s) were calculated for all variables. All data was tested for normality using the Shapiro Wilks normality test. Main and interaction effects between maturation status (Pre-, Mid and Post-PHV) and athlete status (ESP vs. CON) on performance (BH and BV CMJ, 10 m acceleration and 20 m sprint) were analysed using 2-way between factor ANOVAs (between factor 1: maturation status; between factor 2: athlete status). Post-hoc analyses were then performed using paired t-tests with Bonferroni-correction to determine differences in performance between ESP and CON at different stages of maturation. Percent changes in jump and sprint performances were calculated from pre- to mid- to post-PHV. Simple effect size, estimated from the ratio of the mean difference to the pooled standard deviation, was also calculated. Effect size ranges of < 0.20, 0.21-0.60 and

0.61-1.20, 1.21-2.00 and > 2.00 were considered to represent trivial, small, moderate large and very large differences, respectively (9). Statistical analyses were completed using SPSS version 21 (SPSS Inc., Chicago, IL), and the significance level was set at $P < 0.05$.

RESULTS

Anthropometric analyses

There was a main effect of maturation status for height, body mass, leg length and age ($F > 317.569$, $P < 0.001$; Table 1), with post-PHV demonstrating greater height, body mass, leg length and age than mid-PHV ($P < 0.001$), who also demonstrated greater height, body mass, leg length and age than pre-PHV ($P < 0.001$). The results of post-hoc analyses from significant interactions between ESP and CON at different stages of maturation are presented in Table 1. Post-PHV ESP were significantly taller, heavier and had longer limb lengths than CON (Table 1).

10 m Sprint

There was a main effect of maturation status ($F = 92.019$, $P < 0.001$), with post-PHV accelerating faster than mid-PHV ($P < 0.001$), who performed better than pre-PHV ($P < 0.001$; Figure 1). There was also a main effect of athlete status ($F = 18.540$, $P < 0.001$), with ESP able to accelerate quicker than CON (1.877 ± 0.164 vs. 1.918 ± 0.178 s, respectively). There was no interaction between athlete status and maturation status for 10 m sprint performance ($F = 0.770$, $P = 0.464$), demonstrating that ESP performed better than CON at all three stages of maturation. Moderate effect sizes were associated with differences in 10m-sprint performance between ESP and CON in the post-PHV ($d = 0.63$) and mid-PHV ($d =$

0.63) groups. However, only small effect sizes were associated with differences in 10m-sprint performance between ESP and CON in the pre-PHV group (d = 0.48).

Insert Figure 1 about here

20 m Sprint

There was a main effect of maturation status for 20 m sprint performance (F = 124.514, P < 0.001), with post-PHV sprinting faster than mid-PHV (P < 0.001), who sprinted faster than pre-PHV (P < 0.001; Figure 2). There was also a main effect of athlete status (F = 21.395, P < 0.001; Figure 2), with ESP able to sprint faster than CON (3.321 ± 0.344 vs. 3.410 ± 0.365 s, respectively). There was no interaction between player status and PHV status for 20 m sprint performance (F = 0.256, P = 0.774), showing that ESP performed better than CON at all three stages of maturation. Moderate effect sizes were associated with differences in 20m-sprint performance between ESP and CON in the post-PHV (d = 0.78) and mid-PHV (d = 0.99) groups. However, only small effect sizes were associated with differences in 20m-sprint performance between ESP and CON in the pre-PHV group (d = 0.49)

Insert Figure 2 about here

Bilateral Horizontal-forward Countermovement Jump (BH CMJ)

There was a significant main effect of maturation status (F = 214.453, P < 0.001; Figure 3), with post-PHV performing better than mid-PHV (P < 0.001), who performed better than pre-PHV (P < 0.001). There was a main effect of athlete status (F = 71.237, P < 0.001; Figure 3), with ESP performing better than CON (161.7 ± 32.1 vs. 146.5 ± 24.9 cm, respectively). There was also an interaction between athlete status and maturation status (F = 18.337, P <

0.001; Figure 3). ESP jumped further than CON at both mid-PHV (P < 0.001; Figure 3) and post-PHV (P < 0.001; Figure 3), but there was no difference between ESP and CON at pre-PHV (P = 0.273; Figure 3). Large effect sizes were associated with differences in BH CMJ performance between ESP and CON at post-PHV (d = 1.32) and mid-PHV (d = 1.30). However, only small effect sizes were associated with differences in BH CMJ performance between ESP and CON at pre-PHV status (d = 0.21).

