

Title: Changes in sprint-related outcomes during a period of systematic training in a girls' soccer academy

Running Title: Sprint-related outcomes in girls' soccer

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Acknowledgments: We would like to thank the players, parents and staff of the Teesside Sport, FA Girls Centre of Excellence for their support throughout this study.

ABSTRACT

Longitudinal data tracking performance indicators collected during structured training are lacking in young female soccer players. Therefore, changes in 5-m acceleration, 20-m speed, change-of-direction speed and repeated-sprint ability were quantified during a three-year period in an FA Centre of Excellence. Fourteen players (mean age = 12.1 years, SD = ± 0.9) were recruited and their best performance scores from pre-season and in-season testing were averaged. Players were typically exposed to soccer (2 x 90 min per week) and strength and conditioning training (1 x 70 min per week) and played 20 soccer matches (50-80 min) during 35-week seasons. Mean ($\pm 90\%$ CL) overall improvements over the three years were 5.9% (1.3) (*most likely large*) for speed, 4.0% (1.0) (*most likely large*) for repeated-sprint ability, 8.8% (1.1) for acceleration and 8.3% (1.4) for change-of-direction speed (both *most likely very large*). Improvements between years one and two ranged from *most likely moderate* to very large. Further small improvements in change-of-direction speed and 20-m speed (both *likely*) were observed between years two and three. Individual differences in response were apparent only for change-of-direction speed, which were moderate and small between years two and three. *Most likely very large* to near perfect within-player correlations were observed between maturation and sprint measures. These data from a single-arm longitudinal study indicate that systematic exposure to training, which includes one dedicated strength and conditioning session each week, is associated with improvements in sprint related physical qualities in girls.

Key words: LTAD; speed; youth sport; soccer

INTRODUCTION

There are approximately 29 million females who play soccer in the world (13). Soccer is also the most popular female team sport in the United Kingdom (45). The optimal development of elite players is part of the Fédération Internationale de Football Association's (FIFA) strategy for the sport. The importance of this development is highlighted in England by the implementation of new 'Regional Talent Clubs' for girls. It is also recognised that there is an association between physical attributes and performance in female soccer players (38).

Long-term athlete development models, such as those proposed by Balyi and Hamilton (3,33) provide a logical framework for coaches to design training in relation to biological maturation, but these models lack extensive physiological evidence (14). The Youth Physical Development Model (3,33) provides more contemporary evidence-based recommendations, emphasizing strength, power, speed, agility and fundamental movement skills, but there is a relative paucity of longitudinal data directly supporting such recommendations in girls' soccer, despite its popularity. Furthermore, gender differences are apparent in the relationship between physical development and maturation. Rapid improvements in physical attributes are observed around the onset of puberty in boys' soccer players (43). In contrast, and without exposure to systematic training, girls have been shown to reach a plateau in sprint performance at around 15 years of age whilst boys continue to improve annually until adulthood is reached (41). Similarly sprint related physical qualities appear not to improve linearly in girls' soccer players. Vesconvi et al., (50) reported no statistically significant differences in 9.2-m speed across the entire age range studied (12-21 years) nor in 18.2-m speed in players after 14 years of age, while Haugen et al., (21) reported no statistically significant differences in 20-m sprinting across age ranges from under 18's to over 25's.

Physical attributes have been shown to differentiate between playing standard in females. Top class players perform more high-intensity running and sprinting during matches than those at a lower level in both men and women (33) and both agility and soccer specific fitness differentiate between youth and senior female players (34). Straight-line sprinting, without the ball, is reportedly the most frequent explosive action when scoring or assisting a goal in professional soccer (12) and acceleration ability appears important in team sport athletes (8,10). Furthermore, a players' physical capacity has been shown to determine the number of such high intensity actions they are able to perform in an elite female soccer match (31). The ability of a player to repeat sprints or high intensity efforts with relatively short recovery is an important physical quality to attenuate the reductions in performance throughout elite women's soccer matches (17) and can also discriminate between playing level (16). Furthermore, change-of-direction speed is a key component of agility, a construct that also encompasses perceptual and decision making processes (44) and important to team sport performance (34,42).

