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1 **PHYSICAL CHARACTERISTICS OF ELITE YOUTH FEMALE SOCCER PLAYERS**
2 **CHARACTERISED BY MATURITY STATUS**

3

4 Emmonds, S; Scantlebury, S; Murray, E; T; Turner, L; Robinson, C; Jones, B.

5

6 Running Head: Female Soccer Physical Characteristics

7

8

9 **ABSTRACT**

10

11

12 The purpose of this study was to investigate the influence of maturity status on the
13 physical characteristics of youth female soccer players. 157 players from 3 elite soccer
14 academies In England completed assessments of anthropometry, strength (isometric
15 mid-thigh pull; IMTP), lower body power (countermovement jump; CMJ), aerobic
16 capacity (YYIRL1), change of direction (CoD: 505-left/right), and speed (10 and 30 m).
17 Each player was classified into 1 of 6 maturity groups based on their estimated years
18 from peak height velocity (YPHV). Magnitude based-inferences were used to assess for
19 practical significance between consecutive groups. Speed, CoD time, CMJ and aerobic
20 capacity were all *possibly-most likely* better in more mature players. However, there was
21 a *likely* difference in relative peak force (PF) between maturity groups -0.5 YPHV (27.13
22 $\pm 4.24 \text{ N}\cdot\text{Kg}^{-1}$) and 0.5 YPHV ($24.62 \pm 3.70 \text{ N}\cdot\text{Kg}^{-1}$), which was associated with a *likely*
23 difference in 10 m sprint time (-0.5 YPHV: $2.00 \pm 0.12\text{s}$ vs. 0.5 YPHV $2.08 \pm 0.16\text{s}$) and
24 *unclear* changes in CMJ and CoD time. Findings provide novel comparative data for this
25 cohort relative to maturity status and can be used by strength and conditioning coaches
26 to inform the design of training programs for youth female soccer players. Strength and
27 conditioning coaches should be aware that youth female soccer players may experience
28 a decrease in relative strength around PHV, which may impact upon the speed, CoD time
29 and CMJ of players.

30

31 Key words: maturation, talent development, fitness testing

32

33 INTRODUCTION

34

35 In recent years female soccer has grown rapidly, with an exponential rise in the number
36 of opportunities to play professionally and also increased youth participation
37 worldwide (33). To support this growth in female soccer, the Football Association (FA)
38 in England have created elite Regional Talent Centre's (RTC's) for the identification and
39 development of talented youth female soccer players, similar to the processes in the
40 men's game (e.g., English Player Performance Plan; EPPP; 29). The RTC's operate within
41 youth age categories (i.e., Under 10 [U10], U12, U14 and U16), whereby girls are
42 selected to train and compete within an academy environment. The aim is to develop
43 youth female players technically, tactically, psychologically and physically to prepare
44 them for the elite senior game (6).

45

46 Currently there is limited research describing the physical characteristics of youth
47 female soccer players, thus comparative data are limited for S&C coaches working with
48 youth players to subsequently profile players against players beyond those within their
49 club (10). To the authors' knowledge only three studies have explored the physical
50 characteristics of youth female soccer players in England (10, 33, 36). However, the
51 studies by Taylor et al. (33) and Wright et al. (36) and were conducted prior to the
52 restructuring of the girls' soccer academies in England and therefore do not reflect the
53 current age group structuring, making comparisons difficult for current practitioners in
54 the field. Furthermore, these data were based on one academy with a small sample size
55 (U13; $n=10$ and U15; $n=9$ (33) $n=14$ players (36)) and one study only reported data by
56 chronological age (33). Emmonds et al. (10) did consider the influence of both age and
57 maturation on the strength characteristics of youth female soccer players, however little

58 is known about the influence of maturation on other physical qualities such as lower
59 body power, change of direction and aerobic capacity, which are all important for soccer
60 performance (6).

