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

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**Running head:** Importance of power in elite youth soccer

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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.

## 1 INTRODUCTION

2 Identifying predictors of long-term success is an extremely important process for elite soccer  
3 clubs competing at the highest level. A holistic multi-disciplinary approach has been  
4 recommended for identifying talented soccer players, with predictors of expertise including  
5 physiological, psychological, sociological, anthropometric and technical factors (24). From a  
6 physiological perspective, a specific physical quality can be indirectly considered important  
7 for determining high-level soccer playing status if elite players outperform non-elite players  
8 (3). Elite youth soccer players (ESP) have previously been shown have greater acceleration,  
9 speed and power capabilities than non-elite players at various youth age groups, including  
10 14-17 yrs (6), U13-U15 (4) and U14 (28). However, significant morphological and neural  
11 changes occur during maturation (12) and cross sectional data consistently shows that from  
12 the age of ~13 years, boys that are advanced in physical maturity status (sexual and skeletal  
13 maturation) are better represented in elite youth soccer teams (13). As the adolescent growth  
14 spurt (the rapid increase in the height and weight of an individual during puberty) varies in  
15 timing and rate, and is closely associated with improvements in speed and power capabilities  
16 in youth soccer players (23), the difference in performance between elite and non-elite youth  
17 soccer players may be somewhat confounded by failure to account for differences in  
18 maturation status (27).

19 The maturation status of an individual can be estimated non-invasively from the  
20 predicted age at which peak height velocity (PHV) occurs (calculated using prediction  
21 equations based on the interaction between stature, sitting height, body mass and  
22 chronological age), with individuals subsequently classified as being pre-, mid- or post-PHV  
23 (15). The importance of certain speed and power characteristics throughout growth and  
24 maturation may depend on the developmental stage of the physiological determinants  
25 underpinning these specific traits. Of these specific traits, acceleration and sprint performance

26 have been shown to be independent capabilities in ESP (10). While early acceleration is  
27 associated with longer ground contact times [(0.12-0.20 s ) and relies on contractile force  
28 capabilities (14), sprinting is associated with shorter ground contact times [(0.09-0.12 s ) and  
29 therefore relies more on the ability of the muscle-tendon unit to perform fast stretch-  
30 shortening cycle actions (29). Similarly, vertical and horizontal-forward CMJ capabilities are  
31 independent qualities (18) and are controlled by different co-ordination strategies (19), with  
32 horizontal-forward CMJs requiring significantly greater biceps femoris electromyographic  
33 activity compared to vertical CMJs (5, 18). Considering the biological changes that occur  
34 during growth and maturation (12), certain physical assessments may be better predictors of  
35 elite soccer playing status at different stages of maturation. However, no study to date has  
36 assessed and compared speed and power performance in cohorts of youth ESP and control  
37 participants (CON), grouped according to maturation status. Thus, the importance and  
38 relevance of acceleration, speed and power qualities at different stages of maturation in elite  
39 soccer remains unknown.

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

46

## 47 **METHODS**

48

## 49 **Experimental Approach to the Problem**

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

64

## 65 **Subjects**

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

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

76

77 Insert Table 1 here

78

## 79 **Procedures**

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

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

96 Jump assessments. Participants performed a minimum of 3 trials of the BH CMJ and  
97 BV CMJ with approximately 30 seconds of recovery between trials and 5 minutes between  
98 jump types. If the third jump measurement (height or distance) was higher than the first or

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

117         Speed assessments. A photocell timing system (Brower Timing System, Salt Lake  
118 City, UT, USA) was used to assess sprints to the nearest 0.001 s. Participants were required  
119 to perform three maximal sprints in which they were instructed to run 24 m as quickly as  
120 possible. The first, second and third timing gates were positioned 1 m, 11 m and 21 m from  
121 the start line, respectively. After assuming a split stance crouch position, with their front foot  
122 behind the start line, participants were instructed to sprint past the final marker which was  
123 situated 3 m from the third timing gate to ensure that participants did not slow down. The



124 time taken for the participants to run between the first and second (10 m), and first and third  
125 (20 m) timing gates was recorded using a hand held wireless controller. The best 10 m and 20  
126 m times of the three sprints were recorded and represented acceleration and sprint  
127 performance, respectively. Participants received verbal encouragement and were given  
128 feedback on performance throughout. Participants performed the speed tests on an artificial  
129 grass surface. The inter-day test-retest reliability of 10 m sprint time and maximal linear  
130 speed (fastest 10 m split time over 40 m) using timing gates has previously been shown to be  
131 acceptable in pre (10 m speed: CV = 2.2%, ICC = 0.48; maximal speed: CV = 1.6%, ICC =  
132 0.90), mid- (10 m speed: CV = 2.2%, ICC = 0.76; maximal speed: CV = 1.4%, ICC = 0.96)  
133 and post- (10 m speed: CV = 2.2%, ICC = 0.70; maximal speed: CV = 1.2%, ICC = 0.97)  
134 PHV male soccer players (1).

