**RATIONALE, TIPS, AND PRACTICAL RECOMMENDATIONS FOR TESTING PROTOCOLS IN FEMALE SOCCER: A NARRATIVE REVIEW**

**Authors**

Marco Beato1\*, Naomi Datson2, Liam Anderson3, Thomas Brownlee3, Alex Coates1, Andrew Hulton4

**Affiliations**

1. School of Health and Sports Sciences, University of Suffolk, United Kingdom
2. Institute of Sport, Nursing and Allied Health, University of Chichester, United Kingdom
3. School of Sport, Exercise and Rehabilitation Sciences, University of Birmingham, Birmingham, United Kingdom
4. Department of Nutritional Sciences, Faculty of Health and Medical Sciences, University of Surrey, United Kingdom

**Correspond author**

Marco Beato, School of Health and Sports Sciences, University of Suffolk, United Kingdom, email: m.beato@uos.ac.uk

**Abstract**

The aim of this narrative review is to evaluate the presented literature on tests (aerobic, speed, changes of direction [COD], strength, power, jump and anthropometry) of the varied components of female soccer and to draw attention to the most suitable protocols to allow practitioners to accurately track players' fitness status. The two most common field tests used to assess aerobic fitness are the Yo-yo intermittent test (level 1 and 2) and the 30-15 intermittent fitness test, due to an ability to measure multiple players at once with a soccer specific intermittent profile. The sprinting performance can be assessed on distances < 30 m, however, longer distances (*e.g.,* 40 m) allow for achieving peak speed (flying sprint test), which can be assessed using global navigation satellite system. COD capacity has been found to be an important component of players testing and training programs, although there is no “gold standard” to assess COD or repeated sprint ability performance in female players. Lower limb power can be assessed using jump tests that can use force platforms, jump mats, optoelectronic devices, whilst maintain a good reliability. Several in-direct tests are currently available for assessing anthropometry parameters such as skinfold thickness, hydrodensitometry, and ultrasound. However, dual-energy X-ray absorptiometry is the most valid and reliable method for assessing body composition in team sport athletes, with the addition of bone health that is a key measure in female athletes. In conclusion, the evidence reported in this review will be able to aid practitioners, coaches, and researchers to decide which tests meet the requirements of their environment.

**Keywords:** women; football; assessments; performance; training

**INTRODUCTION**

The game of soccer has evolved considerably since formative analysis was conducted in the 1960’s and it is now considered one of the most dynamic, energetic and high-velocity sports (144). Research has primarily been dominated with a male focus, but there has been a large growth in female soccer participation. Since 2016, women soccer participation in England has risen exponentially and amassed over 3.4 million players (139) and 30 million players worldwide. However, research is yet to catch up, and there is still a limited amount of research investigating female soccer players (111).

Previous research investigated the demands in female soccer and found that total distance ranged approximately from 9 km to 11.5 km, with high-speed running (>19.8 km.h-1) distances ranging between 344 m to 867 m (33). These physical demands are affected by playing position, for instance, the central midfielders cover a greater amount of distance, while central defenders cover the least amount of distance compared to other outfield positions (33). In addition, female players perform a variety of high-intensity actions, such as sprinting, changes of direction (COD) and jumping (115,124). The importance of high-intensity activities is consistently expressed within the soccer literature, with sprinting, jumping and COD activities observed to be performed every 4 seconds within a female professional soccer game, and therefore may occur more than 1000 times per match (100). Acceleration and deceleration actions are also very common within a game (86,132) and are well-known to be physiologically and mechanically demanding (11). Moreover, female players spend an approximate 4 – 7% of total running distance at sprinting speed during match-play (85,142), (>25.2 km.h-1, 69 m to 274 m) (33) and these high-intensity actions provide the basis of key tactical and technical actions in soccer such as overlapping attacking runs, counter-attacks, closing down opponents, and retaking possession, etc.(103), which highlight the importance of anaerobic metabolism in female soccer (58).

In addition to the high demand for anaerobic activities, aerobic capacity is necessary to maintain activity and optimize recovery throughout the duration of play (136). During female professional matches, the average oxygen consumption is between 77-80% of maximal oxygen consumption ($\dot{V}$O2max), peaking at 96% of $\dot{V}$O2max (62,73). Great demand for aerobic capacity is required to allow players to repeatedly perform and recover between high-intensity efforts (105). Likewise, repeated high speed actions are possibly a key physical component/determinant of soccer, due to the frequency of this intermittent action throughout a competitive match (46,47). It is suggested that the greatest periods of temporal fatigue in match-play follow the most intense bouts of high-speed running (48,101), therefore, possessing a combination of both aerobic capacity and repeated sprint ability allows a player to perform greater successive high-intensity movement with short rest intervals (147). It is also evident that strength and power are essential characteristics for soccer performances (138). Previous research has linked relative strength and performance variables such as the aforementioned sprinting, COD and jumping (49,72,145). These studies have highlighted that players who possessed a greater relative strength had a significantly greater sprinting, COD and jumping performance (143). These specific components of fitness can be key to determining the outcome of the match, therefore, it is essential that training protocols are in place to adequately prepare the players for the aerobic, speed, agility, power and strength demands of the sport (143). Consequently, practitioners/coaches should incorporate testing and monitoring for each of these fitness components to help inform training program design and oversee player development.

