lContextual factors influencing the characteristics of female football players

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ABSTRACT

Women's football participation rates are projected to increase to 60 million worldwide by 2026, doubling the current participation. Growing investment and the increase in research in women's football has had a positive effect on the level of performance over the last 10 years.

The present review will examine the literature on the physical and physiological characteristics of female football players from 2010 to 2019 to reflect the recent changes in professionalism. Characteristics investigated include anthropometry, strength, speed, endurance, power, change of direction and repeated sprint ability. These characteristics are presented in relation to playing position, age and competition-level.

Results revealed that goalkeepers (171 cm, 66 kg) and defenders (168 cm, 61 kg) were the tallest and had the greatest body mass, while attackers were the fastest players over 20 m (3.05 s) and 30 m (4.38 s) and midfielders had the highest endurance (55.4 $ml \cdot kg^{-1} \cdot min^{-1}$) ($p < 0.05$). Characteristics tended to improve with age until full biological maturity around 17 to 18 years of age. Competition comparisons demonstrated international players have significantly greater speed, repeated sprint ability, power and endurance characteristics ($p < 0.05$). By identifying influential factors, coaches may be able to optimise their training and physical assessment practises, to better expose players to the required stimulus to develop these characteristics considered crucial to improved performance.

Key words: Testing, soccer, women, strength, speed

INTRODUCTION

Over the last 10 years, women's football has experienced growing participation rates, increasing financial investment, and a surge in sports-science research. Participation for women and girls playing football increased by 32% to 30 million from 2010 to 2015 (1). The Fédération Internationale de Football Association (FIFA) has predicted women's football participation to increase to 60 million worldwide by 2026, doubling current participation (2). Female participation increased by 10% in Australia between 2016 and 2017 (3) with the highest participation for football (i.e. 402,00 participants), compared to other football codes including, Australian rules, rugby league and rugby union.

Due to a simple function of supply, a significant correlation exists between the number of people participating and elite sport success (r = .535, p = .007) (4). While other factors influence a country's elite sporting success, these results indicate that an important contributor to elite sporting success is the country's overall sport participation rates. This suggests that the increases in mainstream women's football participation have also had a positive effect on the level of performance over the last 10 years.

In addition to increasing participation rates, the introduction of national women's football leagues around the world, including the W-League in Australia (2008), the National Women's Soccer League in the USA (2012), and the Women's Super League in England (2010) stimulated important financial investment. The increased financial investment and introduction of professional contracts (e.g., Division 1 Feminine in France, 2009) signalled a change to the organisational culture of women's football, thus increasing collaboration and accountability all of which may have enhanced physical characteristics and on-field performances.

In addition to the increased financial investment in women's football, there has also been an increase in applied sport science research. Table I to VII in the present review summarises the numerous sport-science research papers published in the scientific literature from 2010-2019. Although it is generally accepted that the transfer rate of basic research into practise is low (5), applied sports-science research can significantly influence training and recovery practises, as well as athletic performance (6). The surge in sports-science research conducted in women's football over the last 10 years, is likely to have been beneficial to the overall performance of elite players.

In response to the increased participation rates, financial investment, and research output observed over the last 10 years, women's football has become more physically demanding (7). Therefore, it is reasonable to assume that over the same period (2010-2020) the players physical and physiological capacities have further advanced. Literature reviews of player physical and physiological characteristics conducted in 2014 (8, 9) included studies from 1992 to 2013.

The present review aims to build on the significant body of work previously published in women's football (8-13) by providing an evidence-based summary of the published scientific research from 2010 that may reflect a more accurate account of the current physical and physiological characteristics of female football players.

PHYSICAL AND PHYSIOLOGICAL CHARACTERISTICS

The activities that most affect the outcome of a football match include 1v1 contests in attack and defence, passing accuracy and effective execution of dead-ball situations including corners, free kicks and throw-ins (14). The explosive physical actions that contribute to these match activities such as sprinting, accelerations, decelerations, jumping and changes in direction are therefore likely influential to the outcome of matches (14-17). These characteristics need to be objectively assessed throughout the season to evaluate players and set individual and team standards that will help achieve improved performance (9, 13, 18).

The physical and physiological characteristics analysed in the present review include anthropometry, strength, speed, endurance, power, change of direction (COD) and repeated sprint ability (RSA). The present review will be structured into two sections, the first part will define the physical and physiological characteristics, providing context regarding the importance of each characteristic to football players and providing summarised data for elite players. The second part of the review explores the contextual factors (playing position, age and competition-level) that influence the physical and physiological characteristics investigating differences among these characteristics and the potential implications to training and performance.

The tables in the present review contain summarised data based on competition-level and age-group for ease of comprehension, due to the quantity of data. The term sub-elite has been taken from either the description in the methods of the reviewed studies or used as a blanket term to included amateur, second-division, club and university-level players. While not included in the tables of the review, reference to elite players is the collation of international and national-level data.

Anthropometry

Physique and body composition are considered important determinates of football performance (19). Anthropometry and body composition are both believed to be important variables in athletic performance, whereby muscle mass is positively related to power production, but excess body fat decreases an athletes power to weight ratio and has a negative influence on performance (20). A minimum amount of body fat, however, is required, for the maintenance of body metabolism (21). For normal reproduction health and hormonal function, a minimum body fat percentage of 14% for adolescent females and 12% for adult females is required, however, the required level of body fat percentage is highly variable and dependant on each individual (22). Elite football players range from 18 to 26 years of age (11, 12, 20, 23, 24). The height of a typical footballer player is between 163 to 172 cm with a body mass of 56 to 64 kg (20, 24) and body fat percentage ranging from 19.5 to 23.1% (20, 25, 26). A summary of the anthropometric characteristics of football players is presented in Table I.

TABLE I HERE

Strength

Strength is a key characteristic of all football players, due to its inextricable link to other physical qualities including power, speed, endurance, COD and RSA (27-30). Absolute strength is important for football players, particularly when trying to absorb or produce force on external objects. The ability to compete for possession or position with an opposition player are examples of where absolute strength is vital (10). Increased lower-body strength has been shown to improve ball speed during kicking, an important finding given kicking is arguably the most important skill in football (31). In contrast, relative strength is the ability to absorb or produce force relative to a players body weight (10). Football movement patterns such as sprinting, acceleration, deceleration, COD, jumping and landing are reported to result in forces between 1.7-4.2 times body weight (29, 32-34), highlighting the importance of relative strength and the ability to absorb forces up to four times body weight.

Evaluation of strength in football players commonly included assessment of maximum load-displacement during gym-based exercises. One common test used in football includes the one-repetition maximum (1 RM) back squat. Back squats are typically used to assess lower-body strength and can provide both an absolute and relative strength measure. Elite players have been reported to back squat approximately 61 kg which equated to one times body weight during a 1 RM back squat (28) (Table II). In respect to absorbing forces generated from football-specific movement patterns, the current day football players appear to have insufficient strength to be able to do this optimally. A major reason for these results may be a lack of exposure to an appropriate stimulus (35).

Other investigations of strength include assessment of maximum concentric strength of the quadriceps using isokinetic dynamometry. Isolating concentric muscle contractions allows for the assessment of peak force or torque, which is similar to powerful movements such as sprinting, jumping and kicking a ball (36). The assessment of eccentric hamstring strength in addition to quadricep strength is also important. The hamstring muscles are involved eccentrically, particularly during decelerating forward movements of the leg and stabilising the knee before and during concentric muscle contractions (36-38). By assessing quadricep and hamstring muscle strength separately, a ratio known as hamstring to quadricep ratio (H:Q ratio) can be established. Elite players have been reported to possess an H:Q ratio in the order of 1.04 at a speed of $60^{o}\cdot s^{-1}$ (30). Measurement of the H:Q ratio may be particularly important for females athletes, with this suggested to be a contributing factor to the higher incidences of ACL injuries (29, 32-34).