61
62 Research in male youth soccer (26, 31) has demonstrated the influence of maturation
63 status on physical performance of youth players, suggesting that it may be more
64 appropriate to consider youth athletes by maturity status instead of traditional
65 chronological annual-age groupings (17). If S&C coaches working with elite youth
66 female soccer players are to use physical testing data to make informed decisions about
67 the 'athleticism' of players and to inform training program design, it is important that
68 S&C coaches are aware of the impact maturation may have on the development of
69 specific physical qualities. While there has been a large body of research exploring the
70 influence of maturation on the physical development of youth male soccer players (4,
71 18, 19, 26, 31) extrapolating male youth data and applying it to females may be
72 erroneous given the different physiological and morphological changes that occur in
73 males and females during maturation (3). Therefore, there is a need for further research
74 specific to female youth soccer players that considers the influence of maturity status on
75 physical qualities. This will allow S&C coaches and other practitioners working with
76 youth female players to make more informed decisions about a player's physical
77 performance in relation to their stage of development. Therefore, the purpose of the
78 study was to evaluate the influence of maturity status on the physical characteristics of
79 elite youth female soccer players. Such findings will help S&C coaches better understand
80 the influence of maturation on the development of physical characteristics in young
81 female athletes. Such findings can be then used to inform the design of individualised
82 S&C program that are relevant to the individual stages of biological development, rather

83 than based on the chronological age.

84

85 **METHODS**

86

87 Experimental Approach to the Problem

88 A cross-sectional study design was conducted to investigate the influence of maturity

89 status on the physical characteristics of elite youth female soccer players. All subjects

90 undertook assessments of anthropometry and completed a physical testing battery at

91 the start of the 2016-2017 season (i.e., September, at the end of preseason). Testing was

92 conducted a minimum of 48 hours post competitive match play or training at each

93 respective RTC. A standardised warm-up, including jogging and dynamic movements

94 for 10-mins followed by jumps and sprints of progressive intensity for 5-mins were

95 undertaken prior to testing. This was then followed by full instruction and

96 demonstrations of the assessments. The lead researcher undertook all testing.

97

98 Anthropometry assessments included stature, sitting height and body mass. The testing

99 battery included assessments of strength (isometric mid-thigh pull; IMTP) on a portable

100 force plate, lower body power (countermovement jump; CMJ), aerobic capacity (Yo-Yo

101 intermittent recovery test level 1 (YYIRL1)), speed (10 and 30 m) and change of

102 direction (CoD 505 test left and right). The YYIRL1 was not conducted at the U10 age

103 category, as this was not current practice at the RTC's.

104

105 Subjects

106 157 female soccer players (U10, $n=30$; U12, $n=38$, U14, $n=43$, U16, $n=46$) were recruited

107 from three elite Tier 1 female soccer RTC's in England. Age categories were defined by

108 chronological age on the 1st September 2016, which established their status for
109 competition. All subjects were free from injury at the time of the study. U10 and U12 age
110 categories trained twice per week (2 x 90 min pitch based sessions and 1 x 60-min S&C
111 session, which included gym and field based sessions) and U14 and U16 age categories
112 trained three times per week (3 x 90 min based sessions and 2 x 60-min S&C sessions),
113 with each age group having on average 20 matches over a 35-week season.

114

115 U10 and U12 age categories trained twice per week (2 x 90 min pitched based sessions
116 and 1 x 30-min strength and conditioning session) and U14 and U16 age categories
117 trained three times per week (3 x 90 min based sessions and 2 x 60-min strength and
118 conditioning session), with each age group having on average 20 matches over a 35-
119 week season. The maturation groups were determined by the predicted years from
120 peak height velocity (PHV) derived from anthropometric assessments (27). Prior to
121 participating in the study, institutional ethics approval was granted from the Research
122 Ethics Committee. Parental consent and subject ascent were obtained prior to
123 commencing the study.

124

125 Procedures

126

127 *Anthropometric Measurements and Maturity Status:*

128 Standing height, sitting height and leg length were determined using previous methods
129 described by Malina and Koziel (21). For the assessment of standing height, subjects
130 were stood in an erect posture with weight evenly distributed between both feet, heels
131 together, arms hanging relaxed at the sides and the head in the Frankfurt horizontal

132 plane. Standing height was measured to the nearest 0.1cm. Sitting height was also
133 measured to the nearest 0.1cm with the distance from a flat sitting surface (40 cm high)
134 to the top of the head taken as the measurement. Subjects sat in standard erect posture
135 with the head in the Frankfurt horizontal plane; knees were together and directed
136 straight ahead. Subjects were dressed in shorts and t-shirt with trainers removed for
137 the assessment of body mass. Body mass was measured to the nearest 0.1 kg.