Despite the association with sports performance, noticeable lower physical capabilities have been reported in female players in comparison to males (38,39). Girls' soccer players have less soccer-specific fitness than boys (7,39) and boys tend to experience larger age related changes in fitness (9). This disparity may be partially explained by anatomical or physiological differences, such as post pubertal increases in fat mass, joint laxity and rates of increases in height, weight and neuromuscular strength (3,33), but clearly training status is critical in determining physical performance (31,38,39). Furthermore, improving neuromuscular capacity in teenage girls, may simultaneously reduce risk factors for injury (46). As such, understanding how girls develop sprint related physical qualities over time may be important in evaluating player development programs.

The acute effects of training interventions have shown girls' soccer players are responsive to training interventions, although this may depend on their stage of maturation (53). Physical performance in girls' soccer players fluctuates throughout a season which may be a result of adaptations to training stimuli, changes in maturation, acute effects of fatigue or additional noise within these data (48). As such, there is a need to understand the longitudinal responses of girls' soccer players. Exposure to systematic training over a three-year period within an English Premier League boys' academy has shown beneficial effects on physical attributes independent from changes in maturation or initial physical performance (54). These data suggest that the systematic training exposure of academy players may be responsible for the differences in physical performance to non-academy players (54). However, to the authors knowledge no researcher has attempted to quantify the long-term changes in physical performance during a period of systematic training in girls' soccer players. Thus, the aim of this paper was to track the development of sprint related physical qualities in players over a three-year period within a girls' soccer center of excellence program.

METHODS

Experimental Approach to the Problem

A single-arm quasi-experimental study design was used to quantify longer-term changes in 5-m acceleration, 20-m speed, change-of-direction speed and repeated-sprint ability in girls' soccer players from an English FA Centre of Excellence.

Subjects

Following institutional ethics approval from the Teesside University School of Social Sciences Business and Law ethics committee, players from an English Girls' Football Centre of

Excellence were evaluated for stature, mass and performance measures over a three-year period. Data were collected before and after pre-season training (July and September) and during the season (December and May). Medical questionnaires, informed consent and parental consent were obtained before the start of the data collection period and subsequently annually prior to pre-season testing. From an initial sample of 32 players, a total of 14 (age 12.1 ± 0.9 years) players who attended three of the four tests each year were included in this study. Player availability for testing was effected randomly by illness or other commitments, e.g. school events or family holidays, but not due to a lack of fidelity to the program. Subject characteristics are presented in Table 1.

****Table 1 near here****

Procedures

Mass, standing height and sitting height were measured prior to each testing session and were used with the players' chronological age to predicted biological maturation using the maturity offset, expressed as years from peak height velocity (37). After a standardized warm-up, consisting of light jogging and dynamic mobility, change-of-direction drills and short sprints, five-meter acceleration, 20-meter speed, change-of-direction speed and repeated-sprint ability were assessed. For detailed explanation of the testing procedures and typical error of the measures in this population we refer to our previous work (48). Repeated-sprint ability was assessed over 6×40 m shuttle runs with 20 s recovery between sprints (28). The best time to complete the 10 m section of the 40 m shuttle run between 15 and 25 m, where a 180-degree turn occurred was recorded as the change-of-direction speed. To reduce the effects of within season variation in fitness (48) the players' best scores from pre-season and in-season testing were averaged.

Training and match exposure

Players were typically exposed to soccer training (2 x 90 minutes), strength and conditioning (1 x 70 minutes) and a match (1 x 50-80 minutes) each week through the season. Approximately, 20 fixtures are played throughout a 35-week season and preseason training typically last around eight weeks. While direct quantification of training load throughout the three-year period was not possible, we have previously presented a snap shot of typical loading these players are exposed to, taken over 17 weeks in 35 players (49). Average weekly RPE-load of 2157 ± 454 arbitrary units were observed and typically soccer accounted for $37 \pm 13\%$ of total load, strength and conditioning $28 \pm 12\%$ and other activity outside of the centre of excellence $36 \pm 10\%$. These other activities included physical education, school soccer and other structured sport such as netball, cricket or judo, however higher within- than between-subject differences in weekly load were apparent, and it is unlikely this constituted a consistent training stimulus. The strength and conditioning session included fundamental movement skill development, proprioceptive, plyometric and resistance training prescribed using the model of progression and regression based upon individual competence, as discussed by Wright and Laas (51).