The identification of testing protocols that incorporate soccer specific physical capacities would allow female soccer players to accurately track fitness status, provide further information on their longitudinal improvements and be used to program training. Although a large amount of research has now been conducted on testing in soccer players, these investigations have primarily focused on male players (69,138). Consequently, this forces female athletes and their practitioners to rely on the guides and results of male literature (41). To the author’s knowledge, no review has evaluated the research studies that include both soccer performance and a female sample group. Therefore, the aim of this narrative review is to evaluate the presented literature on tests (aerobic, speed, changes of direction [COD], strength, power, jump and anthropometry) of the varied components of soccer and to draw attention to the most suitable protocols whilst using a female population. The results of this review could aid both practitioners and coaches to decide which tests meet the requirements of their environment, making their programs both specific and accurate.

**AEROBIC TESTS**

As stated previously, the demands of female soccer include a high aerobic component, highlighted by a coverage of between 9-11.5 km during matches (33). Therefore, the importance to measure and gain a greater insight into the aerobic capacity of players is key. The gold standard method of assessment for aerobic fitness is a treadmill based V̇O2max protocol measuring expired air utilizing a metabolic cart (coefficient of variation [CV] = 1.2%) (125). Traditionally, V̇O2max assessments last approximately 10 – 15 mins in duration and consist of an incremental stepwise protocol, that increases speed and/or inclination. Assumptions of this test include a plateau of V̇O2 despite increasing workload, heart rate within 10 beats/min of age predicted max, respiratory exchange > 1.15 (V̇CO2/V̇O2), and a blood lactate > 8 mmol (37).

Due to the equipment cost, laboratory time and expertise required for the successful implementation of a gold standard test, field tests have now become more commonplace and grown in popularity within team sport settings providing an estimation of V̇O2max. Historically, the Multi Stage Fitness Test (or bleep test) (120), was designed to replicate a treadmill protocol with its continuous and incremental nature. Similar alternatives include the 12-minute Cooper run (30) and the University of Montreal Track Test (UMTT; (75)). The UMTT has a large correlation with V̇O2max, with a r = 0.96 and low standard error of estimate (SEE) of 2.8 mL/kg/min (75). Despite this, there is a clear lack of validity when using continuous protocols to assess aerobic fitness in sports with an intermittent activity profile.

Consequently, there has been a development of intermittent field based protocols, such as the Yo-yo intermittent test (6), including a recovery and endurance version, and the 30-15 intermittent fitness test (27). The Yo-yo intermittent tests comprise of 2 x 20 m shuttle runs, followed by an active recovery period. The shuttle run speed must increase as the test progresses. An audio beep dictates the time allowed to complete the distance, shortening the time span as the test progresses. Total distance is recorded at the point where the individual is no longer able to maintain the required speed. The CV for the Yo-yo intermittent recovery test level 1 was observed to be 7.2% in a population (n=140) of elite female soccer players (35). Test scores may vary dramatically based on age and competition level, with values ranging from 710 ± 210 m in female U15 international players (119) to 1733 m (range: 1120 – 2200 m) in female senior international players (127). The CV of the Yo-yo intermittent recovery test level 2 was = 4.2% in a sample of Premier League academy players (43).

The 30-15 intermittent fitness test comprises of 30 s of continuous shuttle running interspersed with 15 s of passive recovery periods. Following each 45 s stage, the subsequent shuttle run speed increases by 0.5 km.h-1. The running velocity for the last completed stage is recorded as the test outcome. The CV was recorded as 1.8% in a small sample of well-trained female soccer players (31), with a similar CV of 1.5% recorded for female professional futsal players (141). Test scores may range from 18.4 ± 1.0 km.h-1 for U17 female international players (84) to 20.1 km.h-1 for senior international female players (126). Both the Yo-yo intermittent test and the 30-15 intermittent fitness test appear to differentiate between age groups, with international senior female players achieving higher scores compared to their U15, U17 and U20 counterparts (84,119).

Both intermittent field based tests are commonly used in applied practice and research settings due to their high sensitivity (i.e., capacity to discriminate players of different levels as well as to be sensitive to small fitness changes), practicality and relevance compared to laboratory based protocols (23). Furthermore, the 30-15 intermittent fitness test offers additional benefits for training prescription as velocity represents the primary outcome measure, which can be manipulated to support training needs. Caution should be exhibited if interpreting results from the estimation of V̇O2max using different field-based tests, due to the varying outcome measures (*i.e.*, speed vs. distance), and therefore results should not be used interchangeably and compared (Table 1).

**\*\*\* Table 1 here, please\*\*\***

**LINEAR AND REPEATED SPRINT TESTS**

The capacity to perform linear sprints in soccer plays an important role in the success of a team. Linear sprinting has been identified as the single most frequent locomotive action in goal situations performed by both scoring and assisting players (44). In addition, linear sprint capacity is crucial from a physical perspective, specifically, players need to be able to perform high intensity actions during matches (12), with previous research reporting a great amount of high-speed running during female soccer matches (33). Moreover, sprinting represent an important stimulus for neuromuscular adaptations, which could play a role in muscle injury prevention (83). This is specifically because of the mechanical load and characteristics muscle actions required during the terminal swing phase of the sprinting gait (12).