Insert Figure 3 about here

Bilateral Vertical CMJ (BV CMJ)

There was a main effect of maturation status (F = 199.399, P < 0.001; Figure 4), with post-PHV performing better than mid-PHV (P < 0.001), who performed better than pre-PHV (P = 0.001). There was also a main effect of athlete status (F = 28.503, P < 0.001; Figure 4), with ESP jumping higher than CON (29.9 ± 9.0 vs. 28.0 ± 7.1 cm, respectively). There was also an interaction between athlete status and maturation status (F = 10.939, P < 0.001; Figure 4), with ESP jumping higher than CON at both mid-PHV (P < 0.001; Figure 4) and post-PHV (P < 0.001; Figure 4) but there was no difference between ESP and CON at pre-PHV (P = 0.880; Figure 4). Moderate effect sizes were associated with differences in BV CMJ performance between ESP and CON at post-PHV (d = 0.86) and mid-PHV (d = 1.05). However, only trivial effect sizes were associated with differences in BV CMJ performance between pre-PHV ESP and CON participants (d = 0.04).

Insert Figure 4 about here

DISCUSSION

The aim of the current study was to investigate whether acceleration, sprint, horizontal-forward CMJ and vertical CMJ capabilities were indicators of elite youth soccer playing status at different stages of maturation. The main findings were that, while ESP outperformed CON in acceleration and sprint tasks at all stages of maturation, they only outperformed CON in BH and BV CMJ tasks at mid-PHV and post-PHV maturation status. More specifically, the difference in BH CMJ performance between ESP and CON participants for both mid-PHV and post-PHV groups was associated with a large effect size, whereas only moderate effect sizes were associated with the difference between ESP and CON in both mid-PHV and post-PHV groups for acceleration, sprint and BV CMJ performance.

When evaluating physical performance tests for soccer talent identification, growth and maturation are considered to be the main confounding factors (22, 27). By comparing ESP and CON according to maturation status, the current study attempted to overcome this limitation. The data in the present study shows that pre-, mid- and post-PHV ESP achieved greater acceleration and sprint performance compared to CON, thus demonstrating that these physiological capabilities may be determinants of elite youth soccer playing status at all stages of maturation. However, the difference in acceleration and sprint performance between pre-PHV ESP and CON participants was associated with only a small effect size, whereas differences in ESP and CON at mid- and post-PHV were associated with a moderate effect size. In EPL academies, the current competitive match-play format progressively increases the number of players and absolute pitch size until U13 age group, where senior football is simulated on a (larger) full size pitch in 11 vs. 11 format. Consequently, a greater pitch area leads to an increase in both sprint frequency and sprint distances achieved during competitive match-play (2). The larger pitch size and increased sprint demands may therefore, explain the greater effect size when comparing acceleration and sprint performance between ESP and

CON at mid-PHV (~14 years of age) vs. pre-PHV maturation status. The mid- and post-PHV ESP may have developed greater acceleration and sprint capabilities from exposure of playing on the larger pitch sizes and hence, performing a greater number of sprint actions during match-play in comparison to the pre-PHV ESP, who play on smaller pitch areas (2). Alternatively, as player drop-out rate (and subsequently new player recruitment rate) has been reported to be high in elite soccer development programmes [between U10-U17 age groups, a total of 635 ESP were retained and 231 ESP dropped out of the programme (4)], it may be possible that as the pitch size and subsequent sprint demands of competitive match-play increase around the mid-PHV period, EPL elite soccer academies aim to recruit players with superior acceleration and sprint qualities in comparison to pre-PHV periods (when pitch sizes are smaller and the sprint demands of match-play are lower). Although it is possible that this difference is due to a combination of these reasons, longitudinal research is required to establish whether the greater effect size difference between acceleration and sprint capabilities in mid- and post-PHV ESP compared to CON were developed, or due to more selective player recruitment strategies as the pitch size becomes larger. While the results of the current study do support the inclusion of acceleration and sprint assessments in soccer physiological talent identification and selection protocols at all stages of maturation, acceleration and sprint capabilities may be less important in determining elite soccer playing status prior to the onset of PHV.