Statistical analyses

Data were log-transformed prior to analysis and the subsequent summary statistics were back-transformed to obtain equivalent percentage changes using a custom-made spreadsheet (25). Uncertainty of the estimate was described by calculating 90% confidence limits. Magnitude-based inferences were based on the disposition of the confidence limits for the mean difference to the smallest-worthwhile change. This smallest worthwhile change for 5-m acceleration and 20-m speed was defined as per recommendations by Haugen and Buchheit (20) who suggest a change of 4% (5-m acceleration) and 1% (20-m speed). This is equivalent to an approximately

20 cm performance gain and are based on the improvements in running speeds required to win the ball in one-on-one duals, by having the shoulder in front of the opposing player (21). In the absence of a direct anchor between our measures of change-of-direction or repeated-sprint speed and an important change in actual soccer performance the smallest worthwhile change here was defined as 0.2 of the between-participants standard deviation.

The probability that a change in testing scores was beneficial, harmful or trivial was identified according to the magnitude-based inferences approach (4). Descriptors were assigned using the following scales: 0.5%–5%, very unlikely; 5%–25%, unlikely; 25%–75%, possibly; 75%–95% likely; 95%–99.5% very likely; >99.5% most likely (23). An effect was defined as substantial using mechanistic inferences, i.e. with greater than 25% chance of benefit (improvement) and <5% chance of harm (performance decrement) or *visa versa*. The magnitude of responses was evaluated through standardised differences in the means using the following thresholds <0.2 trivial, <0.6 small, <1.2 moderate, <2 large, <4, very large ≥ 4 extremely large (23).

Magnitude-based inferences were also quantified on individual level using a separate custom-made spreadsheet (24) for each player over the three-year period. Players were categorized as improving or decreasing performance if the likelihood of a beneficial or harmful effect was >66% respectively. The magnitude of the individual responses were calculated as recommended previously (2,26) however, without a control group, typical error of estimate was used to reduce the likelihood of noise masquerading as individual responses (e.g. (53)). The magnitude of the individual responses was described by halving the aforementioned thresholds for trivial, small, large, very large and extremely large. The relationship between maturation and performance was assessed by within-subject correlation as recommended (5) using a

computer software package (SPSS, c.22 Armonk, NY: IBM Corp.) within a general linear model.

RESULTS

Large to very large improvements were observed in all measures over the three-year period. Improvements were moderate to very large between year one and year two with further small improvements between year two and year three in speed and change-of-direction speed although effects on acceleration and repeated-sprint ability were trivial. Individual variation in the response for change-of-direction speed was small between years one and two and moderate between years one and three. Most likely very large or near perfect within-player correlations were observed between maturation and change in acceleration and speed ($r = 0.89 \pm 90\%$ confidence limit 0.11) and change-of-direction speed ($r = 0.92 \pm 0.1$) and repeated-sprint ability ($r = 0.92 \pm 0.09$). Data for the group is presented in Table 2, the individual within-player correlations in Figure 1 and the individual responses in Figure 2.

