THE INFLUENCE OF AGE ON THE ANTHROPOMETRIC AND PERFORMANCE CHARACTERISTICS OF HIGH LEVEL YOUTH FEMALE SOCCER PLAYERS

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ABSTRACT

The purpose of this study was to evaluate the anthropometric and performance characteristics of high level youth female soccer players by annual-age category (U10-U16). Data were collected from 157 female soccer players (U16*; n*=46, U14*; n*=43, U12*; n*=38, U10*; n*=30), recruited from three high level female soccer academies in England. Players completed assessments of anthropometry (height and body mass), isometric mid-thigh pull strength (IMTP), jump height (CMJ), aerobic capacity (YYIRL1), change of direction (505-left/right), and speed (10 and 30 m). Magnitude based-inferences were used to assess for practical significance between consecutive age groups. Height (*very likely* – *most likely*), body mass (*very likely* – *most likely*), absolute strength (*most likely*), jump height (*likely* – *very likely*), and distance on the YYIRL1 (*possibly* – *most likely*) were greater in older players. Both speed and change of direction time were *most likely* to *very likely* lower in older players. However, only *most likely trivial-possibly trivial* differences were observed in relative strength between age groups. Findings suggest that physical characteristics except for relative strength differentiate by age categories. These findings provide comparative data and target reference data for such populations and can be used by coaches and practitioners for player development purposes. Practitioners should be aware that relative strength does not differ between age categories in high level youth female soccer players.

Key words: soccer, youth, fitness, performance, anthropometry

INTRODUCTION

Soccer is an intermittent team sport, played worldwide at amateur to professional levels at all ages[1]. In recent years an increased popularity of female soccer has resulted in an increase in participation and more opportunities to play soccer professionally in Europe and the United States of America (USA)[2]. During matches, elite female soccer players have been reported to cover a total distance of ~10 km, with 1.53–1.68 km at high speeds (>15-16 $km \cdot h^{-1}$)[3]. The distance covered during high-intensity and sprinting activities are known to be the main determinants between higher and lower standards of play with elite female players reported to complete 28% more high speed running and 24% greater distance sprinting compared to non-elite level players[4]. Furthermore, it is the explosive actions such as sprinting, jumping, tackling and change of direction (CoD) that appear to influence the outcome of games[5]. Such demands necessitate that players demonstrate a high level of athleticism (i.e. speed, power, strength, aerobic capacity). As such it is important that these physical qualities are developed through structured and progressive strength and conditioning training, in conjunction with field based technical/tactical sessions. Furthermore, the English Football Association (FA) have suggested female soccer players require more 'athleticism' compared to current levels observed in order to compete at an international level and coaches should look to develop athleticism in young players[6].

To support this growth and development of female soccer, the FA in England have created elite Regional Talent Centre's (RTC's) for the identification and development of the next generation of female soccer players, similar to the processes in the men's game (e.g., English Player Performance Plan; EPPP;[7]). The RTC's operate within youth age categories (i.e., Under 10 [U10], U12, U14 and U16), whereby girls are selected to train and compete to develop technical, tactical, psychological and physical qualities, all paramount to soccer performance[3]. Within the RTC's players regularly undertake fitness testing to monitor their physical development.

However, to date research examining the physical qualities of youth female players is limited. As such it is difficult for practitioners working with this cohort to evaluate the physical characteristics of players and develop physical development programmes for these players accordingly. Taylor et al.[8] explored the physical characteristics of youth female soccer players, however the sample size was limited with only 2 age categories (U13 and U15) included and 9-10 participants per age group which are not representative of the current age group structuring at the FA and therefore are limited. Povoas et al.[9] investigated the development of aerobic fitness in 9-16 year old trained Portuguese female soccer players, however different versions of the Yo-Yo test were used at different age groups making comparisons difficult. The physical characteristics of U12-U21 female soccer players from the USA have been investigated[10] but the testing battery did not include anthropometry, aerobic capacity or strength, which are important considerations in the physical assessment and development of youth soccer players[11]. Furthermore, the training systems implemented in female soccer in Portugal and the USA are different to the RTC's in England. Finally, with the increased professionalism within female soccer (i.e., structured strength and conditioning), data presented by Vesocovi et al.[10] may not be reflective of the physical characteristics of current youth female players in England. Therefore, the presentation of up to date sex specific physical characteristics of youth female soccer players is necessary for use by strength and conditioning coaches to inform training prescription design.

the purpose of the current study was to present the anthropometric and performance characteristics of high level youth female soccer players aged 9-16 years in England. The secondary purpose was to evaluate the differences in anthropometric and performance characteristics between age categories (i.e., U10, U12, U14 and U16).