TABLE II HERE

Speed

Sprinting represents a small amount of the total distance covered during a football match (39-41), however, it is linked to critical movements within the game making speed an important characteristic for football players (15). Faster running speeds allow players to reach the ball before their opponents and position themselves more quickly, which ultimately leads to a defensive or attacking advantage (42, 43). There is an abundance of studies investigating sprint performance in football players (Table III). The most common assessment of speed is the 20 m sprint time, with elite players performing 20 m in 3.05-3.60 s (12, 44, 45). Ten metre sprint time is most commonly used to access acceleration ability in football players (12, 13, 26, 46, 47). Interestingly, the majority of the distance covered during high-speed running and sprinting in football, occurs over distances of less than 10 m (40, 48), suggesting that 5 m acceleration time may also be an important characteristic of football players. Despite the body of research investigating sprint times of football players, the use of different testing procedures limits comparisons between studies. The height of the timing gates may affect sprint times, with the lower-body breaking the light beam before the upper-body when the gates are positioned at or below hip height (10, 49). The start stance and positioning distance in relation to the start line have also been demonstrated to affect sprint time (10, 50). Using a pressure sensor or starting closer to the start line increases sprint times due to a reduced centre of mass velocity before breaking the first light beam (10, 50). Given many studies fail to report such variables in detail, standard testing procedures and reporting of this data in detail are essential for comparisons between studies.

TABLE III HERE

Endurance

Endurance is a strong predictor of football performance (51, 52), correlating with the total distance covered and the amount of high-speed running performed during a match (52, 53). A player's ability to recover between high-intensity efforts relies heavily on the aerobic energy system (23, 54). Maximal oxygen uptake (VO_{2max}) of elite players has been demonstrated to be between 47-55 $ml \cdot kg^{-1} \cdot min^{-1}$ which is a combination of estimated VO_{2max} from the various aerobic tests and actual VO_{2max} data, measuring oxygen consumption during an incremental treadmill test (11, 28, 54) (Table IV).

The level reached or the number of high-intensity running intervals completed during intermittent endurance tests such as the Yo-Yo intermittent recovery level 1 (YYIR1), Yo-Yo intermittent endurance test (YYIE1) and 30-15 intermittent fitness test (30-15 IFT) are strongly correlated to the amount of high-intensity running performed during a match (11, 55). The distance covered during intermittent endurance tests has also been shown to predict the probability of future international careers in youth football players (56). The main objective of the Yo-Yo test is to measure the capacity to perform intense intermittent exercise, including an ability to rapidly recover (10, 46, 57). The Yo-Yo intermittent recovery level 1 is designed to primarily test endurance capacity, whereas Yo-Yo intermittent recovery level 2 (YYIR2) has a greater emphasis on anaerobic qualities (10, 46, 57). Players with slower sprint speeds may not perform as well on the YYIR2 because they physically can't run at sufficient speed to make the beeps, rather than an inability to recover from the repeated high-intensity running (10). The importance of endurance during football matches is highlighted by the fact that the aerobic energy system is substantially fatigued throughout a match, with reductions of 60% in the YYIE1 compared to pre-game (58). This reduced capacity of the aerobic energy system has been linked to a reduction in high-intensity activities toward the end of a match (58).

TABLE IV HERE

Power

Power is defined as the product of force and velocity (59), meaning an athlete will be limited in the level of power they can develop if they do not possess a high level of relative strength

(30, 60). A specific form of power particularly important in speed and power-based sports is reactive strength (59, 61). Reactive strength is the ability to quickly change from the eccentric muscle contraction phase to the concentric phase during the stretch-shortening cycle (SSC) (59). The assessment of power in football players is commonly measured through the countermovement jump (CMJ) (10, 44, 62), which utilises the SSC and is an acceptable measure of power (62) (Table V).

Elite football players have been reported to jump between 26.8-48.6 cm during CMJ assessments performed with their hands on their hips (10, 12, 58, 62, 63).

Large variation in CMJ performance has been observed across several studies and can be attributed, in part to the differences in testing equipment and protocols used (35, 61, 62, 64). Both contact mats and Vertec devices tend to under-report jump performance compared to force plates which are considered the gold standard assessment tool for vertical jump performance (10, 65). In addition to equipment-related factors, variation in countermovement depth and the training background of players may play a role in the observed variation in jump performance (60, 66, 67). Whether athletes are allowed to use arm swing or have their hands on their hips, also strongly influences jump height, whereby sequential activation of the upper and lower body joints can increase total body momentum and jump height (10, 67). Analysing the force-time curve of a CMJ allows for a greater mechanistic understanding of the movement strategies employed to achieve the outcome of jump height (60, 68). Impulse has been suggested as the most appropriate variable for assessing explosive performance, as it is the product of the magnitude of force produced over the time of force application (60). The force produced, rate of force development and impulse during the eccentric phase of a CMJ have all been suggested as the key contributors to jump performance (60). Proficient jumpers with a higher jump height have been shown to have a greater impulse during the eccentric phase (60). The only limitation of analysing the force-time curve of a CMJ is that it requires the use of a force platform which may not be readily available, particularly during field-based assessments.

TABLE V HERE

Change of direction

Change of direction is the ability of a player to decelerate, change the direction of movement, and then accelerate again (29). Change of direction is premediated where the player knows the planned movement or direction before commencing. Agility refers to an unknown COD or movement in response to a sport-specific stimulus (29, 63, 69). It is the stimulus and the cognitive decision making aspect of agility that makes it difficult to test, however, it is most applicable to the dynamic, chaotic nature of team sports (29, 63, 69). Nevertheless, COD is still important in providing the foundational physical and technical skills underlying agility (29). Interestingly, COD has been demonstrated to be an independent characteristic, demonstrating no relationship to sprint performance (69, 70).

There is a great deal of variation in tests used to measure COD (Table VI), although the most common measure of COD was the 505 test. The 505 test involves a 10 m rolling start, where the player sprints 5 m completes a 180º COD and sprints back 5 m. The time to complete the 5 m shuttle is measured and used as the performance outcome (71). Elite players COD ability, as assessed using the 505 test, varies between 2.38-2.76 s, with similar times for both left and right-footed COD (10, 12).

TABLE VI HERE

Repeated sprint ability

Repeated sprint ability is the ability to perform multiple sprints with brief recovery periods, minimising the fatigue or loss of speed between each effort (23, 63). As discussed previously, both acceleration and top speed are important qualities for football players (24, 43, 44). Therefore, the ability to perform repeated high-intensity efforts are also critical to football performance and influence the outcome of a match (43, 45). The most common testing procedure used to access RSA is a protocol of seven sprints over 30 m with 30 s recovery, however, several other procedures have also been used (Table VII).

TABLE VII HERE

CONTEXTUAL FACTORS INFLUENCING PHYSICAL AND PHYSIOLOGICAL CHARACTERISTICS

The physical and physiological characteristics of football players as discussed above are influenced by contextual factors including playing position, age and competition-level.

Playing position

Positional differences in player movement patterns are known to exist in football (72, 73). Large variations in movement patterns during match-play have been demonstrated for defenders and midfielders, suggesting further categorisation is required. It has been proposed that players be classified as central or wide players due to the different locations they typically adopt during match-play (40). Most investigators have divided outfield positions into five positional groups: central defenders, wide defenders, central midfielders, wide midfielders and attackers (74). Where possible, the present review uses these five positional groups, to create a more comprehensive understanding of the impact of positional demands on physical and physiological characteristics of players.