Muscular power is a component of acceleration and sprint performance (26), but horizontal-forward and vertical CMJs assess separate leg power qualities (18) and have previously been shown to have different development patterns during adolescence in elite youth soccer players (23). It was therefore deemed relevant to determine the importance of these independent capabilities at different stages of maturation. The present results showed no difference in BH CMJ or BV CMJ performance between ESP and CON participants in the pre-PHV groups. In contrast, mid-PHV and post-PHV ESP achieved greater BV CMJ and BH CMJ performance than maturation-matched CON. The current data therefore suggest that, from a physiological perspective, vertical and horizontal-forward power performance are determinants of elite soccer playing status during the mid-PHV and post-PHV periods, but cannot discriminate between ESP and CON during the pre-PHV period. As it has been reported that the percentage of muscle mass increased by 0.6% and 29% per year from the age of 7 to 13.5, and 13.5 to 15 yrs, respectively (11), the large increase in muscular power from the beginning of the mid-PHV period (15) could be largely attributed to the increase in muscle volume during growth and its direct relationship with peak power (15, 20). It therefore appears that vertical and horizontal-forward power can only discriminate between ESP and CON during the mid- and post-PHV periods when the individual begins to develop his phenotypic muscle mass profile. However, the significant difference in BH CMJ and BV CMJ between ESP and CON participants at mid-PHV and post-PHV were associated with large (BH CMJ) and moderate (BV CMJ) effect sizes. Hence, it appears that, during the mid-PHV and post-PHV periods, the BH CMJ is able to better discriminate between ESP and CON than the BV CMJ. These specific findings are supported by previous longitudinal research that documented horizontal-forward CMJ capability was the key physical factor at a young age influencing future contract status and playing minutes after reaching professional status (4).

It must be acknowledged that attempting to identify the physical determinants of EPL youth soccer in the current cross sectional study by comparing ESP and CON may have limitations. We cannot discount that this particular cohort of players developed greater physical capabilities as a result of their exposure to an elite soccer development training programme and were therefore, perhaps not initially selected based on a superior physical profile. However, previous longitudinal research showed large variations in the rank scores in speed and power performance measures for ESPs (age: 12 yrs) exposed to the same training programme (players only included if they attended over 90% of training sessions) over a four-year period (ICC values, 10 m sprint time: 0.66; BV CMJ: 0.66) (1). This research suggests that ESP physical development during maturation may in fact, be largely determined by genetic profile rather than the training environment players are exposed to.

In conclusion, the current study provides evidence that the physiological assessments used as part of a holistic approach to talent identification and selection in elite youth soccer need to be dynamic, and specific to maturation status. Acceleration and sprint performance appear to be physiological determinants of elite soccer playing status at all stages of maturation but more so at mid- and post-PHV. Vertical and horizontal-forward power, on the other hand, only appear to be important physiological determinants of elite soccer playing status during mid- and post-PHV periods, thus suggesting that jump assessments may be unnecessary for pre-PHV talent identification protocols. Horizontal jump performance showed the greatest practical difference between ESP and CON, and should therefore be prioritized in talent selection protocols for mid- and post-PHV ESP. As speed does not seem to be the main physiological determinant of pre-PHV elite soccer playing status, future research should investigate additional physiological factors that may be determinants of pre-PHV elite youth soccer playing status, such as co-ordination skills. Moreover, it is recommended that longitudinal research is conducted to determine whether ESP are selected based on inherited superior speed and power capabilities, or whether these traits are developed from long-term exposure to an elite soccer training program.