METHODS

Experimental Approach to the Problem

A cross-sectional study design was conducted to evaluate the anthropometric and performance characteristics of high level youth female soccer players by age category. All participants undertook an anthropometric and physical testing battery at the start of the 2016-2017 season (i.e., September). Testing was conducted a minimum of 48 hours post competitive match play or training at each respective RTC. The testing battery included assessments of anthropometry (height and body mass), strength (isometric mid-thigh pull [IMTP]), lower body power (countermovement jump [CMJ]), change of direction (505 test; left and right), speed (10 and 30m) and Yo-Yo intermittent recovery test level 1 (YYIRL1). The YYIRL1 was not conducted at U10 as this was not current practice at the RTC's and not routinely part of the clubs testing battery. With the exception of IMTP, the testing battery was consistent with the testing battery players regularly undertake within the academies. A standardized warm-up, including jogging, dynamic movements, and stretches was carried out before testing, followed by full instruction and demonstrations of the assessments. The sprint, CoD and YYIRL1 tests were all carried out on an indoor surface with players wearing trainers to ensure consistency in the surface and conditions. All testing was undertaken by the lead researcher.

Subjects

One hundred and fifty seven female soccer players (U10, n=30; U12, n=38, U14, n=43, U16, n=46) were recruited from three Tier 1 female soccer RTC's in England. All subjects were free from injury at the time of the study. U10 and U12 groups trained twice per week and U14 and U16 groups trained three times per week. Each age group had one competitive fixture per week during the season. Prior to participation, institutional ethics approval and assent was provided by players and their parents/guardians after being made aware of the benefits and risks of the study. Age categories were defined by chronological age on the 1st September 2016, which established their status for competition.

Procedures

Anthropometry

Participants standing height (cm) was recorded to the nearest 0.1cm using a 132 Seca Alpha stadiometer (model 2251821009, Germany). Body mass (kg) was measured to the nearest 0.1kg using calibrated Seca Alpha (model 770, Germany) scales.

Strength

The IMTP was performed on a portable force platform (AMTI, ACP, Watertown, MA) with a sampling rate of 1,000 Hz, which is consistent with previous methodologies[12]. Participants performed the IMTP on a customized pull rack, using a self-selected position similar to that of the second pull of a power clean, with a flat trunk position and their shoulders in line with the bar[11]. The self-selected position was preferred, as differences in knee and hip joint angles during the IMTP have previously been shown to have no influence on kinetic variables[13]. Participants were given two practice maximal trials prior to testing commencing. Participants were instructed to pull as "fast and hard" as possible, and received loud, verbal encouragement[12].

Each participant completed two trials lasting 5 secs, with 5 mins rest between each trial. The start of the IMTP was identified in the software using a 5 standard deviations (SD) gathered from a 1 second standing noise period before the start of the pull. Previous literature has suggested an onset threshold of 5 SD as it accounts for the signal noise during the weighing period and therefore there is a greater certainty that the onset of contraction identifies a true meaningful change in force[11]. The highest peak force (PF) achieved over the 2 trials was considered the participants 'best trial' and recorded for analysis. Relative PF was calculated using the ratio scaling method (i.e. PF / body mass)[14]. Intraclass correlation coefficients (ICC) and coefficient of variation (CV) for PF were r=0.933, CV=3.6%.

Lower Body Power

Lower body power was assessed using a CMJ. The CMJ were performed as described by Le Gall et al.[10], using a portable photoelectric cell system (Optojump; Microgate, Bolzano, Italy). This equipment has been reported to be reliable (CV=6%) and valid for CMJ assessment compared with a biomechanical force plate[15]. Jump height was calculated using the cell system software (Optojump Next v1.7.9; Microgate). Participants completed 3 submaximal CMJ efforts prior to testing commencing. The CMJ started from an upright position. When given a verbal command, the subject made the downward countermovement to their preferred depth and then jumped as high as possible. Subjects were allowed to use their arms during the swing phase of the jump[5,11], and were required to maintain straight legs while airborne. The highest jump was selected for analysis from the 3 repetitions completed with 2 mins recovery between jumps. ICC and CV's for CMJ were r=0.957, CV=4.5%.