Goalkeepers

Goalkeepers are generally the tallest players, have the greatest body mass, the highest sum of skinfolds (62) and body fat percentage (21, 25) compared to all other playing positions. The increased height may be advantageous for goalkeepers due to the importance of clearing or gaining possession of aerial balls in defensive areas. Additionally, goalkeepers are required to make themselves as big as possible in the goal to prevent or make it more difficult for opposition players to score. Goalkeepers have very different movement patterns to outfield players, with limited exposure to high-speed running demands typically exhibited during match-play. As a result, goalkeepers generally demonstrated the slowest sprint times over the initial acceleration phase of 5 m and 10 m, and slowest sprint times over 30 m (44, 62).
The assessment of lower-body power and the utilisation of the SSC assessed through the CMJ (40, 61) revealed that goalkeepers perform the lowest jump height compared to all other playing positions (62). Considering goalkeepers are required to produce explosive jumping actions, it is perhaps unexpected that they would perform poorly during jumping assessments. While this might be at least partially reflective of their greater body mass, mechanistic variables available through analysis of the force-time curve such as contact time, force or impulse of the concentric and eccentric phases may provide greater insight into the relatively poor jump performance of goalkeepers compared to other positions (60, 68).

Defenders

Of the outfield players, central defenders had the greatest height and body mass (54, 62). Similar to goalkeepers, this increased height may assist with the clearance of aerial balls in defensive areas. Greater height and body mass of central defenders appear to not affect their speed capabilities, with only small to trivial differences to other outfield players (62). Given central defenders are required to defend the ball and attacking players, similar speed characteristics to attackers appear to be crucial in being able to defend against players trying to get behind the defensive line to score. Wide defenders generally completed the greatest distances (1698 m) during the YYIR1 test (40), most commonly used to assess high-intensity running ability of football players. Wide defenders are presented with more space and dependant on tactics, provide overlapping runs out wide to provide an attacking option and greater complexity for defenders.

Midfielders

The importance of midfielders ability to accelerate has been highlighted through positional comparisons that have shown midfielders to be significantly faster over 5 m in comparison to defenders and goalkeepers (42). However, when comparing central and wide players, central midfielders have slower times over 5 m (40) Midfielders and particularly central midfielders have limited space due to the congestion centrally, and therefore are regularly moving and performing short explosive efforts with prior velocity. Consequently, a 5 m sprint from a standing start may not reflect the movement patterns of the game for a central midfielder and explain their relative inability to accelerate from a standing start to the same degree as other playing positions. Midfielders are generally the shortest and lightest players (21) and have the highest VO_{2max} (measured directly through oxygen consumption) compared to all other playing positions. However, these results did not distinguish between central and wide players (54). Midfielders typically score higher on the 30-15 IFT compared to all other playing positions (54). Both the 30:15 IFT and VO_{2max} test demonstrate that midfielders endurance is superior compared to other outfield players. Midfielders higher endurance is likely to be reflective of the demands of match-play supporting both attacking and defensive actions, where midfielders covered greater distances and had the shortest recovery times between high-intensity activity (39, 62).

Based on playing position and the specific demands of the game, wide midfielders have better RSA times in comparison to central midfielders and central defenders (62). The protocol used consisted of seven sprints over 30 m with 30 s rest, which may be a reflection of wide midfielders performing longer sprints in a match (1, 40). Sprinting has been demonstrated to be the most frequent action in goal scoring situations for both the scoring and assisting player, with wide midfielders involved in more sprints before assisting goals (15).

Attackers

Attackers have been reported to be the fastest players over 20 m and 30 m (44, 62), potentially a result of the longer sprints experienced during matches (40). Attackers had moderately higher CMJ compared to goalkeepers and small to trivial differences in CMJ height compared to all other playing positions (62). Based on playing position and the specific demands of the game, attackers also demonstrate better RSA times in comparison to central midfielders and central defenders (62). The RSA protocol used consisted of seven sprints over 30 m with 30 s rest between sprints, which again might be due to attackers typically performing longer sprints in a match (1, 40). Sprinting and explosive actions are the most frequent action required during goal-scoring situations (15), therefore it would be beneficial for attackers to be faster and be able to repeat a higher number of sprints and explosive actions during a match to enhance the chances of scoring goals.

Age

All physical and physiological characteristics e.g. strength, speed, endurance, power, COD and RSA tended to improve up until the age of 17 or 18 years (75, 76). However, due to different maturation-levels of players and the optimal trainability of certain characteristics, the age at which these maturation-related improvements plateau can vary for the different physical and physiological characteristics (76, 77). Improvements that occur due to growth and maturation include hormonal changes, the development of the central nervous system improving general motor control and the inter and intra-muscular coordination, along with morphological changes of muscles (13, 26, 75). Other factors contributing to the improvements seen with increased age may also reflect the structured training programs of elite athletes who are generally older than youth athletes. The exposure to higher training loads allows for a further increase in physical capacities. The structured strength and conditioning programs that are associated with elite players are optimised for the development of the specific characteristics to maximise performance and minimise the risk of injury (62).

Skinfolds are lower in elite senior players compared to U17, U19 and U20 players, which may be consistent with the tendency for females to experience an increase in fat mass around peak weight velocity (76, 78, 79). Muscle mass contributes to the production of power, whereas excess body fat decreases the power to weight ratio (20). Reduced measures of power such as single-leg horizontal jumps and CMJ for U17 players compared to elite senior players may be a result of the increase in body fat mass that occurs before the players reach adulthood and their relatively lower strength and conditioning experience (30, 40).

Reduced lower-body strength has been reported in high school players where significant changes were evident in an eight-week strength training program (35). The lack of exposure to an appropriate stimulus may be a major reason for the insufficient lower-body strength-levels of football players. Adlof and colleagues (35) conducted an eight-week strength program consisting of back squats and deadlifts along with a push and pull upper-body exercise, three times a week. High school players initial lower-body strength was 47 kg for a 1 RM back squat, equating to 0.8 times body weight. After the program players achieved a back squat of 79 kg, approximately 1.3 times body weight (35). This improvement demonstrates the potential impact an optimised training program can have on this particular population of football players.

Senior elite and U20 players H:Q ratio at a speed of $60^{o}\cdot s^{-1}$ has been demonstrated to be 1.04 and 1.03, respectively, with lower values of 0.90 for U17 players at the same movement speed (30). College players also demonstrated a H:Q ratio of 0.80 at a movement speed of $60^{o}\cdot s^{-1}$ (37). With an optimal H:Q ratio of 1.00, this may suggest that younger athletes have less hamstring strength in relation to quadricep strength potentially increasing the risk of lower-body injuries, particularly the hamstring and ACL. It is therefore important, that training practises focus less on quadricep strength and more on eccentric hamstring strength as a protective mechanism to injuries, and to increase performance during sprinting and COD activities (37).

Small differences were observed between U17 age-group in comparison to U19 and elite senior players for 5 m sprint times and large differences were demonstrated for 30 m sprint times (62). The differences observed in 5 m and 30 m times between age-groups may be a result of the different development rates of acceleration and maximum speed capabilities that typically occur around peak height velocity and maturation (75). As athletes reach full biological maturity around 17 to 18 years of age, the biological changes begin to slow down meaning any additional improvements in speed qualities are likely to be a result of adaptations to training. This is consistent with the finding of similar sprint times for U19 and elite senior players (10, 13). Increases in sprint performance over 10 m and 30 m for youth players has been attributed to maturation and growth, but more specifically the changes in leg length and the resulting increase in stride length (75, 77). Adaptations to training stimulus for youth players include enhanced coordination, motor unit recruitment, activation of the central nervous system and improved technical skills during running (47). Speed training for one hour a week over eight weeks, defined as sprints over distances of approximately 20 m, has shown to improve 10 m sprint times by 4.1% and 20 m times by 3.2% for youth football players (47). Sprint speed for football players will increase with age until biological maturity, however, the exposure to appropriate training stimulus also plays an important role in the development of speed. It is in part the strength and conditioning coaches' responsibility to provide the required training stimulus, especially when maturation-related plateaus in speed occur.