138

139 Maturity was estimated from anthropometric measurements using the protocol
140 proposed by Mirwald et al. (27) equation (Equation 1) in which stature, sitting height,
141 leg length, chronological age and the interaction between these variables are used in
142 order to predict the number of years from PHV (YPHV, maturity offset). While some
143 studies have questioned the use of this method (20, 22), this method was chosen due to
144 the non-invasive nature of the assessment and the satisfactory levels of measurement
145 accuracy (27). The equation has been reported to be a reliable ($R^2= 0.91$, $SEE=0.50$),
146 non-invasive practical solution for the measure of biological maturity for matching
147 adolescent athletes (27) and has previously used for the assessment of maturation in
148 youth female soccer in previous research (36). YPHV was calculated for each subject by
149 subtracting the age at PHV from chronological age.

150

151 Maturity Offset = $-16.364 + 0.0002309 \times \text{leg length and sitting height interaction} + 0.006277 \times$
152 $\text{age and sitting height interaction} + 0.179 \times \text{leg by height ratio} + 0.0009428 \times \text{age and weight}$
153 interaction.

154 Equation 1.

155

156 Each subject was categorized into 1 of 6 maturity-offset groups (i.e., $-2.5 \text{ YPHV } [\leq 2.0]$, -
157 $1.5 \text{ YPHV } [-1.99 \text{ to } -1.0]$, $-0.5 \text{ YPHV } [-0.99 \text{ to } 0.0]$, $0.5 \text{ YPHV } [0.01 \text{ to } 1.0]$, $1.5 \text{ YPHV } [1.01$

158 to 2.0], and 2.5 YPHV [≥ 2.01]). These categories were consistent with previous
159 categories used in the literature to define maturity status (23).

160

161 *Strength:*

162 The IMTP was performed on a commercially available portable force platform (AMTI,
163 ACP, Watertown, MA) with a sampling rate of 1000Hz, which is consistent with previous
164 methodologies (9). Subjects performed the IMTP on a customized pull rack, using a self-
165 selected position similar to that of the second pull of a power clean, with a flat trunk
166 position and their shoulders in line with the bar (12). The self-selected mid-thigh
167 position was preferred, as differences in knee and hip joint angles during the IMTP have
168 previously been shown to have no influence on kinetic variables (5). Subjects were
169 given two practice trials prior to testing commencing. Subjects were instructed to pull
170 as “fast and hard” as possible, and received loud, verbal encouragement (9). Each
171 subject completed two trials lasting five seconds, with five mins rest between each trial.
172 The highest PF achieved over the two trials was considered the subjects ‘best trial.’ PF
173 was identified as the maximum force value obtained during the best trial of the IMTP.
174 PF intraclass correlation (ICC) and coefficient of variation (CV) PF were $r = 0.93$, $CV =$
175 3.6% . In addition to highest PF, relative PF was calculated using the ratio scaling
176 method (i.e. PF / body mass) (14).

177

178 *Lower Body Power:*

179 Lower body power was assessed using a CMJ in an indoor gym facility that provided a
180 consistent stable flooring to minimize the influence of external factors (e.g., weather,
181 foot-surface interaction) and were allowed 2-mins recovery between jumps. The CMJs
182 were performed according to previously described methods (30) using a portable

183 photoelectric cell system (Optojump; Microgate, Bolzano, Italy). This equipment has
184 been reported as both reliable and valid (CV = 6%, SEE = 1%) for vertical jump
185 assessment compared with a biomechanical force plate (11). Jump height was
186 calculated using the cell system software (Optojump Next v1.7.9; Microgate). Subjects
187 completed 3 submaximal CMJ efforts prior to testing commencing. The CMJ started from
188 an upright position. When given a verbal command, the subjects made the downward
189 countermovement to their preferred depth and then jumped as high as possible.
190 Subjects were required to keep their legs straight during the airborne phase of the
191 jump. The highest jump was selected for analysis. ICC and CV for CMJ were $r = 0.96$, CV
192 = 4.5%.

193

194 *Aerobic Capacity:*

195 Aerobic capacity was assessed using the YYIR1. The YYIR1 was selected as it has been
196 reported as a valid and reliable test ($r = 0.98$, CV = 4.9%) for the assessment of soccer
197 specific fitness (15). The test consisted of repeated 20 m shuttle runs at progressively
198 increasing speeds dictated by an audio bleep emitted from a CD player. Between each
199 shuttle a recovery period of 10 seconds is allowed involving walking around a marker
200 placed 5 m behind the finishing line. Failure to achieve the shuttle run in time on two
201 occasions resulted in termination of the test. The final level achieved and total running
202 distances were recorded.