****Table 2 near here****

****Figure 1 near here****

DISCUSSION

In the present single-arm quasi-experimental study, we aimed to track sprint related physical qualities over three years of systematic exposure to training in a girls' soccer centre of excellence. Large to very large improvements were observed over three years of exposure in all tests. Improvements were greatest between years one and two of the pregame, which could reflect the beginning of the plateau in fitness in girls post peak height velocity (9). Nevertheless,

very likely small improvements were still observed in speed and change-of-direction speed between years two and three and we found very large to near perfect within-player correlations between maturation and testing scores. As such, we observed a more linear relationship between physical qualities and maturation than in previous studies (9,41). These data also compare well with previously reported changes over three years in boys' players (54). The girls in our study were initially slower over 20-m than academy players (mean $3.24 \pm$ standard deviation 0.16 s) but comparable to non-academy players (3.5 ± 0.16 s). However, their improvement in speed was less than the boys' academy players 0.21 ± 0.08 s versus 0.31 ± 0.16 s, but greater than non-academy players 0.13 ± 0.13 s. Our findings provide some support for the trainability of girls' in sprint related physical qualities but to ensure continued progression in players with increased training age practitioners may need to employ methods to ensure a sensible but progressive training stimulus to further drive adaptations.

****Figure 2 near here****

We observed a greater magnitude of improvement in change-of-direction than in straight-line 20-metre speed over three years, supporting previous research in girls' soccer (50). Changing direction is multifaceted requiring neuromuscular attributes to be translated into good technique, e.g. lowering of centre of mass and applying horizontally orientated force (44). Our change-of-direction test required straight-line speed, deceleration and re-acceleration to be performed in a co-ordinated manner. Aforementioned improvements in straight line speed may contribute to improved change-of-direction speed but, greater speed taken into the change-of-direction requires a proportional increase in eccentric control to decelerate and, whilst not measured directly, these data suggest the players' ability to decelerate may have improved too. Change-of-direction speed appears to decline temporarily around peak height velocity in both boys' and girls' soccer players which may be a result of a temporary loss of co-ordination or

“adolescent awkwardness” declining technique (43,53). This has connotations for both performance and injury risk given neuromuscular control on landing and deceleration are associated with ACL injury risk (22,30). In this study players were exposed to strength and conditioning training which included neuromuscular training methods to control and reduce force during deceleration e.g. (1,51). Previous research has reported a positive relationship between long-term exposure to strength training and change-of-direction performance in young male soccer players (29). Length of exposure to resistance training significantly effects measures of strength, explosive power and agility in youths while frequency of training does not (32). Despite exposure to only one session per week we speculate this may have been important in driving the neuromuscular adaptations (e.g. increase in neural drive, co-ordination or improved fundamental movement skills) that are likely to improve deceleration technique during direction change (34). Our data suggest when girls' players are exposed to systematic training, change-of-direction speed can improve and any reductions in performance throughout peak height velocity may be temporary. Furthermore, whilst small to moderate individual differences in the magnitude of the response were observed all players possibly, likely or very likely improved their performance between years one and three.

Very large improvements were shown in repeated-sprint ability over three years but the effect was trivial between years two and three. Near perfect correlations were observed between maturation and repeated-sprint ability. These data support previous research demonstrating repeated-sprint ability improves in line with maturation in boys' soccer players until u15's (40). The ability to perform repeated sprints can be limited by a variety of muscular, metabolic or neurological factors (19). Children have a lower glycolytic capacity to supply adenosine triphosphate during high-intensity exercise (6) and repeated-sprint performance has previously been associated with increased glycolytic capacity in boys (40). Therefore, age related development of anaerobic glycolysis may, in part, explain these results. Although, given we

have previously reported the strong association between change-of-direction speed and repeated-sprint performance in the same cohort (52) we cannot discount the influence of improved efficiency in changing direction.

Limitations to methodology

A limitation of this single-arm study is the lack of a control group. We found it difficult to recruit age-matched and appropriate control participants for this study population and over the full duration of the study. Although a control group was absent, in keeping with quasi-experimental analyses, we quantified the relationship between change in maturation status and longitudinal change in performance using a general linear model and found very large to near perfect correlations. This finding is interesting given the non-linear relationship shown in fitness qualities in girls previously, where a performance plateau has been observed (9,35,41). Exposure to systematic training in maturing girls in our study demonstrated a more linear relationship and, even without a direct comparator group, provide evidence for the trainability of girls' soccer players.