From a testing perspective, the most common way to assess linear sprinting capacity is to use timing gates (correctly referred to as photocell timing systems), which can be placed at the distance that practitioners wish to assess. During a match, sprint distances typically range between 5 m and 30 m, therefore it would seem logical to use a distance within this range for such assessments. However, in recent years, it was reported that longer distances (*e.g.*, 40 m) allow for achieving higher sprint velocities (74), so practitioners should consider performing longer sprint tests to ensure they assess the peak speed of their athletes. Consequently, when practitioners are more interested in assessing the average sprinting capacity measuring time (*e.g.*, from a standing position), it could be suggested to use a sprinting test between 5 to 30 m (CV range from 3.3% to 1.4%) (43), although the reliability for 5 m tests could be questionable in some cases. While, if the aim is to assess the peak speed, it would be recommended to use a longer track, *e.g.*, 40 m. While timing gates allow for assessing time and average speed, they are not suitable to assess peak speed (since with them it is possible to assess only average speed), therefore global navigation satellite system (GNSS) could be used to assess such parameter during this test (12). Previous research has demonstrated that GNSS technology (which is capable of acquiring multiple satellite systems such as Global Positioning System, GLONASS, Galileo, BeiDou) provides the best possible positional information is valid and reliable (sprints from 5 to 30 m, CV = 3.28%) to assess linear peak speed (9,10,14), therefore, it can be used with confidence by practitioners working in female soccer. To facilitate reaching peak speed, players could start their test in motion, using for example a flying sprint test protocol (*i.e.*, 10 m acceleration + 30 m sprint) (99). The knowledge of the peak speed allows practitioners, first, to understand the linear sprinting capacity of their players, second, to tailor speed training based on individual characteristics, and lastly, to individualize the sprinting threshold based on the peak speed recorded in the test (12). When analysing physical match/training performance, the sprinting threshold is commonly set at distance covered >25.2 km.h-1 for all players, independent of their peak speed. However, this approach could underestimate or overestimate the actual load of each player. Consequently, the use of the peak speed to individualize the sprinting threshold (*e.g.*, 80% peak speed) could be a suitable approach to avoid this issue (52). Although this practice is nowadays common among male football players, very limited information is currently available to women soccer players.

During a soccer match, players need to repeatedly perform high-intensity actions, therefore coaches could be interested to assess the repeated sprinting ability (RSA) of their players (105). The literature reports a large amount of research on this topic (8,22,43,146), which highlight the ecological validity of RSA for both testing and training purposes. This is further supported by recent research with women soccer players that reports international players have significantly greater speed and lower repeated sprint ability (RSA mean time) than their non-international counterparts (51). Although there are several RSA protocols used within the literature, currently there is no existing gold standard. Therefore, we propose the use of one of the most common RSA protocols used in soccer, which is a 20 + 20 m shuttle (with a 180° COD), followed by a 20 s period of passive recovery (after each shuttle) repeated 6 times (7,68). The common parameters that this test offers are: best RSA time (CV = 1.3%), mean RSA time (CV = 0.8%) and RSA decrement (CV = 30.2%). Practitioners need to be aware that the mean RSA time is the parameter with the greatest absolute reliability, while RSA decrement is the least reliable (68). From an applied point of view, RSA tests can be used by practitioners to assess their players’ fitness level and, subsequently, individualized the training based on players’ test results.

**CHANGE OF DIRECTION TESTS**

In soccer, players need to perform multidirectional speed actions that “comprise linear speed, COD speed, curvilinear speed, contextual speed and agility, which each having unique physiological, biomechanical, and neurocognitive characteristics” as reported by McBurnie et al., (91). During games, players need to perform rapid COD for specific technical and tactical motivations, for instance, to evade defenders in attack, as well as respond to an opponent’s (or the ball) movement and attempt to reduce their decision-making time in defense (3).

Assessing COD speed can consist of simple pre-planned movements (90); whereas integrating an element into testing where players change direction in reaction to a stimulus assesses agility (these two terms are sometimes and incorrectly used interchangeably). COD ability is considered the mechanical and physical basis for effective agility and is important to understand in isolation (131). COD ability has been found to be an important component of players testing and training programs as it can discriminate (both male and female) players of different playing standards (26,103) and it is important for the progression from youth to senior players (81). In addition, COD are common actions in the buildup to goal scoring situations (89) and are performed at regular intervals throughout match play (102). This helps us to understand the growing importance of COD speed in gaining an advantage over an opposition and can become a critical element for success, specifically for moving into space away from a defender to score a goal or following an opponent’s COD to block a shot or pass.

Given the interest in player’ COD ability, studies assessing this physical component in high-level female players are starting to materialize (42,78,96,103). Indeed, previous research by Stewart et al. (2014) who analyzed both male and female participants separately and pooled (135), concluded that all COD tests completed in their investigation (Illinois, L-Run, Pro-Agility, T-test, and 505) were found to have a high retest reliability and acceptable CV with only marginal differences between tests. Apart from the T-test, the CVs were lower within the female population compared to the males and ranged between 1.63% (i.e., L-run) to 2.29% (i.e., T-Test). Based on the similarity between COD tests and their high reliability, only one of them is needed to be completed by players and that the test chosen should be that which replicates the movement patterns of the sport best. In soccer, tests are required to be specific to the movement demands required during the game. For example, Morgan et al. (2021) identified that 78% COD within male academy players match play are <90°, decreasing the ecological validity of performing tests where turns are performed at 180° (*i.e.,* 505-agility test) (102). Despite such information, currently there is no “gold standard” to assess either agility or COD speed in female or male players (76). This is because soccer related tests use differing angles of COD, sprint distance and volumes of sprints and shuttles, leading to variated test scores (*i.e.*, 1.0s in 505 test and 6.2s in Illinois) (42,55,79).