203

204 *Change of Direction (CoD) Time:*

205 CoD was assessed using the 505 test, whereby the subjects were positioned 15 m from a
206 turning point. Timing gates (Brower Timing Systems, IR Emit, USA). were placed 10 m
207 from the start point and 5 m from the turn point. Subjects accelerated from the start

208 through the timing gates, turning 180° at the 15 m mark and sprinted back through the
209 timing gates. Subjects completed 3 alternate attempts on each foot (i.e., right and left
210 leg), separated by a 2–3 minute rest period. Only attempts whereby the subjects' foot
211 crossed the 15 m mark were included. Times were recorded to the nearest 0.01 sec with
212 the quickest of the 3 attempts used as the final score. Data are presented as dominant
213 (D) or non-dominant (ND) foot based on preferred kicking foot. ICC and CV for the 505
214 test were $r = 0.995$, $CV = 2.2\%$.

215

216 *Sprint time:*

217 Sprint times were assessed over 10 m and 30 m using timing gates (Brower Timing
218 Systems, IR Emit, USA). Subjects started 0.5 m behind the initial timing gate and were
219 instructed to set off in their own time and run maximally past the 30 m timing gate.
220 Each subject had 3 attempts, separated by a 3-minute rest period. Times were recorded
221 to the nearest 0.01 seconds with the quickest of the three attempts used for the sprint
222 score. ICC and CV's for 10 and 30 m sprint time were $r = 0.76$, $CV = 4.8\%$ and $r = 0.78$, CV
223 $= 3.9\%$, respectively.

224

225 Statistical Analyses

226 Data are presented as mean \pm SDs by maturity status. All data were log transformed to
227 reduce bias as a result of non-uniformity error. Magnitude based-inferences were used
228 to assess for practical significance between consecutive maturity groups for each
229 variable (13). The threshold for a difference to be considered practically important (the
230 smallest worthwhile difference; SWD) was set at $0.2 \times$ between subject SD for the
231 comparison groups, based on Cohen's d effect size (ES) principle. The probability that
232 the magnitude of difference was greater than the SWD was rated as $<0.5\%$, *almost*

233 *certainly not*; 0.5-5%, *very unlikely*; 5-25%, *unlikely*; 25-75%, *possibly*; 75-95%, *likely*;
234 95-99.5%, *very likely*; >99.5%, *almost certainly* (16). ES were rated as *trivial* (<0.2),
235 *small* (0.2<0.6), *moderate* (0.6<1.2) *large* (1.2<2.0) or *very large* (2.0<4.0) (14). Where
236 the 90% Confidence Interval (CI) crossed both the upper and lower boundaries of the
237 SWD (ES±0.2), the magnitude of difference was described as *unclear* (13).

238

239 RESULTS

240

241 The anthropometric and physical characteristics of elite youth female soccer players by
242 maturity status are presented in Table 1 and the standardized differences for
243 anthropometric and physical characteristics between consecutive maturation groups
244 are shown in Table 2. Stature and sitting height were *very likely to most likely* greater in
245 more mature players. *Likely to most likely* differences in leg length were observed in
246 consecutive maturity groups until 0.5 YPHV, with only *possibly* differences observed
247 between consecutive maturity groups post-PHV. *Likely to most likely* differences in body
248 mass were observed between consecutive maturity groups, with more mature players
249 being heavier than less mature players

250

251 ***Insert Table 1 Near Here****

252

253 PF was *likely to most likely* greater for more mature players. However, differences in
254 relative PF between consecutive maturity groups were *possibly small to possibly trivial*,
255 except for between maturity groups -0.5 YPHV and 0.5 YPHV, where a *likely* difference
256 was observed. There were *likely* differences in CMJ between consecutive maturity
257 groups -2.5 to -0.5 YPHV but only *possibly small* differences between groups -0.5 and 0.5

258 YPHV were observed. *Most likely* differences in CMJ height were observed in maturity
259 groups 1.5 YPHV – 2.5 YPHV. Both 10 and 30 m sprint times were lower in more mature
260 players, with *possibly to most likely* differences observed between consecutive maturity
261 groups until 1.5 YPHV. Differences in 10 and 30 m sprint times between the maturity
262 groups 1.5 YPHV – 2.5 YPHV were *possibly trivial to possibly small*, respectively.