PRACTICAL APPLICATIONS

When identifying and selecting elite soccer talent relative to physiological outcome measures from mid-PHV and post-PHV maturation groups, the current study suggests that while elite soccer clubs should employ acceleration, sprint and BV CMJ assessments, the BH CMJ should be prioritized amongst these performance tests. In contrast, when identifying pre-PHV soccer talent we only recommend the inclusion of acceleration and sprint assessments, but also recognize that practitioners should be aware that additional physiological outcome measures not assessed in our study may also predict pre-PHV elite soccer playing status.

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Figure Legends

Figure 1. 10 m sprint performance in pre-PHV (ESP: n = 97; CON: n = 26), mid-PHV (ESP: n = 24; CON: n = 14) and post-PHV (ESP: n = 70; CON: n = 32) maturation groups. * Significant main effect between elite players and controls ($P < 0.001$). ESP, elite soccer players; CON, control participants; PHV, peak height velocity.

Figure 2. 20 m sprint performance in pre-PHV (ESP: n = 97; CON: n = 26), mid-PHV (ESP: n = 24; CON: n = 14) and post-PHV (ESP: n = 69; CON: n = 32) maturation groups. * Significant main effect between elite players and controls ($P < 0.001$). ESP, elite soccer players; CON, control participants; PHV, peak height velocity.

Figure 3. Bilateral horizontal-forward countermovement jump (BH CMJ) performance in pre-PHV (ESP: n = 99; CON: n = 44), mid-PHV (ESP: n = 25; CON: n = 15) and post-PHV (ESP: n = 68; CON: n = 34) maturation groups. * Significant difference between ESP and CON ($P < 0.001$). ESP, elite soccer players; CON, control participants; PHV, peak height velocity.

Figure 4. Bilateral vertical countermovement jump (BV CMJ) performance in pre-PHV (ESP: n = 99; CON: n = 38), mid-PHV (ESP: n = 25; CON: n = 14) and post-PHV (ESP: n = 85; CON: n = 54) maturation groups. * Significant difference between ESP and CON ($P < 0.001$). ESP, elite soccer players; CON, control participants; PHV, peak height velocity.

Fig. 1

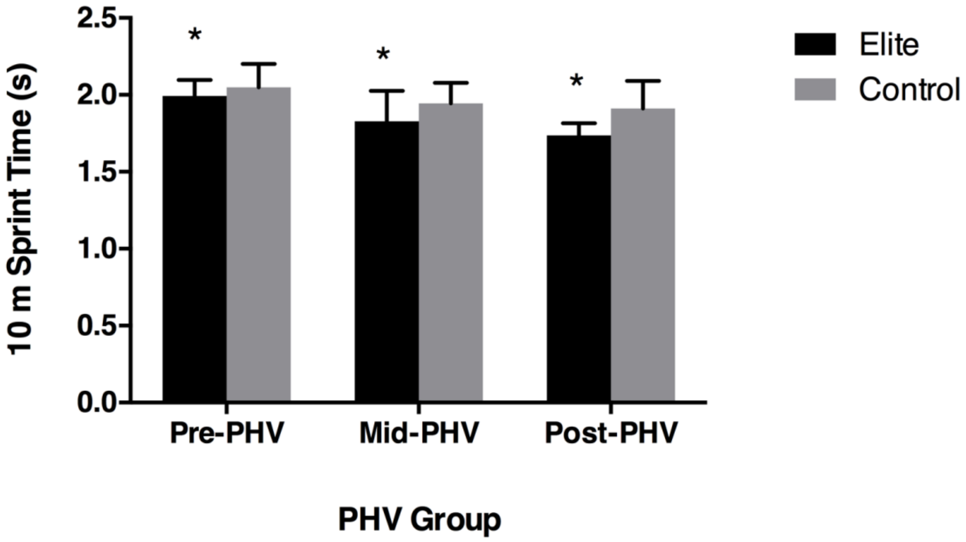

2.5
2.0
1.5
1.0
0.5
0.0
10 m Sprint Time (s)
*
*
*
Elite
Control
Pre-PHV
Mid-PHV
Post-PHV
PHV Group