Another point that is worth knowing is that although tests involve COD movements, the final scores are not due only to this ability, they encompass other physical components, for instance, linear sprinting (when distances are increased over 10 m) and physiological factors when repeated COD actions are performed (*e.g.*, RSA test). Therefore, it is important to be aware of other physical components the test is potentially assessing, or undertake a test that best isolates COD speed and playing demands. In addition, a further measure that can be added to existing tests, such as the 505 test, is the COD deficit (108). This is a practical measure to isolate COD ability independent of sprint speed and other attributes.

In addition to the tests reported above, the importance of deceleration capacity has received a lot of attention of late due to the high mechanical load that this locomotive activity imposes on the athlete (32). Indeed, a meta-analysis by Harper et al. (59) found that there is a greater frequency of high and very high intensity decelerations compared to accelerations in all team sports apart from American football. Moreover, the importance of decelerations (and accelerations) has been recently reported in a soccer-specific meta-analysis (132). With regards to testing protocols specifically for deceleration, there is less knowledge and direction for practitioners on how to assess this horizontal characteristic (16). Nevertheless, there is a novel protocol using an acceleration-deceleration ability test that measures maximal horizontal deceleration (60). The authors used a radar technology (data was averaged throughout the deceleration phase) to assess horizonal braking force, power and impulse, which all provided good overall intra-day (CV = 5.1% to 5.7%) and inter-day reliability (CV = 8.9% to 9.3%), and sensitive to detect moderate changes in horizontal deceleration ability (61). However, the use of radar technology in soccer daily practice could be limited because of the cost of this device and the limited time available for testing, which is a common problem in professional soccer.

Based on what said so far, it is clear that the scientific literature does not have a gold-standard test for the assessment of COD ability, therefore, it is recommended the practitioners/coaches determine which tests to undertake to appropriately utilize them as part of the training program design and talent identification process (See Table 2).

**\*\*\* Table 2 here, please\*\*\***

**STRENGTH TESTS**

Muscle strength testing protocols (absolute and relative to a person’s body weight) play an important role in players' needs analysis and for the following design of sport specific and individualized training programs, which in turn likely enhances future match performances (4,65,67,140). For example, by enhancing overall strength, the player is likely to move the ball more easily, battle opponents more forcefully and kick the ball further and harder (34). From a physical point of view, previous research reported that lower-limb strength training has a positive effect on agility, repeated sprinting with COD, lower limb peak power, and enhanced specific neuromuscular adaptations (57). Research has linked the relationships between relative strength and performance variables such as the aforementioned sprinting and COD as well as jumping (29,113,137,145). Additionally, these studies have highlighted that players who possessed greater relative strength had a significantly greater sprinting and jumping performance. Indeed, strong correlations were found, albeit with male soccer players, with 1RM and 10 m sprint times (r = 0.94), 30 m sprint times (r = 0.71), 10 m shuttle test (r = 0.68) and jump height (r = 0.78) (138). Furthermore, an in season strength training program resulted in an improvement in maximal back squat performance, which also demonstrated positive improvements to speed (5 m: r = 0.62; 10 m: r = 0.78; 20 m: r = 0.60) (130). These specific components of fitness can be key to determining the outcome of the full-time result by impacting actions such as running through on goal and scoring, jumping for a header or save and even turning a player to evade or tackle them. Therefore, it is essential for a practitioner/coach to incorporate testing for these components of fitness to help inform training program design. These can, and should, be reinforced with strength tests, which in turn should be shown to be valid and reliable in female populations. These would span from 1 RM testing to isometric and eccentric contraction testing as well as the gold-standard of isokinetic dynamometry (15,20). These tests previously reported an excellent level of test–retest reliability (intraclass correlation coefficients [ICC] = 0.93–0.95) and an acceptable level of technical error of measurement (around 4–5%) (13). One recent study has examined muscular strength measured via use of the isometric midthigh pull throughout a season in elite youth female soccer players though this is the extent of such relevant research (42). Within the study the isometric midthigh pull peak force ICC and CV were 0.93 and 3.6%, respectively. Because of its practicality and reliability, this test can give insights for the design of strength and conditioning program to practitioners.

Few articles have investigated strength in female soccer, suggesting certainty around the attribute with specific regard to the sport is very limited at this time (110,113). despite there being some reference data for other measures (*i.e.*, countermovement jump (CMJ) height, sprint performance, and aerobic fitness) (36), research on strength measures in female populations is quite limited. Furthering our understanding in this area is of great importance as it has been shown in male soccer players that understanding lower-limb muscle strength ﻿testing could be used to evaluate possible inference on injury prevention and performance (15). If this is also true for female players, then the importance of strength testing could not be clearer. In addition, it has been shown previously that strength testing via isokinetic assessment has the ability to differentiate level of male soccer players (15). Again, this suggests determining if the same is true for female players could be very valuable for talent identification and training purposes. Since the current evidence are quite limited, future research needs to investigate if the lower limb strength tests that are currently used in male soccer can be used also with female soccer players. Future research could verify the validity and reliability of the most common tests enrolling female samples before their implementation into soccer teams and respective academies. These tests should be capable to help talent identification procedures, performance increment (since these parameters will be used for training decision making), and injury prevention (42).