Change of Direction Speed

Change of direction (CoD) speed was assessed using the 505 test[17]. Timing gates (Brower Timing Systems, IR Emit, USA) were placed 10m from the start point. The participants accelerated from the start, through the timing gates, turning 180^{0} at the 15m mark and sprinted back through the timing gates. Participants completed 3 alternate attempts of turning off each foot, separated by a 2–3 mins rest period. Only attempts whereby the participant's foot crossed the 15m mark were recorded. Times were recorded to the nearest 0.01 sec with the quickest of the 3 attempts used. Data are presented as dominant (D) or non-dominant (ND) foot based on preferred kicking foot. ICC and CV for the 505 test were r=0.99, CV=2.2%.

Speed

Sprint time was assessed over 10 and 30m using timing gates (Brower Timing Systems, IR Emit, USA). Participants started 0.5m behind the initial timing gate and were instructed to set off in their own time and run maximally past the 30m timing gate. Each subject had 3 attempts, separated by a 3 min rest period. Times were recorded to the nearest 0.01 sec with the quickest of the three attempts used for the 10m and 30m speed score. ICC and CV's for 10 and 30m sprint time were *r*=0.76, CV=4.8% and *r*=0.78, CV=3.9%, respectively.

Aerobic Capacity

The YYIRL1 was used as a *proxy* measure of aerobic capacity, due to the validity of the test for the assessment of soccer specific fitness[16]. The test consisted of repeated 20m shuttle runs at progressively increasing speeds dictated by an audio bleep emitted from a CD player. Between each shuttle there was a recovery period of 10 sec, involving walking around a marker placed 5 m behind the finishing line. Failure to achieve the shuttle run in time on two occasions resulted in termination of the test. Total running distance, including the last missed shuttle was recorded and reported. ICC and CV for the YYIRL1 test have been reported as *r*=0.98, CV=4.9%[16].

Statistical Analyses

Data are presented as mean ± SD by annual-age category, with comparisons made between consecutive age groups (e.g., U10 vs. U12). All data were log transformed to reduce bias as a result of non-uniformity error. Magnitude based-inferences were used to assess for practical significance[18]. The threshold for a difference to be considered practically important (the smallest worthwhile difference; SWD) was set at 0.2 x between subject SD for the comparison groups, based on Cohen's *d* effect size (ES) principle. The probability that the magnitude of difference was greater than the SWD was rated as <0.5%, *almost certainly not*; 0.5-5%, *very unlikely*; 5-25%, *unlikely*; 25-75%, *possibly*; 75-95%, *likely*; 95-99.5%, *very likely*; >99.5%, *almost certainly* (16). Where the 90% Confidence Interval (CI) crossed both the upper and lower boundaries of the SWD (ES±0.2), the magnitude of difference was described as *unclear*[18].

RESULTS

The performance characteristics of elite youth female soccer players by annual age category and standardized differences between consecutive age groups are presented in Table 1.

Insert Table 1 here

Height and body mass were *most likely* to *very likely* greater in each successive older age groups. Peak force was *most likely* greater for older age groups, however relative PF was *possibly* to *most likely trivial* between consecutive age groups. Differences in CMJ height were *likely* to *very likely* greater in older players. YYIRL1 was *most likely* to *possibly* greater in older players. Both 10 and 30 m sprint times were *most likely* to *very likely* lower in older players between U10-U12 and U14-16, and *possibly* lower between U12-U14. 505 CoD was *very likely* to *very likely* lower in older age groups.

DISCUSSION

This is the first study to present the anthropometric and performance characteristics of youth female soccer players in England. The findings from this research provide novel reference data for high level youth female soccer players, aged 9-16 years and suggest that height, body mass, absolute strength, lower body power, CoD and speed improved in older youth female soccer players, although no differences for relative strength were observed. The findings of this study can be used for both player development purposes and to inform the design of individual specific strength and conditioning programmes for youth female soccer players.