263

264 CoD time was less in more mature players with *possibly to very likely* differences
265 observed between maturity groups, except for between maturity groups -0.5 YPHV – 0.5
266 YPHV, where differences between groups were *possibly trivial*. *Likely small* differences
267 in distance covered on the YYIRL1 were observed between maturity groups 0.5 YPHV –
268 -0.5 YPHV. All other differences between consecutive maturity groups were *possibly*
269 *trivial*.

270

271 ***Insert Table 2 Near Here***

272

273 **DISCUSSION**

274

275 The aim of this study was to investigate the influence of maturation on the physical
276 characteristics of youth female soccer players. Findings demonstrate that speed, CoD,
277 lower body power and aerobic fitness were improved in more mature players.
278 However, the development of physical characteristics was non-linear between
279 consecutive maturation groups. S&C coaches need to consider the maturity status of
280 youth female soccer players when evaluating physical testing data and consider the
281 non-linear development of physical qualities. Such data can also be used as comparative

282 data by S&C coaches working in youth female soccer when assessing the performance of
283 their own players.

284

285 Differences in leg length between consecutive maturity groups were greatest between
286 groups -2.5 – -0.5 YPHV. These findings are consistent with normal somatic growth,
287 whereby peak leg length growth occurs just before PHV (17). The development of
288 anthropometric characteristics with advancing maturity likely accounts for a number of
289 observed changes in physical characteristics between consecutive maturity groups (19),
290 therefore highlighting the importance of regularly assessing maturity status
291 (approximately every 3 months, (17)).

292

293 PF was greater in more mature female soccer players, which may be attributed to
294 biological changes associated with advanced maturity, including increased body mass
295 (3). Furthermore, given more mature players were typically older, the greater PF may
296 also be explained by an increased exposure to a structured S&C program within the
297 academies at the older age groups (i.e. structured gym based resistance training at the
298 U14 and U16 age categories twice per week for 60-mins). However, when made relative
299 to body mass, relative PF did not increase linearly between consecutive maturity groups,
300 highlighting the importance of considering relative versus absolute measures of PF.
301 Greatest relative PF was observed in the maturity group -0.5 YPHV (0.99 to 0.0 YPHV),
302 which may be related to hormonal and morphological changes (i.e. increase in muscle
303 mass) reported to occur around PHV (3). These findings are consistent with previous
304 longitudinal (7) and cross-sectional (2) strength assessment research for non-elite
305 female athletes. A *likely moderate* difference in relative PF was observed between
306 maturity groups -0.5 YPHV and 0.5 YPHV, with lower relative PF in the more mature

307 players (0.5 YPHV). In line with this finding, there were also unclear changes in lower
308 body power (CMJ height) between these respective maturity groups. Together these
309 findings suggest that female soccer players may experience a reduction in relative PF and
310 consequently lower body power at 0.5 YPHV [0.01 to 1.0 YPHV]. This may be explained
311 by a potential increase in fat mass associated with peak weight velocity (PWV), that
312 occurs in females 3.5 to 10.5 months after PHV (3), which has a non-functional role for
313 athletic performance. However, a limitation of this study was that it was not possible to
314 obtain body composition data for players, therefore the reason for the observed
315 differences is speculative and requires further research. Nonetheless, S&C coaches should
316 be aware of this possible reduction in relative PF after PHV in youth female soccer
317 players, given the known relationship between strength and athletic performance (32)
318 and the relationship between low relative strength and increased risk of injury in
319 children (8). Findings support the need for youth female soccer players to regularly
320 undertake structured strength training as part of their training program, particularly
321 after PHV.

322

323 Both 10 and 30 m sprint times were less in more mature players, indicating faster sprint
324 times with advanced maturity. However, findings demonstrate that acceleration ability
325 (10 m) and maximum speed (30 m) are unique physical qualities, which do not develop
326 at the same rate between consecutive maturity groups. Greatest differences in 30 m
327 sprint time between consecutive maturity groups was observed between -2.5 – 0.5 YPHV,
328 with *very likely- likely* differences observed. This may be explained by the *very likely -*
329 *most likely* differences in leg length between these respective groups, which has been
330 reported in male youth athletes to account for improvements in stride length and thus
331 sprint time (23). In contrast, 10 m sprint time may be influenced more by relative

332 strength, improved running mechanics and neuromuscular control (24). Players -0.5
333 YPHV had faster 10 m sprint times than players 0.5 YPHV. As previously discussed, this
334 was in line with a *likely moderate* difference in relative PF between these consecutive
335 maturity groups, which may have had a negative influence on force production
336 capabilities (25). Again, this supports the need for youth female soccer players to
337 regularly undertake strength training as part of their weekly training schedule as
338 strength development in addition to the development of correct movement patterns and
339 neuromuscular control, underpins the development of other physical qualities (31).