Fig. 2

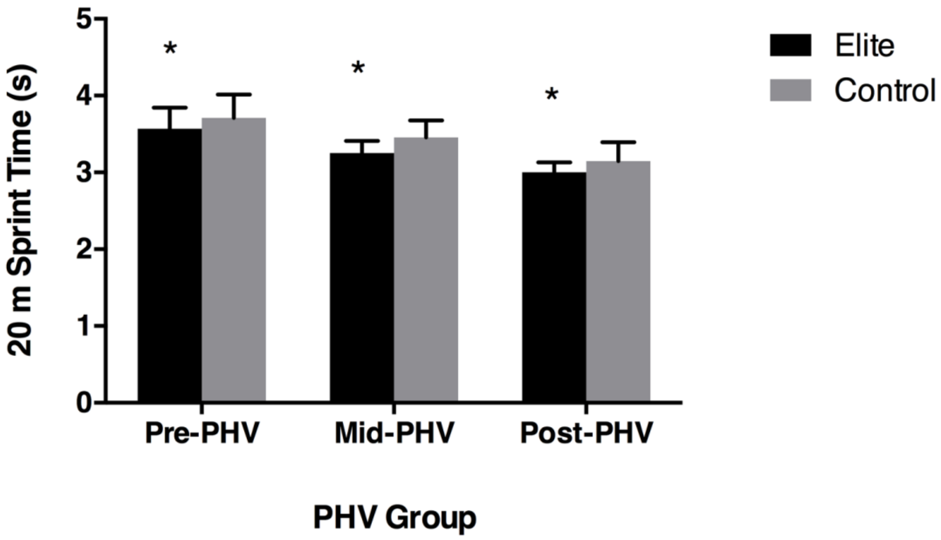

5
4
3
2
1
0
20 m Sprint Time (s)
*
*
*
Elite
Control
Pre-PHV
Mid-PHV
Post-PHV
PHV Group