135

### 136 **Statistical Analyses**

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

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

149 0.61-1.20, 1.21-2.00 and > 2.00 were considered to represent trivial, small, moderate large  
150 and very large differences, respectively (9). Statistical analyses were completed using SPSS  
151 version 21 (SPSS Inc., Chicago, IL), and the significance level was set at  $P < 0.05$ .

152

## 153 **RESULTS**

154

### 155 **Anthropometric analyses**

156 There was a main effect of maturation status for height, body mass, leg length and age ( $F >$   
157  $317.569$ ,  $P < 0.001$ ; Table 1), with post-PHV demonstrating greater height, body mass, leg  
158 length and age than mid-PHV ( $P < 0.001$ ), who also demonstrated greater height, body mass,  
159 leg length and age than pre-PHV ( $P < 0.001$ ). The results of post-hoc analyses from  
160 significant interactions between ESP and CON at different stages of maturation are presented  
161 in Table 1. Post-PHV ESP were significantly taller, heavier and had longer limb lengths than  
162 CON (Table 1).

163

### 164 **10 m Sprint**

165 There was a main effect of maturation status ( $F = 92.019$ ,  $P < 0.001$ ), with post-PHV  
166 accelerating faster than mid-PHV ( $P < 0.001$ ), who performed better than pre-PHV ( $P <$   
167  $0.001$ ; Figure 1). There was also a main effect of athlete status ( $F = 18.540$ ,  $P < 0.001$ ), with  
168 ESP able to accelerate quicker than CON ( $1.877 \pm 0.164$  vs.  $1.918 \pm 0.178$  s, respectively).  
169 There was no interaction between athlete status and maturation status for 10 m sprint  
170 performance ( $F = 0.770$ ,  $P = 0.464$ ), demonstrating that ESP performed better than CON at  
171 all three stages of maturation. Moderate effect sizes were associated with differences in 10m-  
172 sprint performance between ESP and CON in the post-PHV ( $d = 0.63$ ) and mid-PHV ( $d =$

173 0.63) groups. However, only small effect sizes were associated with differences in 10m-sprint  
174 performance between ESP and CON in the pre-PHV group ( $d = 0.48$ ).

175

176 Insert Figure 1 about here

177

### 178 **20 m Sprint**

179 There was a main effect of maturation status for 20 m sprint performance ( $F = 124.514$ ,  $P <$   
180  $0.001$ ), with post-PHV sprinting faster than mid-PHV ( $P < 0.001$ ), who sprinted faster than  
181 pre-PHV ( $P < 0.001$ ; Figure 2). There was also a main effect of athlete status ( $F = 21.395$ ,  $P$   
182  $< 0.001$ ; Figure 2), with ESP able to sprint faster than CON ( $3.321 \pm 0.344$  vs.  $3.410 \pm 0.365$   
183 s, respectively). There was no interaction between player status and PHV status for 20 m  
184 sprint performance ( $F = 0.256$ ,  $P = 0.774$ ), showing that ESP performed better than CON at  
185 all three stages of maturation. Moderate effect sizes were associated with differences in 20m-  
186 sprint performance between ESP and CON in the post-PHV ( $d = 0.78$ ) and mid-PHV ( $d =$   
187  $0.99$ ) groups. However, only small effect sizes were associated with differences in 20m-sprint  
188 performance between ESP and CON in the pre-PHV group ( $d = 0.49$ )

189

190 Insert Figure 2 about here

191

### 192 **Bilateral Horizontal-forward Countermovement Jump (BH CMJ)**

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

198 0.001; Figure 3). ESP jumped further than CON at both mid-PHV ( $P < 0.001$ ; Figure 3) and  
199 post-PHV ( $P < 0.001$ ; Figure 3), but there was no difference between ESP and CON at pre-  
200 PHV ( $P = 0.273$ ; Figure 3). Large effect sizes were associated with differences in BH CMJ  
201 performance between ESP and CON at post-PHV ( $d = 1.32$ ) and mid-PHV ( $d = 1.30$ ).  
202 However, only small effect sizes were associated with differences in BH CMJ performance  
203 between ESP and CON at pre-PHV status ( $d = 0.21$ ).