**LOWER-LIMB POWER AND JUMP TESTS**

For female soccer players, the ability to produce powerful actions from the lower limbs is an essential aspect of sport specific physical performance (50,54). Lower-limb power is a prerequisite of speed and agility performance (92,94), which can influence players’ capacity to respond to critical situations within match play such as increased linear or COD speed to score or defend a goal (89). In addition, lower limb power is essential for the demands of the game since female players change the intensity of activity 1326-1379 times per match as well as performing 125-154 and 20-27 high intensity runs and sprints with distances totaling between 1300-1680 m and 250-460 m, respectively (5,100). As reported, the high-intensity nature of the female’s game is evolving (24), with a growing importance of developing lower-limb power for success of soccer players. Finally, lower limb power and jump performance are considered integral parts of soccer match performance, with relative aerial duels won found to be an important contributor to match outcome in elite female soccer (70). Jumping has also been shown to be a common action in goal scoring situations (44,89). This is supported by the fact that 24% of goals scored in the Australian W-League were the result of a cross from wide areas (87).

Jump testing is commonly used in field settings to provide an estimation of a player’s lower limb muscular capacity. This is highlighted by jump power testing performance significantly correlating (r = 0.70-0.93) to speed and agility test performances (109). In practical settings, there are several types of jump tests commonly employed. These include, the CMJ, squat jump, drop jump and broad jump. Countermovement jumps (with hands placed on the hips) performed on a force platform has been suggested to be the most valid and reliable for isolated lower-limb power (53). Countermovement and drop jumps are stretch-shortening cycle (SSC) movements, which involve a high-intensity eccentric contraction immediately prior to a rapid concentric contraction (66), whereas the squat jump assesses the capability to rapidly develop force solely during a concentric movement (95). The broad jump requires the individual to propel themselves horizontally (17), whereas the CMJ, squat jump and drop jump are concerned with vertical movement (18,110). Typically, the CMJ appears to be the most prevalent jump test in the literature which is likely due to the ease of assessment and minimal athlete familiarization (40). The exact protocol often varies, with some studies permitting individuals to use an arm swing (133), whereas others stipulated a fixed arm position whilst jumping (130). Research has shown that jump height is higher when adopting an arm swing, yet there is *good* to *excellent* inter-session reliability for such protocols (0.82-0.97 ICC) (13,134). The reliability of the CMJ (highest jump height recorded to the nearest 0.1 cm) has been assessed in elite female soccer players (140 national team players, age range: 12-33 years) reporting a good test-retest CV was 3.9% (95% CI, 3.4% to 4.3 %) (35). Countermovement jump performance has been shown to differentiate between standards of competition, with National team players outperforming their First division and junior elite counterparts by 8% (Cohen’s d = 0.6) and 9% (Cohen’s d = 0.5) respectively in jump height (63). Predicted reference centiles for CMJ performance in National team female players have previously been reported and provide a useful benchmark for performance (36). The authors present an example of a players who achieved a score of 27 cm at 17 years old, which improves to 35 cm at 21 years old, resulting in the player moving from the 25th centile to the 75th centile. This reference data, albeit from only one National association, is a simplistic tool to track progress of players over time. In addition, horizontal jumps can be used to assess power in a different plane of movement, although research of this on female players is limited to the distance of a triple hop test with arm swing, it is strongly correlated to CMJ (r = 0.834) (56). While these methods seem relatively simple to perform, there is huge variability in the protocol used for the tests performed. Such rigor of the test protocol used can have huge impact on the results and it is difficult to make comparisons between the two protocols (64). In addition to the test performed, there is also large variability in the equipment/technology used to assess lower limb power and jump performance with assessments been taken utilizing manual measurement (56), timing mat (28), mobile application (116), video assessment (77), accelerometers (25), and linear encoder to estimate a force-velocity curve (128). Therefore, the practitioner should consider the aim of the testing session when contemplating which lower limb test(s) and technology to employ (See Table 3). Moreover, it is important when testing lower-limb power to utilize a ‘best practice’ in terms of equipment (*i.e.*, best equipment available) and standardized protocol with the same technology equipment (66,117,118).

**\*\*\* Table 3 here, please\*\*\***

It is generally accepted that force platforms are considered the gold standard for jump testing, as they provide force-time data which enables a more detailed interpretation of any mechanistic changes which may result in an increase or decrease in performance, *i.e.*, jump height or power (93). That said, force platforms may not be accessible or feasible in all performance settings, therefore, field-based testing equipment (*e.g.*, jump mat or optoelectronic devices) provide a realistic alternative and estimate jump height from flight time (36,114). Further, with the development of technology and potential financial restrictions with female soccer, a recent investigation validated a smartphone application (My Jump Lab), which was shown as both a valid and reliable means of measuring CMJ (r = 0.98) (21), which may add to the availability of methods to collect lower limb power.