Endurance as assessed by YYIR1 test improved with age (10, 13, 62, 75), moderate increases were demonstrated between U15 and U19 age-groups, with small increases between U15 and U17, and U17 and U19 age-groups (62). Youth players from U16-U19 typically covered 720-1357 m in the YYIR1 (10, 26, 62, 75), although one group of U17 players completed 1760 m (10). Except for the 1760 m recorded by elite U17 English players (10), elite senior players were able to achieve greater distances in the YYIR1 test (930-1635 m) compared to youth players (10, 11, 62). Peak oxygen uptake has been demonstrated to increase exponentially following peak height velocity and may explain the steady age-related increase in endurance during the YYIR1 test (77).

Competition-level

Higher levels of competition have been associated with greater explosive and faster movement patterns such as high-speed running, sprinting, and repeated high-intensity efforts (72, 80, 81). The physical and physiological characteristics that contribute to the increased movement patterns evident between competition-levels include speed, RSA, power and endurance.

International-level players are generally faster over 20 m than national and sub-elite players (44, 45). Greater speed characteristics for higher levels of competition highlight the importance of speed as a discriminating factor between competition-level. The development of speed during training should, therefore, be a strong focus for football players. Speed attributes also contribute to RSA, with the initial 20 m sprint time shown to have a significant relationship ($r = 0.96$) to the total sprint time (45). Using a protocol of six, 20 m sprints on a 15 s cycle, international-level players have significantly lower total sprint times compared to national-level players (20.9 s compared to 23.3 s) (45). A contributing factor to the faster speed characteristics of international players is likely to be their greater muscular power, the ability to produce force at a high velocity (60). International players jump between 8% and 9% higher during a CMJ compared to national-level and junior elite players (44). Countermovement jumps have been strongly correlated to sprinting, most likely due to the similar musculature and utilisation of the SSC during both activities (23).

By comparing competition-level, it is evident that international players possess more muscular power allowing faster and more forceful movements. Emphasising these specific characteristics will expose players to the appropriate stimulus for the desired adaptations of improved performance and reducing the risk of injury. Unfortunately, this review was unable to identify any studies that directly compared muscular strength across different competition-levels in football players. However, international players likely have better developed strength characteristics compared to all other competition-levels.

The underlying energy system maintaining all the explosive actions and contributing to these actions occurring repeatably is the aerobic energy system (23, 54). International players perform more high-intensity intervals and have better endurance compared to national players

(55). During the 30-15 IFT, international players achieved a speed of 18 km·h^{-1} compared to 16.8 km·h^{-1} for national players, where a change or difference of 0.5 km·h^{-1} is considered significant (55). Similar results were found during the YYIR1 and the YYIE2, where international players covered a greater distance in comparison to sub-elite (10), U20 and national-level players (11). Endurance is reported to be greater for players competing in higher competition-levels, likely a result of the high reliance on the aerobic energy system and the larger distances covered during football match-play by international-level players. Therefore, the development of a football players' endurance is vital to maximising match performance, although such training should emulate the movement patterns during a match, as opposed to the exclusive use of continuous moderate-intensity endurance training.

Given the current evidence around competition-level and the superior physical and physiological characteristics of international players, it is surprising that both body fat percentage and COD performance were similar between competition-levels (10). Body fat percentage was estimated from a sum of three-site skinfolds, which may account for the lack of differences, however, the same methodology was utilised for both competition-levels (10). The limited research comparing competition-level particularly for COD and body composition makes it difficult to conclude differences in competition-level for these characteristics. Further research is required comparing players physical and physiological characteristics across competition-levels, to better understand the distinguishing characteristics.

CONCLUSION

The identification of the influential factors such as playing position, age and competition-level on the physical and physiological characteristics of female football players can be utilised to inform talent identification guidelines of national or international players, age groups, and specific playing positions. Identifying optimal physical and physiological characteristics of elite-level female football players may also assist in guiding training programs to emphasise and develop important characteristics.

Identifying the recurrent and consistent physical and physiological characteristics highlighted the importance of speed, power and endurance for female football players. The development of speed, power and endurance are all underpinned and enhanced through the development of strength. Given the importance of strength to the development of other physical and physiological characteristics, coaches should initially prioritise strength as the foundation. The development of foundational strength is reinforced throughout the age group comparisons. Natural improvements occur with biological maturity, training initially needs to emphasise the fundamental characteristics of strength, speed and endurance which are significantly higher in senior football players in comparison to young age groups.

While the physical and physiological characteristics of female football players were the focus of the present study, it is important to acknowledge that other factors such as talent will always make players standout, what aspect of physical, tactical or technical that is, is a part of the challenge of talent identification.

REFERENCES

1. FIFA. Physical analysis of the FIFA womens World Cup Canada 2015. galledia ag, Switzerland: 2016.

2. FIFA. Women's football strategy. Zurich, Switzerland: 2018.

3. Morgan R. Football participation stabilises with more women playing. 2018.

4. van Bottenburg M, editor Sport for all and elite sport: Do they benefit one another? 9th World Sport for All Congress, ‘Sport for all and elite sport: Rivals or partners?; 2002; Papendal, the Netherlands.

5. Crowley Jr WF. Translation of basic research into useful treatments: How often does it occur? Am J Med. 2003;114(6):503.

6. Bishop D, Burnett A, Farrow D, Gabbett T, Newton R. Sports-science roundtable: Does sports-science research influence practice? Int J Sports Physiol Perform. 2006;1(2):161-8.

7. Griffin J, Larsen B, Horan S, Keogh J, Dodd K, Andretta M, et al. Women's football: An examination of factors that influence movement patterns. J Strength Cond Res. 2020;Epub ahead of print.

8. Datson N, Hulton A, Andersson H, Lewis T, Weston M, Drust B, et al. Applied physiology of female soccer: An update. Sports Med. 2014;44(9):1225-40.

9. Martinez-Lagunas V, Niessen M, Hartmann U. Women's football: Player characteristics and demands of the game. J Sport Health Sci. 2014;3(4):258-72.

10. Turner E. Physical and match performance of female soccer players: University of Salford; 2016.

11. Bradley P, Bendiksen M, Dellal A, Mohr M, Wilkie A, Datson N, et al. The application of the Yo-Yo intermittent endurance level 2 test to elite female soccer populations. Scand J Med Sci Sports. 2014;24(1):43-54.

12. Emmonds S, Nicholson G, Beggs C, Jones B, Bissas A. Importance of physical qualities for speed and change of direction ability in elite female soccer players. J Strength Cond Res. 2017;33(6):1669-77.

13. Emmonds S, Till K, Redgrave J, Murray E, Turner L, Robinson C, et al. Influence of age on the anthropometric and performance characteristics of high-level youth female soccer players. Int J Sports Sci Coach. 2018;13(5):779-86.

14. Soroka A, Bergier J. Actions with the ball that determine the effectiveness of play in women's football. J Hum Kinet. 2010;26:97-104.

15. Faude O, Koch T, Meyer T. Straight sprinting is the most frequent action in goal situations in professional football. J Sports Sci. 2012;30(7):625-31.

16. Trewin J, Meylan C, Varley M, Cronin J. The match-to-match variation of match-running in elite female soccer. J Sci Med Sport. 2018;21(2):196-201.

17. Mara J, Thompson K, Pumpa K, Morgan S. The acceleration and deceleration profiles of elite female soccer players during competitive matches. J Sci Med Sport. 2017;20(9):867-72.

18. Milanovic Z, Sporis G, James N, Trajkovic N, Ignjatovic A, Sarmento H, et al. Physiological demands, morphological characteristics, physical abilities and injuries of female soccer players. J Hum Kinet. 2017;60(1):77-83.