340

341 This finding is in contrast to the findings of youth male soccer players who have been
342 reported to display an improvement in sprint times after PHV (23). These differences may
343 be due to the different physiological changes that occur in males and females with the
344 onset of maturation, with males experiencing a greater increase in lean muscle mass
345 which results in improved expression of both concentric strength and power (16). As
346 previously discussed, an increase in body mass and fat mass in females after PHV may
347 possibly explain why 10 m sprint times increased in the maturity group 0.5 YPHV.
348 Therefore, coaches working with youth female soccer players who are -0.5 - 0.5 YPHV
349 need to be aware that players may experience increases in sprint times during this period
350 of development and consider this when evaluating the physical performance of players.

351

352 CoD times were less in more mature players, indicating more efficient CoD ability,
353 however greatest differences between consecutive maturation groups were observed -
354 2.5 - -1.0 YPHV (*likely - very likely*). Improvements in CoD time in players at this stage of
355 maturation may be explained by improvements in neuromuscular control and co-
356 ordination (8). Players at the U10 and U12 age groups included in this study, were

357 regularly taking part in a structured S&C session each week, in addition to two field based
358 soccer training sessions. Given that previous research has shown CoD time can be
359 improved in less mature players using neuromuscular training (8), potentially this may
360 have also facilitated improvements in neuromuscular control beyond the natural
361 development of this physical attribute at this stage of development. Differences in CoD
362 time between maturity groups circa-PHV (-0.5 – 0.5 YPHV) were *unclear*. Given that
363 relative strength has previously been reported to be strongly correlated with CoD time in
364 female athletes, the lower relative PF observed in females 0.5 YPHV in this study may
365 explain why differences in CoD time at these maturity groups were *unclear*.

366

367 Distance covered on the YYIRL1 was greater for more mature players. *Likely* differences
368 were observed between maturity groups -0.5 – 0.5 YPHV. This is consistent with findings
369 for 8-16-year-old untrained youth females, where aerobic fitness was observed to be
370 greatest around circa-PHV and decrease post-PHV (28). Previous research has reported
371 that growth-related changes to the central and peripheral cardiovascular system,
372 including increases in stroke volume and cardiac output, as well as changes in muscular
373 function and metabolic capability occur around the onset of PHV (3). This may explain
374 the *likely* differences in aerobic capacity observed between maturity groups -0.5 – 0.5
375 YPHV. Furthermore, research has shown that percentage body fat is an important factor
376 in the variation of aerobic fitness of youth females (1, 28). Therefore, *unclear* differences
377 in distance covered on the YYIRL1 test between maturity groups post-PHV in this study
378 may be explained by a possible increase in fat mass at this stage of development. As such
379 it is important that S&C coaches working with this cohort actively look to develop the
380 aerobic capacity of youth female players post-PHV.

381

382 While this study provides S&C coaches with a better understanding of the influence of
383 maturity status on the physical development of youth female athletes, it must be noted
384 that this study is not without its limitations. Firstly, the estimation of maturation from
385 somatic measures and predictive equations rather than using a measure of biological
386 maturation likely results in some degree of error (20, 22), which coaches must consider
387 when interpreting the data. Analysis of such data is further complicated by the different
388 categories used in the literature to define maturity status. Given that players may not
389 have all entered the RTC at the same age, a second limitation of the study was that it was
390 not possible to obtain information on the training age of the players which may influence
391 physical performance. Therefore, future research should also look to consider the
392 training age of players in addition to other variables not evaluated in this study which
393 may impact on physical performance (i.e. menstrual cycle, training loads). Finally, this
394 study adopted a cross-sectional design, thus future studies should look to employ
395 longitudinal designs to infer development trajectories as opposed to differences by
396 maturation status.