**ANTHROPOMETRY**

A favorable anthropometric profile is viewed as an advantageous characteristic during locomotor activities including specific technical skills required for sport (97,122), with positive profiles including low levels of fat mass (FM) allied with high levels of fat free mass (FFM). Assessment of body composition provides a broad measure of fitness that may be useful for the determination of athletic status and for monitoring progression/effectiveness of injury rehabilitation, dietary and training interventions (2,38,98). Anthropometric observations, including body mass (BM) and percentage body fat (%BF), within female soccer have highlighted differences between elite and non-elite players (129), providing a rationale for assessments. Furthermore, from a health perspective, a desire to maintain a low BM or %BF may lead to calorie restriction and a low energy availability which can impair bone health and result in suboptimal menstrual function (107). This would be indicative of the Female Athlete Triad or Relative Energy Deficit (REDs), which has detrimental health implications if not addressed (1). Therefore, caution should be taken when obtaining and translating results from anthropometric assessments.

There are a variety of methods available for the measurement of body composition, with the only direct method being the cadaveric dissection, which is obviously not appropriate. Therefore, indirect methods have been developed and include dual-energy X-ray absorptiometry (DXA), skinfold thickness, hydrodensitometry, air displacement plethysmography and ultrasound. Further, doubly in-direct methods that use predictive regression equations are available. These include bioelectric impedance, 3D photonic scanning, and estimations for %BF from ultrasound and skinfold thickness measures. DXA is the method purported to be the most valid for body composition assessment as no gold standard currently exists in free living individuals (71). The method provides measures of FM, FFM, %BF, bone mineral content and density, but found primarily in clinical settings making them difficult for teams to regularly utilize in addition to the high cost of use (45,104). DXA is valid and reliable for assessing body composition in team sport athletes (123), with low co-efficient of variation for both FFM (CV = 0.5–0.6%) and bone mineral content (CV = 2.2–2.3%), although less accurate when assessing fat mass in lean athletes, DXA has greater validity and reliability than similar estimates derived from BIA and skinfolds (19).

Compared to elite male soccer teams, monetary investment in elite female soccer is significantly lower, therefore, it is unlikely many female teams have access to DXA. Consequently, a cheaper, accurate alternative method of assessing body composition, such as skinfold thickness, may be more applicable for this population. Skinfold measures are an indirect measure if used to produce a sum of the sites measured, primarily referring to the sum measured in mm’s for eight sites (biceps, triceps, subscapular, iliac crest, supraspinale, abdominal, anterior thigh and medial calf), advocated by The International Society for the Advancement of Kinanthropometry (88). This method is more cost effective, more accessible than DXA and other methods, and commonly used in applied settings (112). However, many practitioners and coaches will utilize doubly indirect methods to calculate %BF, but limitations and caution exist as over one hundred anthropometric equations have been developed, with varying reliability depending on the populations on which they are developed (80). Indeed, Doran et al. (39) encourage the use of an absolute skinfold thickness as their findings, albeit in a male team sport population, failed to predict %BM with DXA within an accepted ±3.5% utilizing doubly in-direct equations. Nonetheless, a specific calculation for senior male soccer players utilizing 4 sites (anterior thigh, abdominal, triceps and medial calf) was developed by Reilly et al. (122) that accounted for 78% of the variance in DXA criterion values. No specific calculation for senior female players exist, though equations are available for adolescent players for both sexes that present no differences and no trend regression line when compared with DXA accounting for 86% variance in DXA %BF (82).

In light of the limitations and potential inaccuracies calculating %BF from skinfold thickness, recommendations by Reilly et al. (122) to use the sum of the eight sites for skinfold measurements still hold true today and supported with a contemporary review (71). Additional verification within a recent female soccer review (121) support the rationalization from Nana et al. (106), suggesting where appropriate DXA or the ISAK method of skinfold thickness (sum of 8) should be employed. If the use of DXA is an option then this method may be prioritized, as an advantage over skinfold thickness is the improved accuracy and importantly the additional measures on bone health. However, one caveat on the use of the DXA may be the legal and ethical issues with regards to the dose of radiation that is emitted, even though this is a small amount when compared to other devices that emit radiation in healthcare [119]. If monthly anthropometric measurements are required, then the ISAK sum of eight should be recommended, as there is concern over the number of DXA scans that individuals should receive, and importantly within the female population it is inappropriate to scan females who may be pregnant. Therefore, it may be recommended that DXA is used annually or bi-annually for measures on bone health, with the ISAK sum of 8 used throughout the season for body composition.

