Abstract:

Soccer match-play dictates that players possess well-rounded physical capacities. Therefore, player physical development plans must consider developing several fitness components simultaneously. Effective individualization of training is likely facilitated with appropriate player profiling, therefore, developing a time-efficient and informative testing battery is highly relevant for practitioners. Advances in knowledge and technology over the last decade have resulted in refinements of the testing practices used by practitioners working in professional male and female soccer. Consequently, a contemporary approach to test selection and data analysis has progressively been adopted. Furthermore, the traditional approach of using a testing battery in a single day may now be outdated for full-time players, with a flexible approach to the scheduling of testing perhaps more suitable and time efficient. Here, guidance on testing for maximal aerobic, submaximal aerobic, linear and change of direction speed and stretch-shortening cycle performance (i.e., jump testing) are presented for male and female players, with emphasis on time efficient tests, while facilitating effective individualized training prescription. Normative and meaningful change data is presented to aid decision making and provide a reference point for practitioners. Finally, a time-efficient approach to scheduling fitness testing is presented, which complements daily training outcomes of a weekly periodization approach.
Introduction:
Soccer match-play is characterized by high-to-maximal intensity activity bouts, interspersed with low-intensity activity (29,90). During match-play elite male players cover distances of ~10-13 km, with ~800 m at high-speed (>19.8 km·hr\(^{-1}\)) and up to 300 m at very-high speed (>25.2 km·hr\(^{-1}\)) (16). Similarly, elite female players cover distances of ~9-11 km, with >1000 m at high speed (>18.0 km·hr\(^{-1}\)) and ~250 m (>25.0 km·hr\(^{-1}\)) at very-high speed (29). Tackling, jumping, kicking, and changing direction are also performed regularly during match-play (29,90). Consequently, well-rounded physical capacities are necessary at elite level, and player physical development programmes must consider the appropriate development of multiple fitness components throughout the season.

Fitness testing represents a useful tool in the physical development of players, and allows objective identification of strengths and weaknesses, data informed talent identification, objective assessment of the effectiveness of training interventions/rehabilitation and facilitates the prescription of individualized programmes (73). Improving training prescription for individuals is challenging in team-sports, but a shift towards testing protocols that can provide deeper understanding of the factor’s influencing performance has enhanced opportunity for individualised prescription. Traditionally fitness testing has included measures of sprint, jump, agility/change-of-direction, and aerobic performance (96). However, advances in knowledge, technology and data processing have enabled a more comprehensive approach to assessing these capacities. While the premise of testing is not new (73), the ability to collect and process data to quickly inform training practices has progressed in soccer, highlighting a need to reconsider how we approach the fitness testing process.

This article aims to provide strength and conditioning practitioners working in male and female soccer with an overview of existing testing practices and a contemporary perspective on fitness testing that can be used to monitor physical capacities and facilitate an individualized approach towards training prescription. Furthermore, an alternative perspective on the scheduling of fitness testing which is complementary to player training schedules is presented with a view to implementing a time-efficient testing strategy.

Aerobic fitness:
Soccer players with superior aerobic fitness exhibit a reduction in fatigue related decrements in technical performance in the latter part of a match and have greater robustness (60,80). The gold-standard of aerobic fitness assessment is measurement of maximal oxygen uptake (\(\text{VO}_2\text{max}\)) and an associated velocity at \(\text{VO}_2\text{max}\) (often termed maximal aerobic speed), which are generally derived through lab-based graded exercise tests (GXT). Elite male and female
players are reported to possess a \( \dot{V}O_2 \text{max} \) in the range of 62-65 and 50-52 ml·kg·min\(^{-1} \), respectively (29,98). However, the use of lab-based assessments is time-consuming, and \( \dot{V}O_2 \text{max} \) might not be a sensitive enough measure in soccer and may not discriminate between playing standards (3,98). Therefore, field-based tests are predominantly used by practitioners.

Time-trial assessments present another means of assessing aerobic fitness, with 1600-2200 m (~5 to 8 minutes) time-trials being a time-efficient alternative to GXT for prediction of maximal aerobic speed (MAS) (6). Strong agreement between MAS derived through GXT and average time-trial speed have been observed \((r = 0.80)\), with low typical errors \((CV 1-3\%)\) reported for short duration time-trial performance in well-trained athletes, indicating good reliability (20,27). Furthermore, a minimum detectable change of 1.3% for 1500 m time trial performance, reported for young professional players (16-18 years), suggests high-sensitivity to changes in fitness status (36). Alternatively, set-time time trials (e.g., distance covered in 5-minutes) have been proposed as a means of predicting MAS via mean running speed achieved, however, given the importance of pacing in this type of test given the lack of a clear endpoint, it has been suggested that this method may only be suitable for trained runners (12). The use of MAS to prescribe aerobic intervals is an established practice (31,102), but using MAS to monitor training loads is gaining popularity given the potential benefits of using physiological constructs to individualize locomotor thresholds (36). Despite the utility of MAS in the training and monitoring process, using MAS alone is limited with respect to the prescription of supramaximal (i.e., performed at an intensity >MAS) training intensities, which are a necessity in team-sports. Using MAS in combination with maximal sprinting speed i.e., anaerobic speed reserve (ASR) presents a viable solution (13). It was recently proposed that considering MAS and ASR might allow for individualized prescription of player programmes based on the physiological typology of players, potentially facilitating enhanced fitness outcomes (81). However, further research is needed to provide empirical evidence for this concept.