Fig. 3

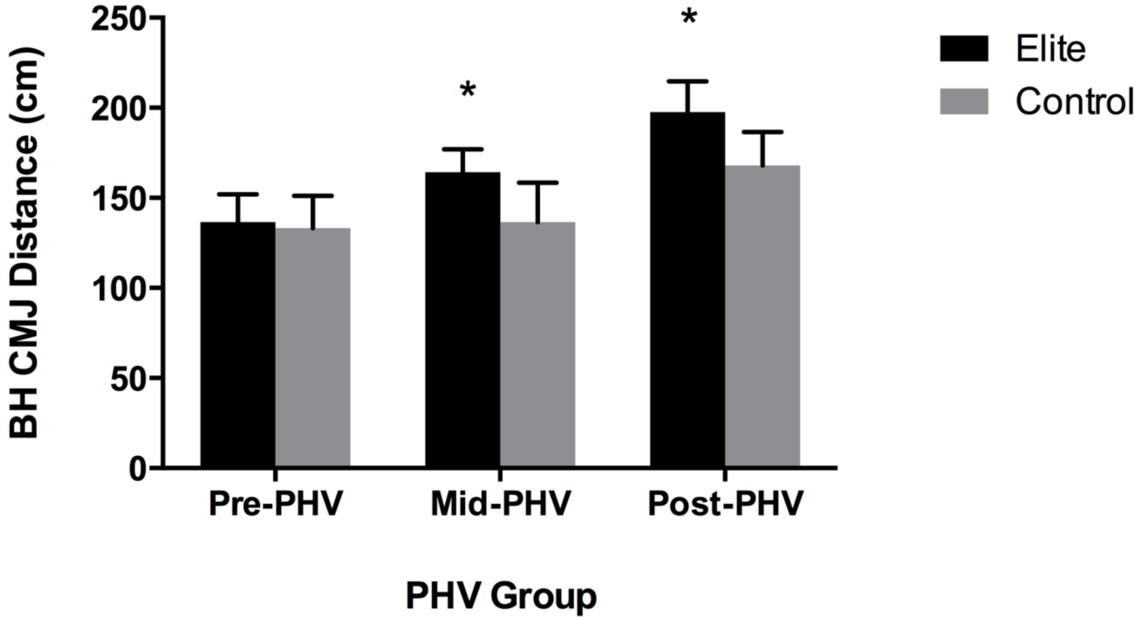
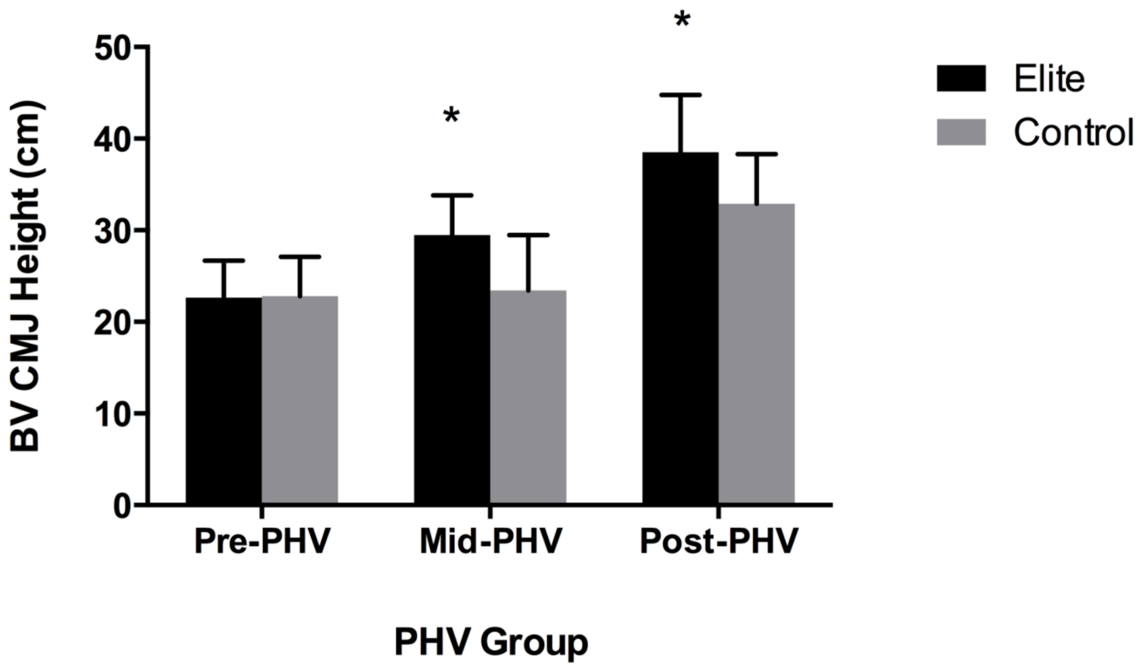

250
200
150
100
50
0
BH CMJ Distance (cm)
*
*
Elite
Control
Pre-PHV
Mid-PHV
Post-PHV
PHV Group

Fig. 4


50
40
30
20
10
0
BV CMJ Height (cm)
*
*
Elite
Control
Pre-PHV
Mid-PHV
Post-PHV
PHV Group

Tables

Table 1. Participant characteristics in pre-PHV (ESP: n = 99; CON: n = 44) mid-PHV, (ESP: n = 25, CON: n = 15) and post-PHV (ESP: n = 87, CON: n = 54) maturation groups.

	Age (years)		Height (m)		Leg length (m)		Body mass (kg)	
	ESP	**CON**	**ESP**	**CON**	**ESP**	**CON**	**ESP**	**CON**
Pre-PHV	10.9 ± 1.3	11.2 ± 1.3	144.1 ± 7.6	145.1 ± 7.6	68.2 ± 5.3	69.5 ± 5.1	35.9 ± 5.2	37.5 ± 5.8
Mid-PHV	13.8 ± 0.8	13.6 ± 0.6	163.3 ± 5.8	162.6 ± 5.2	79.8 ± 3.9	79.6 ± 3.9	48.3 ± 5.8	51.2 ± 8.1
Post-PHV	17.5 ± 2.1	18.6 ± 3.7	180.0 ± 6.5*	175.0 ± 6.2	85.6 ± 4.5*	83.0 ± 4.4	72.0 ± 9.6*	69.3 ± 8.9

Key: ESP, elite youth soccer player group; CON, control group; PHV, peak height velocity.

* ESP significantly greater than maturation-matched CON ($P \leq 0.02$).