19. Nikolaidis P. Physiological characteristics of elite Greek female soccer players. Med Sport. 2010;63(3):343-51.

20. Mala L, Maly T, Zahalka F, Bunc V, Kaplan A, Jebavy R, et al. Body composition of elite female players in five different sports games. J Hum Kinet. 2015;45(1):207-15.

21. Strauss A. Anthropometric profile, selected physical parameters, technical skills and match demands of university-level female soccer players: North-West University; 2018.

22. Turocy PS, DePalma BF, Horswill CA, Laquale KM, Martin TJ, Perry AC, et al. National athletic trainers' association position statement: Safe weight loss and maintenance practices in sport and exercise. J Athl Train. 2011;46(3):322-36.

23. Shalfawi S, Enoksen E, Tonnessen E. The relationship between measures of sprinting, aerobic fitness, and lower body strength and power in well trained female soccer players. Int J Appl Sports Sci. 2014;26(1):18-25.

24. Vescovi J. Sprint speed characteristics of high-level American female soccer players: Female Athletes in Motion (FAiM) Study. J Sci Med Sport. 2012;15(5):474-8.

25. Nikolaidis P. Physical fitness in female soccer players by player position: A focus on anaerobic power. Hum Mov. 2014;15(2):74-9.

26. Emmonds S, Sawczuk T, Scantlebury S, Till K, Jones B. Seasonal changes in the physical performance of elite youth female soccer players. J Strength Cond Res. 2018;Epub ahead of print.

27. Shalfawi S, Haugen T, Jakobsen T, Enoksen E, Tonnessen E. The effect of combined resisted agility and repeated sprint training vs. strength training on female elite soccer players. J Strength Cond Res. 2013;27(11):2966-72.

28. Sporis G, Jovanovic M, Krakan I, Fiorentini F. Effects of strength training on aerobic and anaerobic power in female soccer players. Sport Sci. 2011;4(2):32-7.

29. Jones P, Thomas C, Dos'Santos T, McMahon J, Graham-Smith P. The role of eccentric strength in 180° turns in female soccer players. Sports. 2017;5(2):1-11.

30. Manson S, Brughelli M, Harris N. Physiological characteristics of international female soccer players. J Strength Cond Res. 2014;28(2):308-18.

31. Ozbar N. Effects of plyometric training on explosive strength, speed and kicking speed in female soccer players. Anthropologist. 2015;19(2):333-9.

32. Campo SS, Vaeyens R, Philippaerts R, Redondo JC, de Benito AM, Cuadrado G. Effects of lower-limb plyometric training on body composition, explosive strength, and kicking speed in female soccer players. J Strength Cond Res. 2009;23(6):1714-22.

33. Turner E, Munro AG, Comfort P. Female soccer: Part 2-Training considerations and recommendations. Strength Cond J. 2013;35(1):58-65.

34. Wallace B, Kernozek T, White J, Kline D, Wright G, Peng H-T, et al. Quantification of vertical ground reaction forces of popular bilateral plyometric exercises. J Strength Cond Res. 2010;24(1):207-12.

35. Adlof L, Cosio-Lima L, Crawley A, Lee Y. The effects of concurrent training on female soccer players. Sports Exerc Med Open J. 2018;4(1):16-23.

36. Delextrat A, Baker J, Cohen D, Clarke N. Effect of a simulated soccer match on the functional hamstrings-to-quadriceps ratio in amateur female players. Scand J Med Sci Sports. 2013;23(4):478-86.

37. Jenkins N, Hawkey M, Costa P, Fiddler R, Thompson B, Ryan E, et al. Functional hamstrings: quadriceps ratios in elite women's soccer players. J Sports Sci. 2013;31(6):612-7.

38. Aagaard P, Simonsen E, Magnusson P, Larsson B, Dyhre-Poulsen P. A new concept for isokinetic hamstring: quadriceps muscle strength ratio. Am J Sports Med. 1998;26(2):231-7.

39. Bradley P, Dellal A, Mohr M, Castellano J, Wilkie A. Gender differences in match performance characteristics of soccer players competing in the UEFA Champions League. Hum Mov Sci. 2014;33:159-71.

40. Datson N, Drust B, Weston M, Jarman I, Lisboa P, Gregson W. Match physical performance of elite female soccer players during international competition. J Strength Cond Res. 2017;31(9):2379-87.

41. Meylan C, Trewin J, McKean K. Quantifying explosive actions in international women's soccer. Int J Sports Physiol Perform. 2017;12(3):310-5.

42. Lockie R, Moreno M, Lazar A, Orjalo A, Giuliano D, Risso F, et al. The physical and athletic performance characteristics of division 1 collegiate female soccer players by position. J Strength Cond Res. 2018;32(2):334-43.

43. Risso F, Jalilvand F, Orjalo A, Moreno M, Davis D, Birmingham-Babauta S, et al. Physiological characteristics of projected starters and non-starters in the field positions from a division 1 women's soccer team. Int J Exerc Sci. 2017;10(4):568-79.

44. Haugen T, Tonnessen E, Seiler S. Speed and countermovement-jump characteristics of elite female soccer players, 1995–2010. Int J Sports Physiol Perform. 2012;7(4):340-9.

45. Gabbett T. The development of a test of repeated-sprint ability for elite women's soccer players. J Strength Cond Res. 2010;24(5):1191-4.

46. Lockie R, Jalilvand F, Moreno M, Orjalo A, Risso F, Nimphius S. Yo-Yo intermittent recovery test level 2 and its relationship with other typical soccer field tests in female collegiate soccer players. J Strength Cond Res. 2017;31(10):2667-77.

47. Gunnar M, Svein A. The effect of speed training on sprint and agility performance in female youth soccer players. J Phys Educ Sport. 2015;15(3):395-9.

48. Mara J, Thompson K, Pumpa K, Morgan S. Quantifying the high-speed running and sprinting profiles of elite female soccer players during competitive matches using an Optical Player Tracking System. J Strength Cond Res. 2017; 31(6):1500-8.

49. Cronin J, Templeton R. Timing light height affects sprint times. J Strength Cond Res. 2008;22(1):318-20.

50. Cronin J, Green J, Levin G, Brughelli M, Frost D. Effect of starting stance on initial sprint performance. J Strength Cond Res. 2007;21(3):990-2.

51. McCormack W, Stout J, Wells A, Gonzalez A, Mangine G, Fragala M, et al. Predictors of high-intensity running capacity in collegiate women during a soccer game. J Strength Cond Res. 2014;28(4):964-70.

52. Grieco C, Cortes N, Greska E, Lucci S, Onate J. Effects of a combined resistance-plyometric training program on muscular strength, running economy, and VO2peak in division 1 female soccer players. J Strength Cond Res. 2012;26(9):2570-6.

53. Krustrup P, Mohr M, Ellingsgaard H, Bangsbo J. Physical demands during an elite female soccer game: Importance of training status. Med Sci Sports Exerc. 2005;37(7):1242-8.

54. Ingebrigtsen J, Dillern T, Shalfawi S. Aerobic capacities and anthropometric characteristics of elite female soccer players. J Strength Cond Res. 2011;25(12):3352-7.

55. Covic N, Jeleskovic E, Alic H, Rado I, Kafedzic E, Sporis G, et al. Reliability, validity and usefulness of 30-15 intermittent fitness test in female soccer players. Front Physiol. 2016;7.

56. Datson N, Weston M, Drust B, Gregson W, Lolli L. High-intensity endurance capacity assessment as a tool for talent identification in elite youth female soccer. J Sports Sci. 2019;Epub ahead of print.

57. Schmitz B, Pfeifer C, Kreitz K, Borowski M, Faldum A, Brand S-M. The Yo-Yo intermittent tests: A systematic review and structured compendium of test results. Front Physiol. 2018;9.

58. Krustrup P, Zebis M, Jensen J, Mohr M. Game-induced fatigue patterns in elite female soccer. J Strength Cond Res. 2010;24(2):437-41.