397

398 Practical Applications

399

400 It is recommended that S&C coaches regularly monitor anthropometric variables to
401 detect periods of rapid growth and maturation, which may impact upon the physical
402 characteristics of youth female soccer players. S&C coaches need to be aware that
403 relative PF may decrease following PHV, which may impact upon players lower body
404 power, 10 m acceleration and CoD time. Therefore, coaches should consider a players'
405 stage of biological age when evaluating physical testing scores or designing S&C
406 programs in addition to other factors such as training age. Given the importance of

407 strength for athletic performance (32), it is recommended that S&C coaches should look
408 to improve neuromuscular strength and fundamental movement skills in players pre-
409 PHV. These qualities can be developed by working on correct running mechanics, multi-
410 planer jumping and landing tasks and sprinting as part of fun and engaging pitch based
411 warm ups (35). Players circa-PHV may experience decreases in relative PF, therefore it
412 is important S&C coaches focus on the development of strength during this period of
413 development. However, it is important that coaches are aware that players at this stage
414 may also experience a reduction in co-ordination, therefore the focus of resistance
415 based exercises must first be on technique (35), which can be developed as part of
416 structured gym based training sessions as well as continuing to develop running
417 mechanics and jumping technique as part of pitch based training sessions. Players post-
418 PHV may benefit from individualised gym and pitch based conditioning programmes.
419 Furthermore, findings of this study suggest the coaches should look to actively develop
420 the aerobic system in player's post-PHV. Manipulation of small-sided games combined
421 with short duration intermittent high-intensity running drills may provide an efficient
422 training stimulus whilst concurrently developing technical/tactical skills within the
423 same session.

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426

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431

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530 **Table 1: Anthropometric and physical characteristics of youth female soccer players by maturity offset group**

	Maturity Offset Groups (YPHV)					
	-2.5 (n = 24)	-1.5 (n = 30)	-0.5 (n = 19)	0.5 (n = 22)	1.5 (n = 36)	2.5 (n = 27)
Age (y)	9.16 ± 0.61	10.70 ± 0.62	11.87 ± 0.31	12.83 ± 0.67	14.01 ± 0.65	15.19 ± 0.67
Height (cm)	131.9 ± 6.3	142.4 ± 4.4	151.1 ± 4.5	157.4 ± 4.8	162.2 ± 4.4	165.8 ± 6.9
Sitting Height (cm)	67.3 ± 3.2	70.9 ± 2.9	74.8 ± 2.8	78.7 ± 2.9	82.2 ± 2.6	84.4 ± 3.9
Leg Length (cm)	64.6 ± 4.4	71.5 ± 3.6	76.4 ± 3.5	78.8 ± 2.8	80.0 ± 3.8	81.4 ± 4.1
Body Mass (kg)	28.3 ± 4.5	33.4 ± 3.8	40.5 ± 4.9	49.0 ± 5.0	54.9 ± 5.1	57.5 ± 7.5
Peak Force (N)	729 ± 105	880 ± 112	1093 ± 171	1206 ± 223	1391 ± 196	1523 ± 207
Relative Peak Force (N·Kg⁻¹)	26.16 ± 4.22	26.44 ± 2.89	27.13 ± 4.24	24.62 ± 3.70	25.36 ± 2.73	26.68 ± 3.66
CMJ (cm)	23.46 ± 4.86	25.96 ± 4.44	28.64 ± 3.84	29.61 ± 3.52	28.63 ± 3.87	33.42 ± 4.33
10 m Sprint (s)	2.22 ± 0.13	2.21 ± 0.17	2.00 ± 0.12	2.08 ± 0.16	1.99 ± 0.14	1.98 ± 0.15
30 m Sprint (s)	5.75 ± 0.34	5.40 ± 0.64	5.09 ± 0.21	4.98 ± 0.47	4.90 ± 0.26	4.81 ± 0.27
505 CoD Dominant (s)	2.99 ± 0.39	2.73 ± 0.19	2.69 ± 0.15	2.69 ± 0.20	2.61 ± 0.15	2.54 ± 0.11
505 CoD N-Dominant (s)	3.03 ± 0.41	2.76 ± 0.19	2.71 ± 0.12	2.71 ± 0.17	2.64 ± 0.16	2.53 ± 0.08
YYIRL (m)		668 ± 284	716 ± 234	897 ± 404	888 ± 288	952 ± 320

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Data are presented as mean ± standard deviations

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Table 2: Standardised differences and effect sizes between consecutive maturity offset group in youth female soccer players