204

205 Insert Figure 3 about here

206

### 207 **Bilateral Vertical CMJ (BV CMJ)**

208 There was a main effect of maturation status ( $F = 199.399$ ,  $P < 0.001$ ; Figure 4), with post-  
209 PHV performing better than mid-PHV ( $P < 0.001$ ), who performed better than pre-PHV ( $P =$   
210  $0.001$ ). There was also a main effect of athlete status ( $F = 28.503$ ,  $P < 0.001$ ; Figure 4), with  
211 ESP jumping higher than CON ( $29.9 \pm 9.0$  vs.  $28.0 \pm 7.1$  cm, respectively). There was also  
212 an interaction between athlete status and maturation status ( $F = 10.939$ ,  $P < 0.001$ ; Figure 4),  
213 with ESP jumping higher than CON at both mid-PHV ( $P < 0.001$ ; Figure 4) and post-PHV ( $P$   
214  $< 0.001$ ; Figure 4) but there was no difference between ESP and CON at pre-PHV ( $P =$   
215  $0.880$ ; Figure 4). Moderate effect sizes were associated with differences in BV CMJ  
216 performance between ESP and CON at post-PHV ( $d = 0.86$ ) and mid-PHV ( $d = 1.05$ ).  
217 However, only trivial effect sizes were associated with differences in BV CMJ performance  
218 between pre-PHV ESP and CON participants ( $d = 0.04$ ).

219

220 Insert Figure 4 about here

221

## 222 **DISCUSSION**

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

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

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

266 Muscular power is a component of acceleration and sprint performance (26), but  
267 horizontal-forward and vertical CMJs assess separate leg power qualities (18) and have  
268 previously been shown to have different development patterns during adolescence in elite  
269 youth soccer players (23). It was therefore deemed relevant to determine the importance of  
270 these independent capabilities at different stages of maturation. The present results showed  
271 no difference in BH CMJ or BV CMJ performance between ESP and CON participants in the

272 pre-PHV groups. In contrast, mid-PHV and post-PHV ESP achieved greater BV CMJ and  
273 BH CMJ performance than maturation-matched CON. The current data therefore suggest  
274 that, from a physiological perspective, vertical and horizontal-forward power performance  
275 are determinants of elite soccer playing status during the mid-PHV and post-PHV periods,  
276 but cannot discriminate between ESP and CON during the pre-PHV period. As it has been  
277 reported that the percentage of muscle mass increased by 0.6% and 29% per year from the  
278 age of 7 to 13.5, and 13.5 to 15 yrs, respectively (11), the large increase in muscular power  
279 from the beginning of the mid-PHV period (15) could be largely attributed to the increase in  
280 muscle volume during growth and its direct relationship with peak power (15, 20). It  
281 therefore appears that vertical and horizontal-forward power can only discriminate between  
282 ESP and CON during the mid- and post-PHV periods when the individual begins to develop  
283 his phenotypic muscle mass profile. However, the significant difference in BH CMJ and BV  
284 CMJ between ESP and CON participants at mid-PHV and post-PHV were associated with  
285 large (BH CMJ) and moderate (BV CMJ) effect sizes. Hence, it appears that, during the mid-  
286 PHV and post-PHV periods, the BH CMJ is able to better discriminate between ESP and  
287 CON than the BV CMJ. These specific findings are supported by previous longitudinal  
288 research that documented horizontal-forward CMJ capability was the key physical factor at a  
289 young age influencing future contract status and playing minutes after reaching professional  
290 status (4).

291         It must be acknowledged that attempting to identify the physical determinants of EPL  
292 youth soccer in the current cross sectional study by comparing ESP and CON may have  
293 limitations. We cannot discount that this particular cohort of players developed greater  
294 physical capabilities as a result of their exposure to an elite soccer development training  
295 programme and were therefore, perhaps not initially selected based on a superior physical  
296 profile. However, previous longitudinal research showed large variations in the rank scores in

297 speed and power performance measures for ESPs (age: 12 yrs) exposed to the same training  
298 programme (players only included if they attended over 90% of training sessions) over a  
299 four-year period (ICC values, 10 m sprint time: 0.66; BV CMJ: 0.66) (1). This research  
300 suggests that ESP physical development during maturation may in fact, be largely determined  
301 by genetic profile rather than the training environment players are exposed to.