59. Kovacs M, Roetert P, Ellenbecker T. Efficient deceleration: The forgotten factor in tennis-specific training. Strength Cond J. 2008;30(6):58-69.

60. Sole C. Analysis of the phase characteristics of the countermovement vertical jump in athletes East Tennesse State University; 2015.

61. Castagna C, Castellini E. Vertical jump performance in Italian male and female national team soccer players. J Strength Cond Res. 2013;27(4):1156-61.

62. Datson N. An analysis of the physical demands of international female soccer match-play and the physical characteristics of elite players: Liverpool John Moores University; 2016.

63. Shalfawi S, Young M, Tonnessen E, Haugen T, Enoksen E. The effect of repeated agility training vs repeated sprint training on elite female soccer players physical performance. Kinesiol Slov. 2013;19(3):29-42.

64. Oberacker L, Davis S, Haff G, Witmer C, Moir G. The Yo-Yo IR2 test: Physiological response, reliability, and application to elite soccer. J Strength Cond Res. 2012;26(10):2734-40.

65. Buckthorpe M, Morris J, Folland J. Validity of vertical jump measurement devices. J Sports Sci. 2012;30(1):63-9.

66. Bobbert M, Casius R, Sijpkens I, Jaspers R. Humans adjust control to initial squat depth in vertical squat jumping. J Appl Physiol. 2008;105(5):1428-40.

67. Magrini MA, Colquhoun RJ, Sellers JH, Conchola EC, Hester GM, Thiele RM, et al. Can squat jump performance differentiate starters vs. nonstarters in division I female soccer players? J Strength Cond Res. 2018;32(8):2348-55.

68. McMahon JJ, Suchomel TJ, Lake JP, Comfort P. Understanding the key phases of the countermovement jump force-time curve. Strength Cond J. 2018;40(4):96-106.

69. Sheppard J, Young W. Agility literature review: Classifications, training and testing. J Sports Sci. 2006;24(9):919-32.

70. Vescovi J, McGuigan M. Relationships between sprinting, agility, and jump ability in female athletes. J Sports Sci. 2008;26(1):97-107.

71. Nimphius S, Callaghan S, Spiteri T, Lockie R. Change of direction deficit: A more isolated measure of change of direction performance than total 505 time. J Strength Cond Res. 2016;30(11):3024-32.

72. Andersson H, Randers M, Heiner-Moller A, Krustrup P, Mohr M. Elite female soccer players perform more high-intensity running when playing in international games compared with domestic league games. J Strength Cond Res. 2010;24(4):912-9.

73. Hewitt A, Norton K, Lyons K. Movement profiles of elite women soccer players during international matches and the effect of opposition's team ranking. J Sports Sci. 2014;32(20):1874-80.

74. Di Salvo V, Baron R, Tschan H, Montero C, Bachl N, Pigozzi F. Performance characteristics according to playing position in elite soccer. Int J Sports Med. 2007;28(3):222-7.

75. Emmonds S, Scantlebury S, Murray E, Turner L, Robsinon C, Jones B. Physical characteristics of elite youth female soccer players characterized by maturity status. J Strength Cond Res. 2018;Epub ahead of print.

76. Emmonds S, Morris R, Murray E, Robinson C, Turner L, Jones B. The influence of age and maturity status on the maximum and explosive strength characteristics of elite youth female soccer players. Sci Med Football. 2017;1(3):209-15.

77. Ford P, De Ste Croix M, Lloyd R, Meyers R, Moosavi M, Oliver J, et al. The long-term athlete development model: Physiological evidence and application. J Sports Sci. 2011;29(4):389-402.

78. Quatman-Yates CC, Myer GD, Ford KR, Hewett TE. A longitudinal evaluation of maturational effects on lower extremity strength in female adolescent athletes. Pediatr Phys Ther. 2013;25(3):271-6.

79. Ramos GP, Nakamura FY, Penna EM, Mendes TT, Mahseredjian F, Lima AM, et al. Comparison of physical fitness and anthropometrical profiles among Brazilian female soccer national teams from U15 to senior categories. J Strength Cond Res. 2019;Epub ahead of print.

80. Gabbett T, Mulvey M. Time-motion analysis of small-sided training games and competition in elite women soccer players. J Strength Cond Res. 2008;22(2):543-52.

81. Gabbett T, Wiig H, Spencer M. Repeated high-intensity running and sprinting in elite women’s soccer competition. Int J Sports Physiol Perform. 2013;8(2):130-8.

82. Peart A, Nicks C, Mangum M, Tyo B. Evaluation of seasonal changes in fitness, anthropometrics, and body composition in collegiate division 2 female soccer players. J Strength Cond Res. 2018;32(7):2010-7.

83. Ramirez-Campillo R, Vergara-Pedreros M, Henriquez-Olguin C, Martinez-Salazar C, Alvarez C, Nakamura F, et al. Effects of plyometric training on maximal-intensity exercise and endurance in male and female soccer players. J Sports Sci. 2016;34(8):687-93.

84. McFarland I, Dawes J, Elder C, Lockie R. Relationship of two vertical jumping tests to sprint and change of direction speed among male and female collegiate soccer players. Sports. 2016;4(1):1-7.

85. Suchomel T, Sole C, Bailey C, Grazer J, Beckham G. A comparison of reactive strength index-modified between six US collegiate athletic teams. J Strength Cond Res. 2015;29(5):1310-6.

86. Miller J, Koh Y, Park C-G. Effects of power-based complex training on body composition and muscular strength in collegiate athletes. Am J Sports Sci Med. 2014;2(5):202-7.

87. Palmer T, Thompson B, Hawkey M, Conchola E, Adams B, Akehi K, et al. The influence of athletic status on the passive properties of the muscle-tendon unit and traditional performance measures in division 1 female soccer players and nonathlete controls. J Strength Cond Res. 2014;28(7):2026-34.

88. Esco M, Snarr R, Flatt A, Leatherwood M, Whittaker A. Tracking changes in maximal oxygen consumption with the heart rate index in female collegiate soccer players. J Hum Kinet. 2014;42(1):103-11.

89. Green M, Esco M, Martin T, Pritchett R, McHugh A, Williford H. Crossvalidation of two 20m shuttle-run tests for predicting VO2max in female collegiate soccer players. J Strength Cond Res. 2013;27(6):1520-8.

90. Sjokvist J, Laurent M, Richardson M, Curtner-Smith M, Holmberg H-C, Bishop P. Recovery from high-intensity training sessions in female soccer players. J Strength Cond Res. 2011;25(6):1726-35.

91. Stanforth P, Crim B, Stanforth D, Stults-Kolehmainen M. Body composition changes among female NCAA division 1 athletes across the competitive season and over a multiyear time frame. J Strength Cond Res. 2014;28(2):300-7.

92. Hasegawa N, Kuzuhara K. Physical characteristics of collegiate women's football players. Football Sci. 2015;12:51-7.

93. Kutlu M, Yapici H, Yilmaz A. Reliability and validity of a new test of agility and skill for female amateur soccer players. J Hum Kinet. 2017;56(1):219-27.

94. Rosas F, Ramirez-Campillo R, Martinez C, Caniuqueo A, Canas-Jamet R, McCrudden E, et al. Effects of plyometric training and beta-alanine supplementation on maximal-intensity exercise and endurance in female soccer players. J Hum Kinet. 2017;58(1):99-109.

95. Ramirez-Campillo R, Gonzalez-Jurado J, Martinez C, Nakamura F, Penailillo L, Meylan C, et al. Effects of plyometric training and creatine supplementation on maximal-intensity exercise and endurance in female soccer players. J Sci Med Sport. 2016;19(8):682-7.

96. Ozbar N, Ates S, Agopyan A. The effect of 8-week plyometric training on leg power, jump and sprint performance in female soccer players. J Strength Cond Res. 2014;28(10):2888-94.