Another advantage of controlled trials is that changes in a control group account for noise in the measures. By providing analysis on an individual level, we have both provided greater insight into the individual responses of the players and have, at least partly, accounted for noise. The analysis adopted here takes into account noise using the typical error of the estimate from test-retest data taken one week apart (48) which may not truly reflect the noise over extended periods of time. It is recommended typical error be derived from test-retest data taken over the same period as an intervention and include more than two data points per player (27), unfortunately this is not always practical. Despite these limitations, we present the first data on the development of speed related physical qualities in girls' soccer players over the course of a talent development program. The methodology and statistical analysis is

sufficiently robust to provide important data for practitioners working with this cohort to help inform training and monitoring program. However, care must be taken in extrapolating the findings beyond the current population and practitioners must ensure they monitor interventions in their own environment.

We should also consider limitations to our methods of measuring player performance and maturation. For example, whilst repeated-sprint ability has been proposed as an important physical quality in women's soccer, its validity as a dependent variable has recently been questioned within the literature (47). However, repeated sprints do appear more common in female team sports (47) and we chose a test that has been validated (28) and demonstrated appropriate reliability in girls' soccer players (48). The prediction of biological maturation is also an area of controversy and the authors of a recent meta-analysis suggest maturity offset may overestimate the timing of peak height velocity when applied in year or stage of maturation (36). However, alternative estimates based on skeletal age or secondary sex characteristics are impractical or invasive (11). The equation based method we chose is reliable (36) and we analyzed continuous data, thus avoiding categorizing players as before, during or after peak height velocity and limiting some of the major disadvantages of this technique.

PRACTICAL APPLICATIONS

Large to very large improvements in sprint related physical qualities were observed in girls' soccer players throughout a talent development programme. Whilst, it was beyond the scope of this study to investigate individual session typologies, given the neuromuscular deficit in girls (22) and the wealth of evidence for neuromuscular training (46) then the inclusion of a dedicated strength and conditioning session each week (60-70 minutes) focusing on neuromuscular development is recommended. This may not only reduce injury potential but also contribute to improvements in physical performance. However, to increase the training

response and reduce the gender gap in soccer players (39) it is possible that girls' talented development programmes need to, sensibly, advance the training prescription as a players' training age within the programme increases. This may require closer individual monitoring of players to ensure the risk of injury is managed, but sensible progression of training loads may paradoxically protect players from injury and increase physical performance outcomes (18). Training should be supervised by an appropriately qualified professional and a progressive curriculum of activities that include the following are recommended; fundamental movement skills, dynamic stability, proprioception or coordination training, plyometric training (progressing from low to high intensity, single to multiple sets of 6-10 repetitions), speed and agility (34) and strength training (e.g. 2-5 sets of 6 -15 repetitions, progressing from fundamental movements such as; the squat, lunge or push up, to sports specific exercises, or by increasing load or velocity over time) (15,33,51). Specific recommendations for practitioners to prescribe metabolic and neuromuscular training for girls soccer players have been published previously (51).