	Maturity Offset Groups (YPHV) comparisons				
	-2.5 vs. -1.5	-1.5 vs. -0.5	-0.5 vs. 0.5	0.5 vs. 1.5	1.5 vs. 2.5
Age (y)	<i>Most Likely</i> (-2.50 ± 0.62)	<i>Very Likely</i> (-2.39 ± 0.65)	<i>Most Likely</i> (-1.84 ± 0.64)	<i>Most Likely</i> (-1.79 ± 0.54)	<i>Most Likely</i> (-1.79 ± 0.50)
Height (cm)	<i>Most Likely</i> (-1.92 ± 0.56)	<i>Most Likely</i> (-1.96 ± 0.60)	<i>Most Likely</i> (-1.36 ± 0.59)	<i>Most Likely</i> (-1.04 ± 0.49)	<i>Very Likely</i> (-0.62 ± 0.44)
Sitting Height (cm)	<i>Most Likely</i> (-1.17 ± 0.50)	<i>Most Likely</i> (-1.35 ± 0.55)	<i>Most Likely</i> (-1.36 ± 0.59)	<i>Most Likely</i> (-1.29 ± 0.50)	<i>Very Likely</i> (-0.68 ± 0.44)
Leg Length (cm)	<i>Most Likely</i> (-1.71 ± 0.54)	<i>Very Likely</i> (-1.37 ± 0.55)	<i>Likely</i> (-0.77 ± 0.55)	<i>Possibly</i> (-0.37 ± 0.46)	<i>Possibly</i> (-0.34 ± 0.43)
Body Mass (kg)	<i>Most Likely</i> (-1.23 ± 0.50)	<i>Most Likely</i> (-1.61 ± 0.57)	<i>Most Likely</i> (-1.71 ± 0.62)	<i>Very Likely</i> (-1.17 ± 0.50)	<i>Likely</i> (-0.41 ± 0.43)
Peak Force (N)	<i>Most Likely</i> (-1.39 ± 0.51)	<i>Most Likely</i> (-1.47 ± 0.56)	<i>Likely</i> (-0.57 ± 0.55)	<i>Very Likely</i> (-0.88 ± 0.48)	<i>Very Likely</i> (-0.66 ± 0.44)
Relative Peak Force (N·Kg⁻¹)	<i>Unclear</i> (-0.08 ± 0.46)	<i>Unclear</i> (-0.19 ± 0.50)	<i>Likely</i> (0.63 ± 0.55)	<i>Unclear</i> (-0.23 ± 0.46)	<i>Possibly</i> (-0.41 ± 0.43)
CMJ (cm)	<i>Likely</i> (-0.54 ± 0.47)	<i>Likely</i> (-0.65 ± 0.51)	<i>Unclear</i> (-0.26 ± 0.54)	<i>Possibly</i> (0.26 ± 0.46)	<i>Most Likely</i> (-1.17 ± 0.46)
10 m Sprint (s)	<i>Unclear</i> (0.07 ± 0.46)	<i>Most Likely</i> (1.43 ± 0.56)	<i>Likely</i> (-0.57 ± 0.54)	<i>Likely</i> (0.60 ± 0.47)	<i>Unclear</i> (0.07 ± 0.43)
30 m Sprint (s)	<i>Very Likely</i> (0.68 ± 0.47)	<i>Likely</i> (0.65 ± 0.51)	<i>Possibly</i> (0.30 ± 0.54)	<i>Unclear</i> (0.21 ± 0.46)	<i>Possibly</i> (0.34 ± 0.43)
505 CoD Dominant (s)	<i>Likely</i> (0.85 ± 0.48)	<i>Unclear</i> (0.23 ± 0.50)	<i>Unclear</i> (0.00 ± 0.53)	<i>Possibly</i> (0.45 ± 0.47)	<i>Likely</i> (0.53 ± 0.43)
505 CoD N-Dominant (s)	<i>Very Likely</i> (0.84 ± 0.48)	<i>Possibly</i> (0.31 ± 0.50)	<i>Unclear</i> (0.00 ± 0.53)	<i>Possibly Trivial</i> (0.42 ± 0.47)	<i>Very Likely</i> (0.87 ± 0.45)
YYIRL (m)		<i>Unclear</i> (-0.18 ± 0.50)	<i>Likely</i> (-0.55 ± 0.54)	<i>Unclear</i> (0.03 ± 0.46)	<i>Unclear</i> (-0.21 ± 0.43)

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Magnitude based inferences and effect sizes (ES ± 90 Confidence Intervals)