97. Mara J, Thompson K, Pumpa K, Ball N. Periodization and physical performance in elite female soccer players. Int J Sports Physiol Perform. 2015;10(5):664-9.

98. Nikolaidis P. Weight status and physical fitness in female soccer players: Is there an optimal BMI? Sport Sci Health. 2014;10(1):41-8.

99. Baumgart C, Hoppe M, Freiwald J. Different endurance characteristics of female and male german soccer players. Biol Sport. 2014;31(3):227-32.

100. Loturco I, Pereira LA, Kobal R, Abad CC, Rosseti M, Carpes FP, et al. Do asymmetry scores influence speed and power performance in elite female soccer players? Biol Sport. 2019;36(3):209-16.

101. Milanovic Z, Sporis G, Trajkovic N. Differences in body composite and physical match performance in female soccer players according to team position. J Hum Sport Exerc. 2012;7(1):67-72.

102. McCurdy K, Walker J, Langford G, Kutz M, Guerrero J, McMillan J. The relationship between kinematic determinants of jump and sprint performance in division I women soccer players. J Strength Cond Res. 2010;24(12):3200-8.

103. Vescovi J, Rupf R, Brown T, Marques M. Physical performance characteristics of high-level female soccer players 12–21 years of age. Scand J Med Sci Sports. 2011;21(5):670-8.

NOTES

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Authors' contributions.— Jesse Griffin – Project concept, data collection and preparation of manuscript. Clare Minahan - Project concept, refining, synthesising manuscript. Sean Horan, Justin Keogh – Refining and synthesising manuscript. Karl Dodd, Melissa Andreatta – Project concept and provision of data collection.

TABLES

Table I.— A summary of the anthropometric characteristics of football players.

References	Competition-level	Age (years)	Height (cm)	Weight (kg)	Body Fat (%)
(13, 26, 35, 47, 75)	U16	15.1 – 16.1	162.8 – 165.8	56.8 – 59.3	21.7 (Skinfolds)
(10, 30, 61, 62, 79)	U17	14.7 – 16.5	162.3 – 166.4	55.7 – 59.2	
(61, 62)	U19	16.9	166.3 – 167.0	61.1 – 61.7	
(11, 30, 79)	U20	17.8 – 19.0	166.6 – 167.0	59.8 – 64.8	
(37, 42, 43, 46, 51, 52, 64, 67, 82-92)	College	18.7 – 22.4	159.1 – 170.1	54.7 – 64.0	19.4 – 20.9 (Skinfolds)
		GK 20.5 ^	172.0 ^	72.5 ^	
		D 21.0 ^	165.0 ^	59.2 ^	24.1
		M 20.0 ^	167.0 ^	59.3 ^	(DXA)
		A 19 ^	170.0 ^	67.1 ^	

					20.1 – 29.7 (BIA)
(10, 21, 23, 27, 36, 93-96)	Sub-elite	18.3 – 26.1	160.0 – 168.0	55.5 – 62.7	20.2 – 20.8 (Skinfolds)
		GK 20.6	166.2	66.5	17.2
		D 22.6	159.1	57.4	12.2
		M 21.7	158.7	55.0	11.3
		A 21.3	160.9	56.3	11.8
(10-12, 19, 24, 25, 28, 29, 31, 54, 55, 58, 63, 97-100)	National	18.3 – 25.4	163.6 – 172.9	56.2 – 64.3	21.1 - 23.1
		GK 19.1 – 22.9	166.3 – 172.5	59.5 – 66.5	20.7 – 27.8
		D 18.5 – 21.9	164.8 – 168.6	56.3 – 62.5	21.7 – 21.8
		M 18.3 – 21.7	163. 5 – 165.3	56.0 – 61.3	21.6 – 23.6
		A 17.4 – 20.4	163.6 – 165.0	58.4 – 63.6	20.3 – 22.3 (Skinfolds)
					21.3 – 21.5 (DXA)

(11, 20, 30, 61, 62, 79, 101)	International	23.0 – 26.0	167.3 – 168.8	59.9 – 64.1	19.5 (BIA)
			GK 175.4	71.5	
			CD 171.5	63.9	
			WD 165.8	61.8	
			CM 164.9	60.0	
			WM 163.9	57.0	
			A 166.9	62.3	

All data are expressed as a range of study means, unless otherwise stated

^ Data expressed as median

A = attackers; BIA = bioelectric impedance analysis; CD = central defenders; CM = central midfielders; D = defenders; DXA = dual energy x-ray absorptiometry; GK = goalkeepers; M = midfielders; WD = wide defenders; WM = wide midfielders.

Table II.— A summary of the strength characteristics of football players.

References	Competition-level	H:Q Ratio	1 RM (kg)	Testing Procedures
(35)	U16		78.9 1.3* (Squat) 42.5 0.7* (Bench Press)	
(30)	U17	0.90		Isokinetic dynamometer $60^{o}\cdot s^{-1}$
(30)	U20	1.03		Isokinetic dynamometer $60^{o}\cdot s^{-1}$
(37, 86)	College	0.84 ($60^{o}\cdot s^{-1}$) 1.58 ($240^{o}\cdot s^{-1}$)	74.7 1.2* (Squat)	Isokinetic dynamometer Knee angle < 90^{o}

(36)	Sub-elite	0.85 (Dominant) 0.88 (Non-dominant)		Isokinetic dynamometer $120^{o}\cdot s^{-1}$
(28)	National		61.1 1.0* (Squat) 37.7 0.6* (Bench Press)	
(30)	International	1.04		Isokinetic dynamometer $60^{o}\cdot s^{-1}$

All data are expressed as a range of study means, unless otherwise stated

* Data expressed as $kg\cdot BW^{-1}$

1 RM = 1 repetition maximum, BW = body weight; H:Q ratio = hamstring eccentric strength: quadriceps concentric strength.

Table III.— A summary of the speed characteristics of football players.

References	Competition-level	Time 5 m	Time 10 m	Time 20 m	Time 30 m	Time 40 m	Testing Procedures
(13, 26, 47, 75)	U16		1.91 – 1.99	3.42	4.81		Timing gates, 0.2 – 0.5 m behind start line
(10, 62, 79)	U17	1.04 – 1.08	1.83	3.28 – 3.45	4.65		Timing gates, 1 m behind start line
(44, 62)	U19	1.06	1.70	3.12	4.44 – 4.57	5.77	Timing gates, 0 – 1 m behind start line
(79)	U20			3.39			Timing gates
(42, 43, 46, 64, 84, 90, 92, 102)	College	1.14 – 1.15	1.92 – 2.31	3.59 – 3.76	4.69 – 4.93		Timing gates, standing start 0 – 0.5 m behind start line
		GK 1.19 ^	2.04 ^	3.75	4.86 ^		
		D 1.18 ^	2.00 ^	3.76	4.69 ^		
		M 1.12 ^	1.96 ^	3.74	4.75 ^		
		A 1.15 ^	1.99 ^	3.82	4.74 ^		

(10, 23, 27, 93-96)	Sub-elite	1.08	1.88	3.32 – 3.95	4.93	6.32 – 6.36	Timing gates, 0 – 1 m behind start line
(10, 12, 24, 31, 44, 45, 63, 100)	National	1.06 – 1.17	1.70 – 2.0	3.10 – 3.60	4.43 – 4.8	5.75 – 5.93	Timing gates, 0 – 1 m behind start line
(44, 45, 62, 79)	International		1.67	3.05 – 3.30	4.35	5.64	Timing gates, 0 – 1 m behind start line
		GK 1.11	GK 1.71	3.14	4.48 – 4.75	5.83	
		CD 1.07	D 1.69	3.09	4.40 – 4.52	5.71	
		WD 1.05	M 1.70	3.12	4.44 – 4.52	5.76	
		CM 1.06	A 1.68	3.05	4.34 – 4.41	5.62	
		WM 1.05					
		A 1.02					

All data are expressed as a range of study means measured in seconds, unless otherwise stated

^ Data expressed as median

A = attackers; CD = central defenders; CM = central midfielders; D = defenders; GK = goalkeepers; M = midfielders; WD = wide defenders; WM = wide midfielders.