This study showed that the mean height and body mass of players in this study were smaller and lighter than that reported for female Portuguese players at 9-11 years (Age 9.7±0.7 yrs., Height: 141.0±5.3 cm, body mass: 36.1±6.8 kg), 12-13 years (Age: 12.5±0.9 yrs., Height: 155.7±6.4 cm, body mass: 55.2±14.0 kg) and 14-16 years (Age: 14.8±0.8 yrs., Height: 164.6±7.6

cm, body mass: 57.5±8.5 kg[9]). Anthropometric characteristics were greater in older players, with a similar likelihood of difference demonstrated between each consecutive age group for height and body mass. Differences in height and body mass are associated with increased maturity with increasing chronological age, along with the biological, morphological, hormonal and neurological changes that occur during this period of development[21].

The strength data presented in this study is the first in either male or female youth soccer players, assessed via an IMTP. The IMTP was used rather than a three or five repetition maximum, which has been used in previous research with older players[13], as it offers a safe and reliable strength assessment when working with young athletes and has a strong correlation with dynamic performance[22]. Peak force was greater in older age groups, however relative PF demonstrated only *possibly* to *most likely trivial* differences between age categories. The greater absolute strength in older players is likely two-fold, attributed to biological changes including increased body mass with age[23] and an increased exposure to a structured strength and conditioning programme, with older players undertaking two structured strength and conditioning session per week. The limited difference in relative strength is important for practitioners, whom should acknowledge that relative strength does not increase with age. Changes in strength are likely a consequence of body mass increases with age. Although relative strength did not differentiate between age categories, specific training interventions may be warranted in this cohort. Strength is important for injury prevention, and soccer performance, given the known relationship with anterior-cruciate ligament (ACL) injuries in female athletes[24] and explosive activities[25]. There is limited contact time within an RTC, and strength and conditioning training is still a relatively new in youth female soccer[25].

Countermovement jump height was greater for older age groups However, CMJ height was less than previously observed in female soccer players (Junior [17.3 years] 33.1±3.2 cm and Senior [23.4 years] 38.8±4.8 cm[5]).. Given body mass and CMJ height were greater in older groups, this would suggest an exponential increase in power output with increasing age. Previous literature has also reported improvements in vertical jump performance until 15-16 years in youth female soccer players[10], likely due to growth-related changes in both leg length and muscle mass[28] and hormonal, muscular, and mechanical factors caused by the onset of puberty[29].

U16 players in the current study were quicker than 15-19 year old elite Australian female soccer players (U16: 2.53 ± 0.09 vs. 2.64±0.09s) on the 505 test[31]. CoD ability improved by age, with the greatest changes occurring between U12-U14. This is consistent with youth American female soccer players on the Illinois agility test, where large changes between 12–13 years were observed, followed by modest improvements between 15–16 years[10]. The underpinning mechanisms to explain such development in CoD are likely via nervous system development, governed by improvements in intra-muscular and inter-muscular coordination and general motor control improvement that children and adolescents experience between such chronological ages[21]. Warms ups prior to training may provide a good opportunity to develop CoD technique with supplementary strength training in the gym, further improving CoD ability.

Sprint times for U16 players in this study were quicker than observed in 15 to 19 year old elite Australian (U16: 1.96 ± 0.14 vs. 10m; 2.01 ± 0.08s[31]) players but slower than that reported for 18 to 20 years university female soccer players (10m 1.92 ± 0.13; 30m 4.78 ± 0.22s[32]). Speed has been suggested to develop to a similar magnitude in both male and females up until the age of 12 years[8]. Differences between younger male and female players may therefore be due to training exposure, or differences of expertise between the two training environments. Furthermore, speed development by age is based on population data[33], whereby the data discussed within this study is from trained soccer players that are selected (e.g., identified and invited to join the respective club). As such, deviations around mean population data may explain why male athletes are quicker than female athletes, if indeed females as a population are more homogenous than males. This again may have implications for mixed-sex soccer in England up to the age of U16.