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

318

## 319 **PRACTICAL APPLICATIONS**

320 When identifying and selecting elite soccer talent relative to physiological outcome measures  
321 from mid-PHV and post-PHV maturation groups, the current study suggests that while elite



322 soccer clubs should employ acceleration, sprint and BV CMJ assessments, the BH CMJ  
323 should be prioritized amongst these performance tests. In contrast, when identifying pre-PHV  
324 soccer talent we only recommend the inclusion of acceleration and sprint assessments, but  
325 also recognize that practitioners should be aware that additional physiological outcome  
326 measures not assessed in our study may also predict pre-PHV elite soccer playing status.

327

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330 help and expertise during the testing procedures.

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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

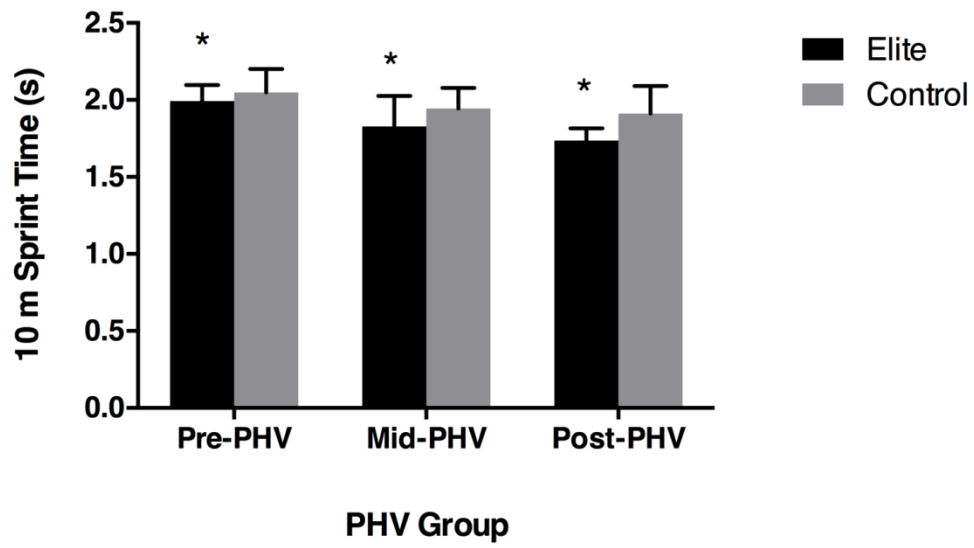


Fig. 2

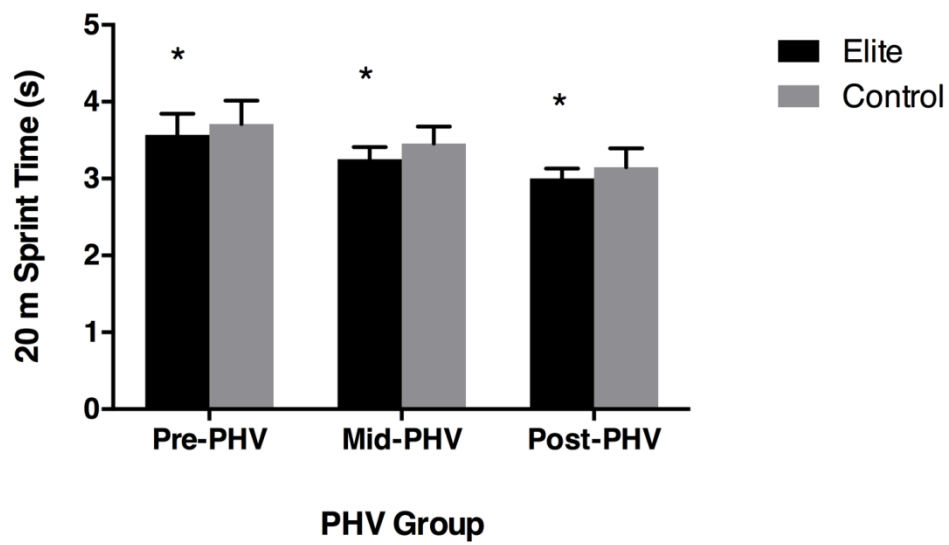


Fig. 3

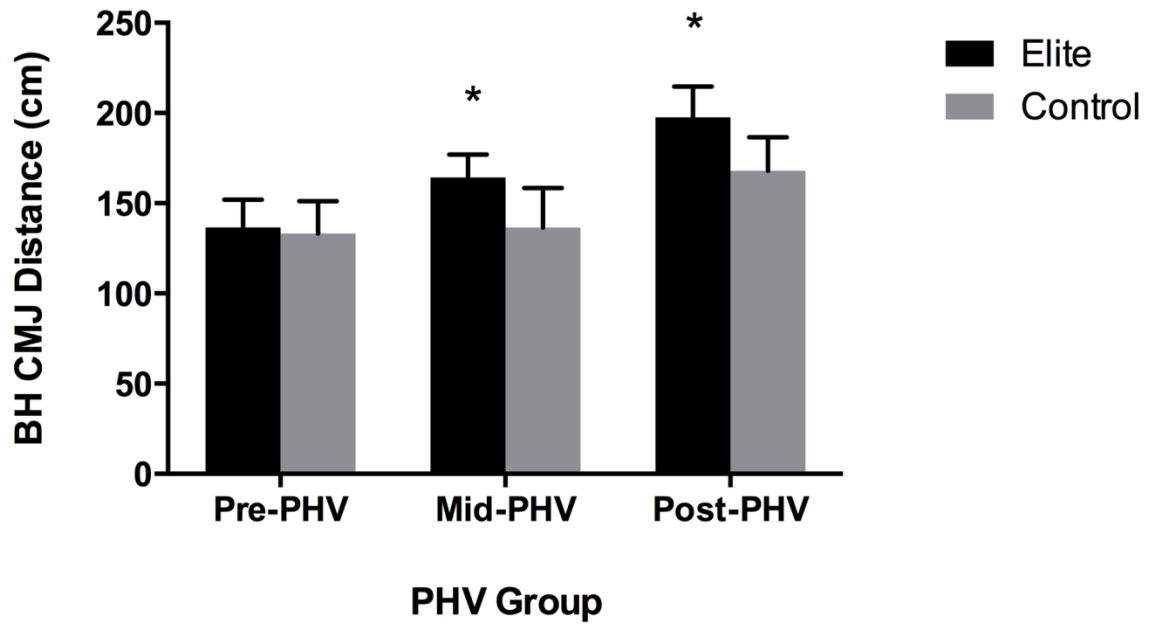
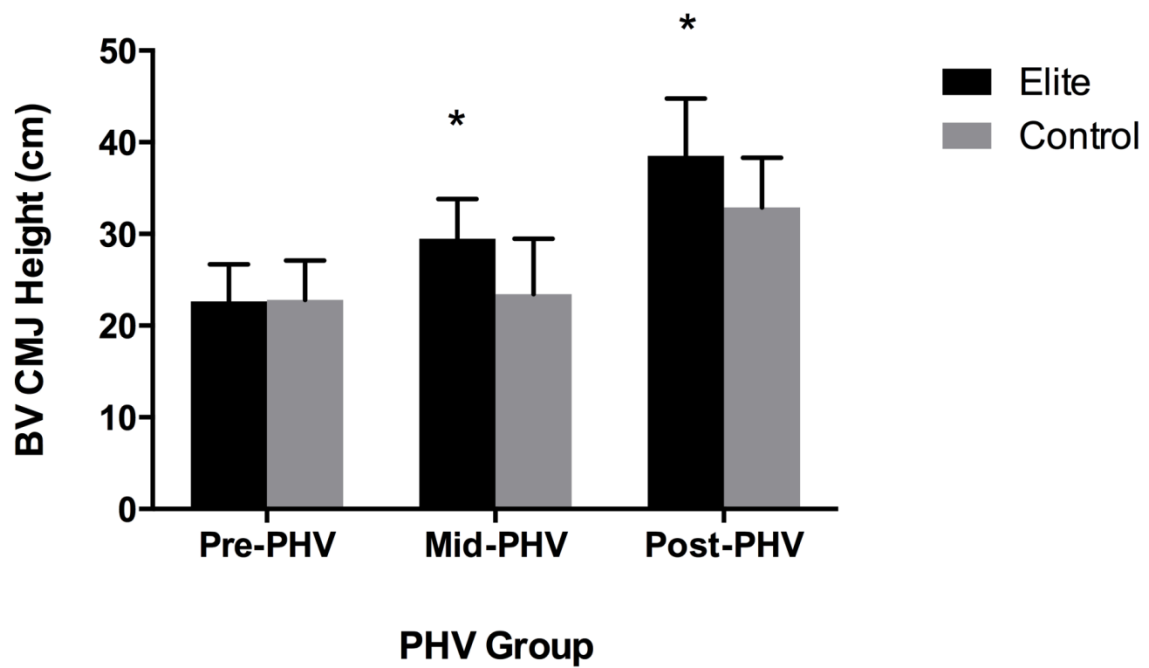


Fig. 4



## 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
<b>Pre-PHV</b>	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
<b>Mid-PHV</b>	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
<b>Post-PHV</b>	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 ( $P \leq 0.02$ ).