**LIMITATIONS AND FUTURE DIRECTIONS**

This review is not without limitation, first, it is not a systematic review of the existing literature. Although the authors have summarized the current evidence and reported several papers to the best of their abilities, it is not possible to state that all existing studies have been reported. Because of the nature of this review, some specific and rigorous aspects of a systematic review have not been used, specifically, search terms, databases used, and inclusion and exclusion criteria. Second, much research has been conducted so far on male soccer players, while much less involved on female players. Therefore, the literature on tests and their consequent use are strongly influenced by what has been completed with their male counterpart. More research is needed to verify if tests used with male players are suitable to assess the female counterpart. Third, because of the limited existing literature on female soccer, it is not possible to fully understand the test reliability (i.e., CV and ICC) of all used assessment protocols. Reliability (e.g., test – retest) plays a paramount role for the selection of the test protocols, as well as help to accurately create target scores for players, therefore, more research around this area is needed. Fourth, we have some practical limitations that affect our comprehension of physical demands in female soccer; specifically, the match demands reported in some studies do not always use the same intensity categorization, for example, high-speed running and sprinting distances are commonly reported as distanced covered above >19.8 km.h-1 and >25.2 km.h-1, however, other studies used different cut-off which complicate the comparison among studies, *e.g.*, high-speed running (>14.4 km.h-1), zone 4 distance (19-23 km.h-1) and zone 5 distance (>23 km.h-1). Fifth, although RSA and COD capacities are considered important for female soccer players, we currently do not have “gold standard” protocols. Therefore, researchers and practitioners have currently used a quite large variety of tests, which complicates the comparison among studies. Finally, female soccer teams have usually a lower budget compared to their male counterpart; therefore, it is unlikely many female players have access to DXA, so practitioners should use ISAK method of skinfold thickness (sum of 8) although its accuracy, test-retest reliability and inter-operator reliability is lower, and it does not offer information about bone health.

**PRACTICAL APPLICATIONS**

The aim of this narrative review was to evaluate all the presented literature on tests of the varied components of female soccer, to draw attention to the most reliable and valid protocols to use in practice.

* From an aerobic point of view, the gold standard method of assessment for fitness is a treadmill based V̇O2max protocol measuring expired air utilizing a metabolic cart (duration approximately 10 – 15 mins). However, this test is expensive and time consuming, therefore, field tests have now become more commonplace. The two most common field tests are: the Yo-yo intermittent test (level 1 and 2) comprised of 2 x 20 m shuttle runs, followed by an active recovery period, and the 30-15 intermittent fitness test. Both appear to differentiate between age groups and female players of different levels.
* The sprinting performance can be assessed on distances ranging from 5 m to 30 m using a photocell timing system. However, longer distances (*e.g.*, 40 m) allow for achieving higher sprint velocities and frequent peak speed (*e.g.*, flying sprint test), which can be assessed using GNSS. RSA capacity can be assessed using a 20 + 20 m shuttle test (with a 180° COD), followed by a 20 s period of passive recovery, repeated 6 times.
* COD has been found to be an important component of players testing and training programs as it can differentiate playing standards and it is important for the progression from youth to senior players. However, there is no “gold standard” to assess COD performance in female players, therefore, practitioners are invited (by the authors of this review) to use the 505 COD test (42) and Illinois COD test (135), which have been reported as valid and reliable tests. Practitioners need to have consistency in testing environments (*e.g.*, floor surface) in order to limit the impact of confounding factors.
* Lower limb strength and power are closely associated with speed and agility performances. Lower limb performance can be assessed using a CMJ test on a force platform (which is valid and reliable). A range of technologies and equipment exist that can support and be used to assess lower limb power at lower cost such as timing mat, mobile application, video assessment, accelerometer, and linear encoder to estimate a force-velocity curve. In practical settings there are several types of jump tests commonly employed: the CMJ, squat jump, drop jump, and broad jump. Jump tests are commonly scrutinized bilaterally but on occasion, unilateral tests may also be conducted, *e.g.*, a triple hop test with arm swing. Jump capacity can be assessed using force platforms, jump mats, optoelectronic devices, video cameras, accelerometers, linear position transducers, and jump and reach devices. Practitioners should use the same protocol and same assessment tools so that they can monitor changes over time without adding possible confounding factors.
* Several in-direct tests are currently available for assessing anthropometry parameters such as DXA, skinfold thickness, hydrodensitometry, air displacement plethysmography, and ultrasound. DXA is the most valid and reliable method for assessing body composition in team sport athletes, although regular testing using these devices are questionable. Doubly in-direct methods are also available and include bioelectric impedance, 3D photonic scanning, and estimations for %BF from ultrasound and skinfold thickness measures. These methods use predictive regression equations, therefore for ecological reasons the ISAK sum of 8 measures collected by the same practitioner may be the best compromise.
* In conclusion, the evidence reported in this review will be able to aid, practitioners, coaches and researchers to decide which tests meet the requirements of their environment (e.g., ecological validity and reliability scores such as CV and ICC), making their programs both specific and accurate.

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**Table 1.** Summary of the aerobic, linear sprint and repeated sprint tests, the current limitations, and future directions.