Table IV.— A summary of endurance characteristics of football players.

References	Competition-level	Endurance Test	Yo-Yo (m)		VO_{2max} (ml·kg^{-1}·min^{-1})
(13, 26, 75)	U16		952 – 1010 (YYIR1)		
(10, 30, 62, 79)	U17	18.4 (km·h^{-1}) (30-15)	720 – 1760 (YYIR1)		46.2
(62)	U19		1357 (YYIR1)		
(11, 30, 79)	U20	18.7 (km·h^{-1}) (30-15)	860 (YYIR1)		47.7
			1490 (YYIE2)		
(42, 43, 46, 51, 52, 64, 82, 83, 88-90, 92)	College	8.9 (level) 9.1 (mins) (MSFT)	890 - 1690 GK 980 ^	533 240 ^	40.8 – 54.3

			D 2000 ^ 680 ^ M 1740 ^ 560 ^ A 1400 ^ 440 ^ (YYIR1) (YYIR2)	
(10, 21, 23, 27, 36, 94, 95)	Sub-elite	7.7 – 8.5 (mins) 1537 (m) 10.9 (level) (MSFT)	561 – 1140 (YYIR1)	41.1 – 42.7
(10, 11, 28, 54, 55, 58, 63, 97, 99)	National	16.8 (km·h^{-1}) (30-15) 1536 (m) (MSFT)	1020 – 1635 (YYIR1) 450 (YYIR2) 1261 - 1265 (YYIE2)	49.2 – 52.3 GK 50.7 D 51.9 M 55.4 A 52.9
(11, 30, 55, 62, 79, 101)	International	18.0 – 19.2 (km·h^{-1}) (30-15)	930 – 1583 (YYIR1)	47.3 – 50.3

GK 1054	
CD 1689	1588
WD 1698	1964
CM 1659	1764
WM 1655	2057
A 1566	1516
(YYIR1)	(YYIE2)

All data are expressed as a range of study means, unless otherwise stated

^ Data expressed as median

30-15 = 30-15 intermittent fitness test; A = attackers; CD = central defenders; CM = central midfielders; D = defenders; GK = goalkeepers; M = midfielders; MSFT = multi stage fitness test; WD = wide defenders; WM = wide midfielders; YYIE2 = Yo-Yo intermittent endurance test level 2; YYIR1 = Yo-Yo intermittent recovery test level 1; YYIR2 = Yo-Yo intermittent recovery test level 2.

Table V.— A summary of the power characteristics of football players.

References	Competition-level	Squat Jump	CMJ	Depth Jump	Horizontal Jump	Testing Procedures
(13, 26, 35, 75, 103)	U16		38.7 (Hands on hips) 31.4 – 48.8 (Arm swing)			Jump mat, Vertec, Optojump
(10, 30, 61, 62, 79)	U17	26.1 – 28.2	28.1 – 30.2	30.0	153 (SL)	Jump mat, Optojump, hands on hips 30 cm drop height
(44, 61, 62)	U19	32.8	28.5 – 34.3			Force platform, Jump mat, Optojump, hands on hips
(30, 79)	U20	29.4	31.6		157 (SL)	Jump mat, hands on hips

(42, 43, 64, 67, 82-85, 87, 90, 92, 102, 103)	College	36.2 – 50.0 (Hand on hips) GK 54.0 ^ D 48.0 ^ M 51.0 ^ A 54.0 ^ (Arm swing)	24.0 – 42.0 29.1 28.2 27.5 25.7 (Hands on hips) 32.1 – 48.8 (Arm swing) 19.0 (SL)	40.0 29.0 (SL)	147 – 197 133 (SL)	Force platform, Accelerometer, Jump mat, Vertec 40 cm drop height SL 20 cm drop height
(10, 23, 27, 94-96)	Sub-elite	24.5 – 27.5	27.3 – 46.8	26.8	192.3	Force platform, Jump mat, hands on hips 30 cm drop height
(10, 12, 31, 44, 58, 63, 100)	National	28.0 – 29.0	26.8 – 48.6	28.0 – 30.5	193.5	Force platform, Jump mat, hands on hips

		14.2 – 15.7 (SL)	15.6 – 17.5 (SL)			30 – 40 cm drop height
(30, 44, 62, 79)	International	32.1	30.7 – 33.4 GK 30.0 – 32.2 D 29.6 – 33.6 M 28.4 – 33.9 A 30.5 – 34.9		163 (SL)	Force platform, Jump mat, hands on hips

All data are expressed as a range of study means measured in centimetres, unless otherwise stated

^ Data expressed as median

A = attackers; CMJ = countermovement jump; D = defenders; GK = goalkeepers; M = midfielders; SL = single leg.

Table VI.— A summary of the change of direction ability of football players.

References	Competition-level	Illinois Agility	Pro Agility	T Test	180^0 Turn	Testing Procedures
(13, 26, 35, 75, 103)	U16		4.92 – 5.01		2.53 – 2.54 (505)	Timing gates, reactive and flying start
(10)	U17				2.66 – 2.85 (505)	Timing gates, 1 m behind start line
(42, 43, 46, 83, 84, 103)	College	18.7 (Supine)	4.87 – 5.09 GK 4.94 ^ D 5.14 ^ M 5.11 ^ A 4.88 ^	11.92		Timing gates, 0 – 0.5 m behind start line, flying start
(10, 23, 27, 93-95)	Sub-elite	18.6 – 19.2 (Supine)		12.17	2.59 – 2.63 (505) 8.17 – 8.26 4 turns, 30 m	Timing gates, 0 – 1 m behind start line

(10, 12, 29, 63)	National		2.38 – 2.76 (505) 9.91 4 turns, 40 m	Timing gates, 1 m behind start line

All data are expressed as a range of study means measured in seconds, unless otherwise stated

^ Data expressed as median

A = attackers; D = defenders; GK = goalkeepers; M = midfielders.

Table VII.— A summary of the repeated sprint ability of football players.

References	Competition-level	RSA Avg	Shuttle	Testing Procedures
(35)	U16		59.2	Reactive start 300-yard test
(62)	U17	4.98		Timing gates, 1 m behind start line 7 x 30 m, 30 s rest
(62)	U19	4.91		Timing gates, 1 m behind start line 7 x 30 m, 30 s rest
(43, 46)	College		13.45 – 13.51	Timing gates, 0.5 m behind start line 60-yard test
(23, 27, 94, 95)	Sub-elite	7.10 – 7.30 (6 x 35 m, 10 s rest)		Timing gates, behind start line

		5.01 – 5.04 (7 x 30 m, 30 s rest)		
(28, 45, 58, 63)	National	23.3 (TT) (6 x 20 m, 15 s rest)	66.5	Light gates 300-yard test
		4.86 (3 x 30 m, 25 s rest)		
		5.94 (10 x 40 m, 60 s rest)		
(45, 62)	International	4.84 GK 5.19 ± 0.26 CD 4.81 ± 0.15 WD 4.80 ± 0.14 CM 4.81 ± 0.16 WM 4.78 ± 0.14 A 4.75 ± 0.15		Timing gates,1 m behind start line 7 x 30 m, 30 s rest

	20.9 (TT) (6 x 20 m, 15 s rest)

All data are expressed as a range of study means measured in seconds, unless otherwise stated

A = attackers; CD = central defenders; CM = central midfielders; GK = goalkeepers; RSA Avg = repeated sprint ability average time, TT = total time; WD = wide defenders; WM = wide midfielders.