Intermittent protocols are popular in soccer due to their perceived specificity. Variations of the Yo-Yo intermittent tests are commonly used to assess aerobic capacity, with Yo-Yo intermittent recovery test level 1 (YYIR1) and level 2 (YYIR2) perhaps the most popular versions. Large correlations \((r = 0.70-0.81)\) between match high intensity running, and YYIR1 performance in male and female players have been reported, suggesting that the YYIR1 has good predictive validity (3). The YYIR1 also has reasonable reliability with a CV of 8.1% (3), and elite male and female players are reported to cover distances >2100-m, and ~1500-m, respectively (3). The YYIR2 places greater emphasis on anaerobic capacities and also has reasonable reliability in male players (CV 10.4%), who are reported to cover >1000-m, data
for female players, however, is lacking (3). A key limitation of the Yo-Yo intermittent tests is the lack of a useable outcome measure for training prescription. Specifically, the distance covered/level at volitional exhaustion provide only an index of aerobic fitness and not a useable unit for distance/intensity prescription.

Consequently, the 30-15 intermittent fitness test (IFT) has gained popularity. Performance on the 30-15 IFT correlates strongly \( (r = 0.68) \) with \( \dot{V}O_2 \) max, and has high construct validity, being reliable and sensitive to changes in fitness status (14). Final stage velocity (Vift) and peak heart rate (the main outcome measures associated with the 30-15 IFT) have been demonstrated to have good reliability, with ICCs of \( r > 0.80 \) and CV of <5% reported for team-sports players (40). Interestingly, final stage velocity of the 30-15 IFT is reported to be approximately 115% of MAS (12). While the 30-15 IFT and the YYIR1 have 50% shared variance (11), indicating that they evaluate a similar fitness construct, the determining factors seem to differ with the YYIR1 more dependent on aerobic processes and the 30-15 IFT encompassing aerobic and anaerobic processes (11). A key strength of the 30-15 IFT is the utility for prescription, with end stage running speed providing an accurate and effective reference point for standardizing the cardiorespiratory demand of interval training (15), for sub-maximal and maximal intensity interval training (13).

In summary, various intermittent tests are used to assess aerobic fitness in soccer, due to their perceived sport specificity. Although time-trial based testing provides valuable information, using time-trial derived MAS alone may be limited for prescription purposes and further research is necessary to support the use of ASR. Although the YYIR tests have received more attention in the scientific literature and normative data is more prevalent, the 30-15 IFT presents valuable information for training prescription and monitoring and is therefore recommended for use. Examples of how the 30-15 IFT has been used to guide training in team sports are available in the scientific literature (12,13,86) and practitioners should refer to these studies for further guidance on programming using this test.

**Submaximal testing:**

While maximal aerobic testing is common practice, submaximal protocols and associated heart rate measures represent a valuable tool for more frequent assessment. This is due to the ease of scheduling as part of warm-up protocols, and the limited fatigue experienced following the testing; furthermore, the use of heart-rate measures presents a non-invasive, time-efficient and relatively cheap method (10). Heart rate measures used during submaximal protocols include heart rate during exercise (HRex) and heart rate recovery (HRR) as an absolute or relative value, both are indicators of cardiovascular fitness i.e., generally the lower
the heart rate and perceived intensity of effort, the better (7,28). To assess HRex, the mean of the last 30-60s of a 4 to 6-minute test is recommended (10), and when expressed in relative terms this provides a good indication of relative exercise intensity (10). While HRR is generally assessed 60-120s after the completion of a submaximal test (28,70), it may be less sensitive to changes in training status (10). The use of HRex and HRR in combination may provide the best chance of correctly identifying changes in aerobic fitness.

Submaximal versions of the Yo-Yo intermittent tests are available to assess the fitness of soccer players. A submaximal 6-minute version of the YYIR1, was demonstrated to have acceptable reliability with respect to HRex (CV ~1-3%) and HRR (CV ~6%) in well-trained players (33,55,70). The submaximal YYIR1 also has good predictive validity with respect to YYIR1 performance (r = -0.81) (3,55), and the smallest worthwhile change in HRex following the submaximal YYIR1 is reported to be 1-4% (70,75). Similarly, the submaximal Yo-Yo Intermittent Endurance Level 2 (YYIE2) is reported to have good reliability with low typical errors (CV 1.4%) in professional players, and good predictive validity with large correlations with YYIE2 (r = -0.75) and match-running performance (r = -0.75) (8).