Both 10 and 30m speed were quicker in older players. The greatest changes in speed were observed from U10-U12 (both 10 and 30m), which is likely due to very large increases in height and therefore stride length, as well as central nervous system adaptation that occur around this age[34]. Literature specific to adult athletes has suggested, sprinting ability over short (10m) and longer distances (30m) is considered to require separate and specific biomechanical and neuromuscular qualities and therefore training techniques[35, 36]. However, findings from this study suggest that indices of acceleration and maximal running speed in young soccer players might share common factors, which is consistent with findings in previous literature for female youth athletes[38] and suggests that both acceleration and maximal sprint speed can be developed using the same training variables in youth soccer players. Given the time restraints within a soccer academy, warm ups prior to field based sessions may provide a good opportunity to work on acceleration and maximum running speed in youth soccer players.

The YYIRL1 distance achieved by players in this study was less than observed in Portuguese trained female soccer players of a similar age (U12: 635 ± 241m vs. U9 to U11 Portuguese players; 705±316m, U14: 886 ± 334 m vs. U12 to U13 Portuguese players; 1214±487m, Povoas et al.[9]). Unfortunately, Povoas et al.[9] evaluated the aerobic capacity in U14 to U16 players using the YYIRL2, thus comparisons with the U14 and U16 players in this study are not possible. YYIRL1 distance for youth male soccer players (U11; 802±259m and U13; 1199±358m, Deprez et al.[27]) was greater than observed in the female players, which may have implications for mixed-sex soccer, which occurs in England up to the age of U16. Mean distance covered on the YYIRL1 for U16 players was 959±299m, which is less than that previously reported for elite senior female players (1224-1379m[5, 20]). Speculatively this is likely to be even higher now given the increased professionalism of the women's game over the last 10 years.

Older players achieved greater scores in the YYIRL1. The greater difference between U12-U14 compared to U14-U16 demonstrates different development trajectories between specific age groups. Developments in aerobic capacity from U12-U14 are likely associated with maturational increases in peak oxygen uptake, which is associated with the attainment of peak height velocity[29]. Furthermore, there is an increased training and match exposure for older players, whereby match duration is increased from 60 mins (U12) to 80 mins (U14). With an increase in match intensity with age previously reported in male youth soccer players[39] this would likely result in enhanced physiological adaptation beyond normal growth and development. Older players also undertake an additional 90-minute pitch based soccer session per week, which included specific aerobic development drills, as well as an additional gym based strength and conditioning work, which may further contribute to the development of more advanced physical qualities.

Given the biological differences in players that likely exist within an annual age category, a limitation of this study was that maturation status was not considered. Future research should look to explore the influence of maturation status on the physical characteristics of youth female soccer players. However, the current structure within the RTC's is based on chronological age (i.e., U10, U12, U14, U16), therefore despite biological differences within an age group, the current data provides normative standards for fitness qualities regularly tested within an academy structure. A second limitation of this study was that it was not possible to obtain training age data of the participants. Therefore, future research should also look to consider the influence of how many years a participant has been within a structured training environment on the physical development of players.

CONCLUSION

This study provides anthropometric and performance characteristics comparative data for 9-16 year old high level female soccer players. Findings demonstrate that anthropometric and performance characteristics develop with increasing age except for relative strength in this cohort. Athletic development of players in addition to technical/tactical development of should be a key focus of training with appropriate strength and conditioning sessions incorporated in to the weekly training structure to develop the athleticism of players.

PRACTICAL APPLICATIONS

The overall athletic development of female soccer players should be a long-term priority for coaches working with this cohort. The development of good movement qualities[38], alongside strength should form the basis of the physical conditioning programme. Aerobic fitness has been shown to discriminate between elite and sub-elite senior female soccer players[20]. Given the strong relationship between high-intensity running in match-play and performance on the YYIRL1[20], it is important that the development of the aerobic capacity of players is strategically planned within the training structure. The concurrent development of the aforementioned performance qualities, within a limited contact time environment can be achieved by prescribing specific strength training sessions, and using warm ups prior to training to develop physical qualities, such as speed and CoD ability. Manipulation of small-sided games combined with short duration intermittent high-intensity running drills may provide an efficient training stimulus to develop the aerobic system whilst concurrently developing technical/tactical skills within the same session[39].

Given that athletes within an elite environment do not likely strive to be average (i.e., comparison to mean data), assessing physical performance in comparison to benchmark percentile data may provide a more useful assessment value[40]. Therefore Table 2 presents the testing data for each annual age group by percentiles. It is recommended that such data should be used by coaches working with youth players to evaluate player physical development

Insert Table 2 here

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