|  |  |  |  |
| --- | --- | --- | --- |
| **Capacity/characteristic** | **Test protocols** | **Limitations** | **Future directions** |
| **Aerobic tests**  | -The gold standard method of assessment for aerobic fitness is a treadmill based V̇O2max protocol (duration 10 – 15 mins). -The two most common field tests are: the Yo-yo intermittent test (level 1 and 2) comprise of 2 x 20 m shuttle runs, followed by an active recovery period and the 30-15 intermittent fitness test.  | -V̇O2max protocol is expensive and time consuming.-Caution should be exhibited if interpreting results from the estimation of V̇O2max using different field-based tests, due to the varying outcome measures (i.e., speed vs. distance). -The familiarization process as well as the standardization of the protocol are key aspects of the internal validity and reliability of field tests. -Practitioners should not use self-designed tests which have not been validated. | -It is not very clear which Yo-yo intermittent tests, or 30-15 intermittent fitness test is the most valid aerobic test for female soccer players. -Future aerobic tests could be validated to offer alternatives to practitioners working with female soccer players. |
| **Linear sprint tests and RSA tests**  | -Sprint test from 5 m to 30 m using a photocell timing system. -Longer distances (e.g., 40 m) allow for achieving higher sprint velocities and peak speeds, which can be assessed using GNSS.-Flying sprint test consisting of 10 m acceleration + 30 m sprint could be used-RSA protocols used in soccer, which is a 20 + 20 m shuttle (with a 180° COD), followed by a 20 s period of passive recovery (after each shuttle) repeated 6 times | -Reliability of short sprinting tests (i.e., 5 m) could be limited. -Practitioners should preferentially use sprint from 10 to 30 m. - Peak speed values cannot be recorded with a photocell timing system, therefore GNSS should be used instead. -GNSS is valid and reliable but expensive. -Research evidence about RSA tests is very abundant in male soccer but limited to female players.  | -Future research should verify what tests can discriminate between players of different levels (e.g., international, national, regional) and among age-groups (U16- U18, first team) -Tests could assist talent identification procedures. -Peak speed can be used to individualize the sprinting threshold (e.g., 80% peak speed) for players. This practice is common among male football players, but very limited information is currently available to female soccer players.  |

V̇O2max = Maximal aerobic power; Repeated sprint tests = RSA; GNSS = Global navigation satellite system

**Table 2.** Summary of the change of direction and strength tests, the current limitations, and future directions.

|  |  |  |  |
| --- | --- | --- | --- |
| **Capacity/characteristic** | **Test protocols** | **Limitations** | **Future directions** |
| **Change of direction tests** | -COD has been found to be an important component of players testing and training programs as it can discriminate players of different playing standards. -COD performance is important for the progression from youth to senior players.-505 COD test and Illinois COD test are common tests used in male and female soccer. | -There is no “gold standard” to assess either agility or COD speed in male or female players. -COD tests involve a COD movement, but the final score is not due only to this capacity, because COD encompasses other physical capacities. | -Further research is needed to verify what test is the most suitable for female soccer, as well as future research should verify what tests can actually discriminate between players’ levels. |
| **Strength tests**  | -Strength is correlated with soccer-specific physical performance variables such as sprinting, COD, and jumping. -The most common assessments consist of 1 RM testing (e.g., squat, mid-thigh pull), isometric (using a load cell), and eccentric contraction testing (e.g., Nordbord). -Isokinetic dynamometry, which is a gold-standard, can be used to evaluate concentric and eccentric strength. | - Research on strength measures in female populations is overall quite limited. -Much more information is needed on the lower limb strength parameters of players of different levels, countries, leagues, and ages. | -Future research needs to investigate if the lower limb strength tests that are currently used in male soccer can be used also with female soccer players. -These tests should help talent identification procedures, performance increment (since these parameters will be used for training decision making), and injury prevention. |

COD = Changes of direction.

**Table 3.** Summary of the lower-limb power, jump and anthropometry tests, the current limitations, and future directions.

|  |  |  |  |
| --- | --- | --- | --- |
| **Capacity/characteristic** | **Test protocols** | **Limitations** | **Future directions** |
| **Lower-limb power and jump tests** | -Jump power testing performance significantly correlates (r = 0.70-0.93) to speed and agility performances. -The CMJ with hands on hips on a force platform is valid and reliable for isolated lower-limb power. -Triple hop test with arm swing, is strongly correlated to CMJ (r = 0.834).- Jump capacity can be assessed using force platforms, jump mats, optoelectronic devices, video cameras, accelerometers, linear position transducers, and jump and reach devices. | -The evaluation of power required the use of technology that can be a barrier to its implementation. -Force platforms are considered the gold standard for jump testing; however, they may not always be accessible or feasible in performance settings, therefore, field-based testing equipment (e.g., jump mats or optoelectronic devices) provides a realistic alternative and estimate jump height from flight time. -Familiarization is a key element of testing reliability, which should be considered by practitioners. | -Future research needs to use a ‘best practice’ in terms of equipment (i.e., the best equipment available) and standardized protocol with the same equipment to offer more insight into power assessment in female players which is currently quite limited. -Jumping performance has been assessed consistently in the literature using the CMJ test but more research is needed for the other bilateral and unilateral tests.  |
| **Anthropometry**  | -DXA, skinfold thickness, hydrodensitometry, air displacement plethysmography and ultrasound are currently available for assessing anthropometry parameters. -DXA is the most valid and reliable method for assessing body composition in team sport athletes. -Doubly in-direct methods are available and include bioelectric impedance, 3D photonic scanning, and estimations for %BF from ultrasound and skinfold thickness measures.  | -The use of anthropometric assessments only can give limited health information to practitioners. -Doubly in-direct methods, which use predictive regression equations have a greater error compared to in-direct methods. -The use of DXA is not without legal and ethical constraints due to the small dose of radiation that is emitted. | -A desire to maintain a low BM or %BF may lead to calorie restriction and a low energy availability which can impair bone health and result in suboptimal menstrual function.-More information is needed about anthropometric assessments and scans to better manage female soccer players’ health (Female Athlete Triad or REDs) in professional contexts. |

CMJ = Countermovement jump; DXA = dual-energy X-ray absorptiometry; REDs = Relative Energy Deficit; BM = body mass; %BF = percentage body fat.