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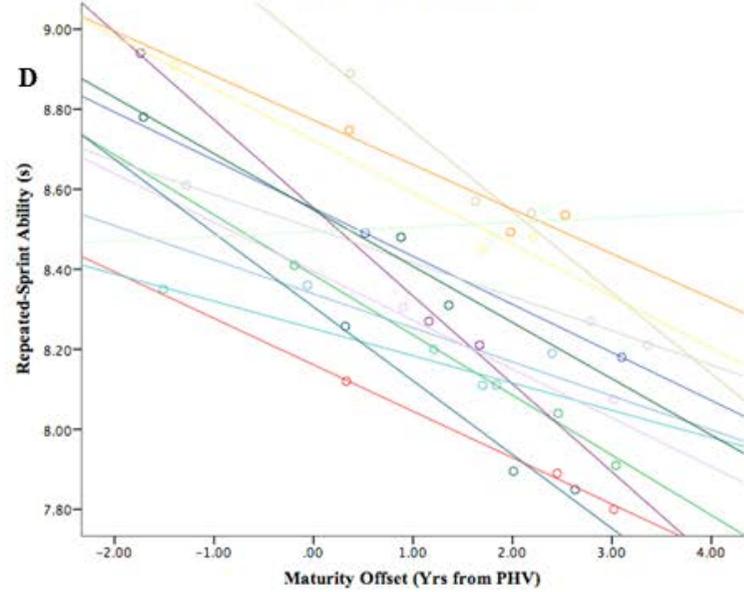
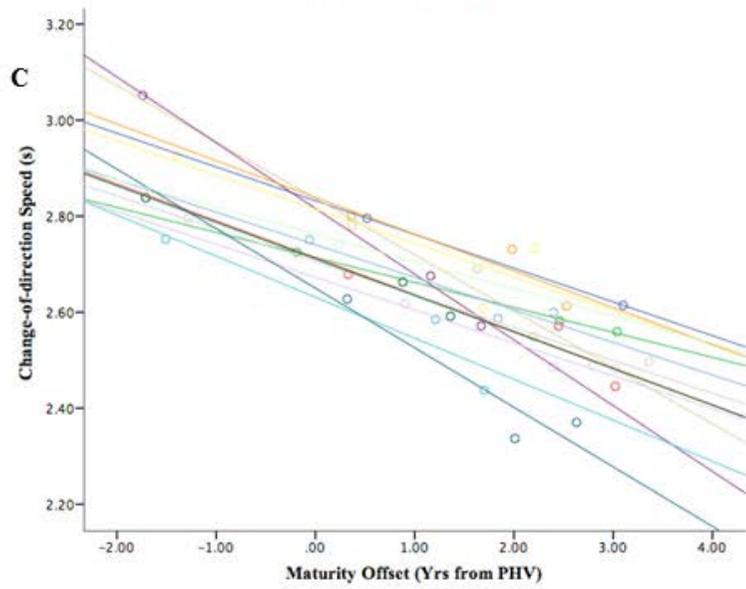
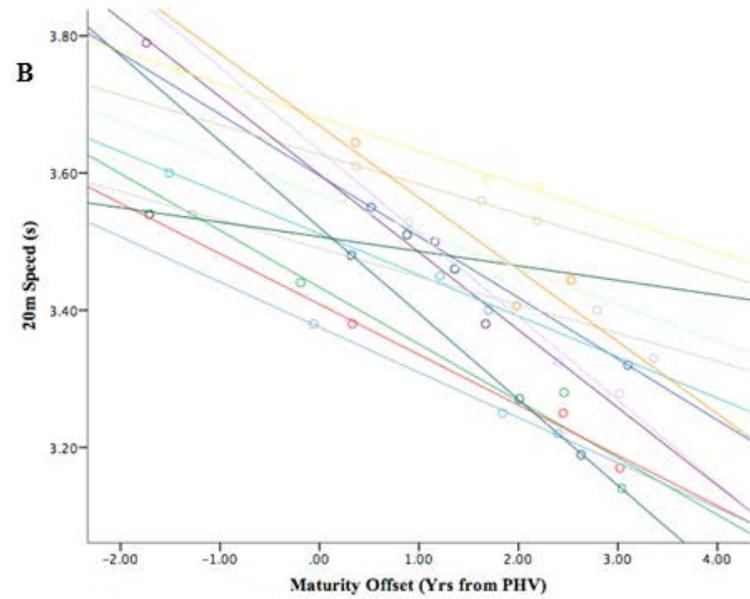
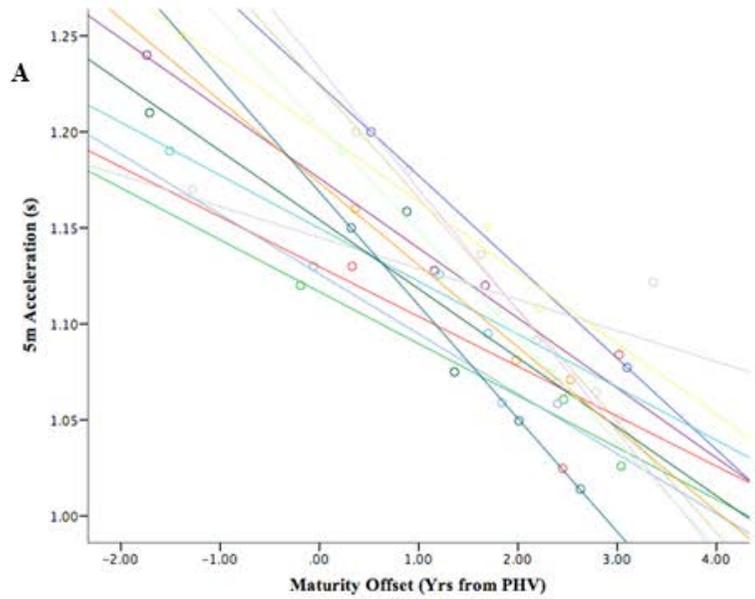
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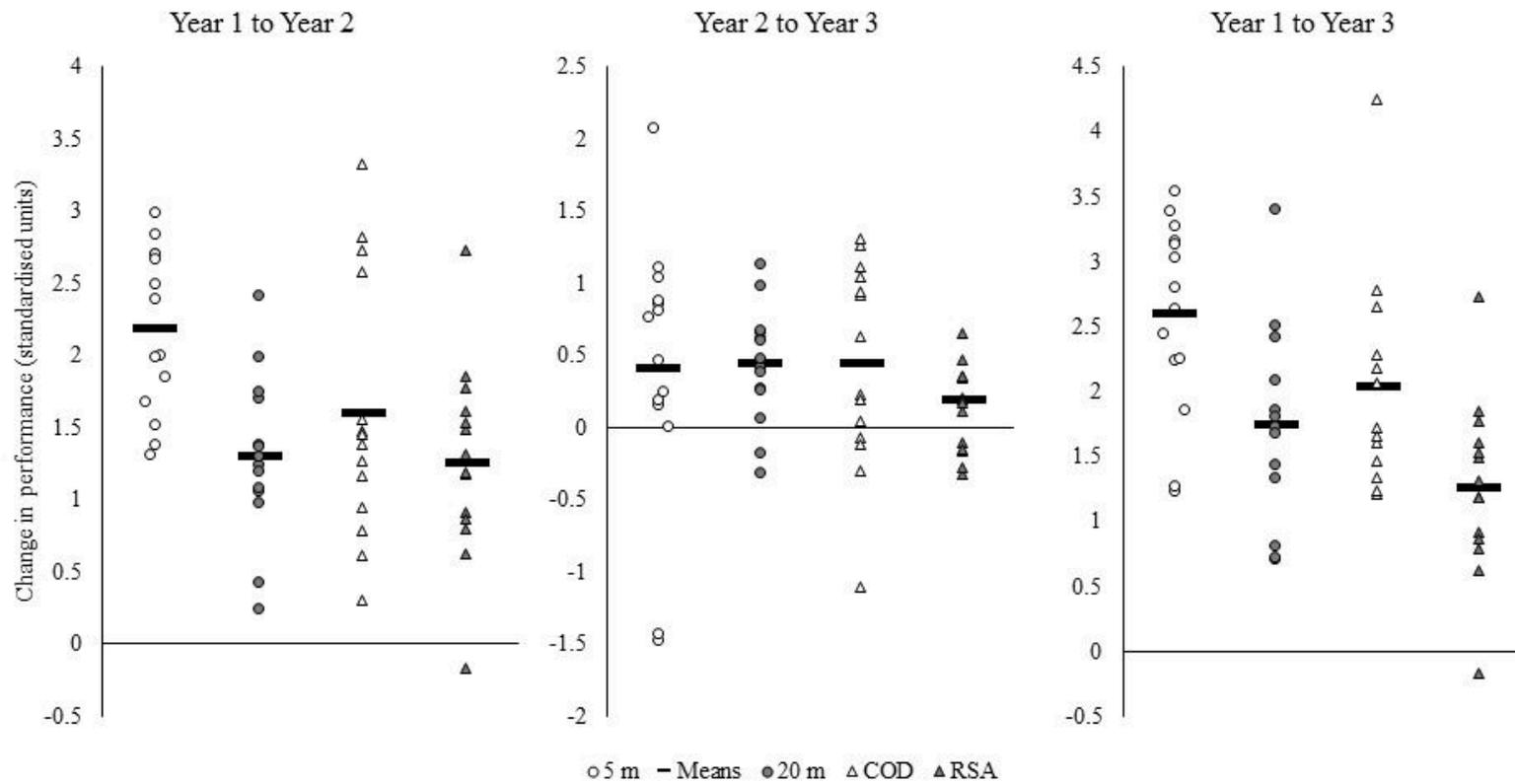
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Figure Legends

Figure 1: Individual within-player associations between maturity offset and sprint test performance.

Figure 2: Distribution of individual responses in sprint performance and numbers of players categorized as improving or decreasing performance. Values are presented in standardized units with positive values indicating faster sprint times.





	Year 1 and Year 3				Year 1 to Year 2				Year 2 to Year 3							
	5 m		20 m		COD		RSA		5 m		20 m		COD		RSA	
	↓	↑	↓	↑	↓	↑	↓	↑	↓	↑	↓	↑	↓	↑	↓	↑
Possibly		2	2	2	3			8		2	1		2	2	4	
Likely		12	8	11	3	12		8	3	3		2			2	
Very Likely			3	1	2			3		5						
Most Likely			1		8			1		5						

↓ Greater than a 66% chance of performance decrement; ↑ Greater than a 66% chance of performance improvement

Table 1: Subject characteristics

Variable	Mean \pm SD
Age (years)	12.1 \pm 0.9
Stature (cm)	148.2 \pm 8.9
Sitting Height (cm)	76.3 \pm 4.5
Body Mass (kg)	38.8 \pm 6.9
Year 1 maturity offset (years)	-0.4 \pm 1
Year 2 maturity offset (years)	-1.9 \pm 0.6
Year 3 maturity offset (years)	-2.5 \pm 0.6

Table 2: Raw data, percentage change and magnitude based inferences with individual responses.

	Raw Data (mean \pm SD)			% Change \pm 90% CL and Practical Inference		
	Year 1	Year 2	Year 3	Year 1 to Year 2	Year 2 to Year 3	Year 1 to Year 3
5m Acceleration	1.18 \pm 0.04 s	1.09 \pm 0.04 s	1.08 \pm 0.03 s	\uparrow 7.4 \pm 1.0 (VL****)	\uparrow 1.5 \pm 1.6 (T****)	\uparrow 8.8 \pm 1.1 (VL****)
20m Speed	3.56 \pm 0.12 s	3.4 \pm 0.11 s	3.35 \pm 0.14 s	\uparrow 4.4 \pm 0.9 (L****)	\uparrow 1.6 \pm 0.7 (S**)	\uparrow 5.9 \pm 1.3 (L****)
COD Speed	2.78 \pm 0.11 s	2.6 \pm 0.11 s	2.55 \pm 0.09 s	\uparrow 6.5 \pm 1.7 (L****)	\uparrow 1.9 \pm 1.5 (S***)	\uparrow 8.3 \pm 1.4 (VL****)
				IR 0.5 \pm 0.8 (M)		IR 0.3 \pm 0.7 (S)
RSA	8.55 \pm 0.27 s	8.25 \pm 0.23 s	8.21 \pm 0.25 s	\uparrow 3.5 \pm 0.8 (M****)	-0.4 \pm 0.5 (T**)	\uparrow 4.0 \pm 1.0 (VL****)

Magnitude of the response: Trivial (T), Small (S), Moderate (M), Large (L), Very Large (VL)

Probabilities: Possibly* Likely** Very Likely*** Most Likely****

Individual Responses (IR) expressed as standard deviations

Faster \uparrow Slower \downarrow