Alternatively, the submaximal warm-up test proposed by Rabbani et al. (74) might be of particular use for monitoring purposes. Rabbani et al. (74) assessed the reliability and validity of a submaximal 4-minute shuttle running (standardized at a running speed of 12.5km·hr\(^{-1}\) with 100 m shuttles) which can easily be integrated into an athlete warm-up. In male professional players, good reliability for HRex (mean of the last 30-s of the test; CV 1.4%) and HRR (mean heart rate 60-s after completion; CV 2.8%) was reported, in addition to large inverse relationships with 30-15 IFT performance for HRex (%, r = -0.5) and HRR (%, r=-0.76), suggesting good concurrent validity. Smallest worthwhile changes of 3% and 6% respectively for HRex and HRR (%), were also reported (74). Given the ease of administration and potential benefits of using a standardized continuous running speed (10), we recommend the submaximal warm-up test for use by practitioners in the field for regular monitoring of players e.g., on a weekly basis.

**Speed testing:**
Sprinting occurs close to key moments in match-play, and therefore speed and acceleration represent key performance parameters (34). Elite players have become faster over time, with an improvement of 2.5% in maximal velocity over a 20-m sprint reported between 1995-1999 and 2006-2010 in male players (47). Furthermore, the number of sprints (~85%), and volume of sprinting (35%) completed within match-play has increased over time in the male professional soccer (5). Acceleration and maximal sprint speed can also distinguish between
playing standards, with elite players reportedly faster than sub-elite players (46). Traditionally, short sprints of 5-30 m have been used to assess speed qualities (acceleration and maximal sprint speed) of soccer players (96), with split-times measured using commercially available timing gates (45). The reliability of assessing short sprint performance using timing gates (≤40-m) has been examined extensively in the literature, with good reliability (CV 1-3%) reported (45).

While assessing short sprint performance using split-times is commonplace, other methods have gained popularity in practice. This includes the use of Global Navigation Satellite Systems (GNSS) to assess maximal velocity (56), which might alleviate scheduling and practical issues associated with fitness testing by allowing maximal velocity to be assessed in training or competition. The use of 10 Hz GNSS has been demonstrated to be valid and reliable for assessment of maximal velocity when compared to radar-gun technology (4,77). Low typical errors (CV ~1.5-2.1%) and high correlations (~ r=0.95) with maximal velocity obtained over a 30-m sprint in team-sports players have been reported (4,77). This is highly relevant given the frequent use of maximal velocity derived from GNSS in the determination of individualized locomotor thresholds (63). In elite players, GNSS derived maximal velocity measures of around 9.6 and 8.0 m·s⁻¹ have been reported for male and female players, respectively (45,71). Despite this, GNSS technology may not be suitable for assessing different aspects of sprint performance such as acceleration. Furthermore, if practitioners choose to assess maximal velocity using GNSS in game-based training or match-play it is important to understand that a true maximal velocity may not be obtained, although there is some debate around this (30,62). If GNSS is the chosen method, players should wear the same units to prevent inter-unit difference from affecting outcomes (77), while it is advised that signal quality is checked to ensure accuracy of data through horizontal dilution of precision and number of satellites (59).

Recent research has demonstrated that it is possible to explore the macroscopic mechanical properties underpinning sprint performance using a simple model (82). Theoretical maximal velocity ($V_0$), maximal force ($F_0$) and horizontal power ($P_{max}$) can be estimated to produce an individualized force-velocity-power profile from a player’s speed time curve during a 30-40 m sprint (65,82). The slope of the force-velocity curve ($s_{FV}$), ratio of horizontal to vertical force (RF) and the rate of decrease in RF throughout the sprint ($D_{RF}$) are also derived from this model and are valuable in the understanding of sprint kinetics and kinematics (65). Therefore, variables which could only previously be calculated in a laboratory, are now assessed in the field. This method can be implemented accurately and reliably using photocell timing gates, a radar gun or high-speed video using the MySprint iPad application (42,78). The use of GNSS
data to calculate sprint force-velocity power profiling has recently been explored (67), but more work is needed to validate this process. Sprint force-velocity-power profiling provides a detailed assessment of sprint capabilities and can facilitate an individualized approach to speed development (49). For example, where horizontal force deficits are observed, programming should focus on horizontal strength work (49). Furthermore, the growth in available normative data for soccer players with respect to $F_0$, $V_0$, sFV, Pmax and RF (%) has made this contemporary approach more viable for practitioners. Acceptable between-trial reliability has been reported for the mechanical outputs in soccer players, with typical errors of $\sim$1.5% for $V_0$, and 3–5% for $F_0$, Pmax, SFV and DRF (42), but practitioners should consider assessing the short-term (i.e., week-week) reliability in their population.

In summary, speed is key to soccer performance and the components of speed i.e., acceleration and maximal velocity should be assessed regularly. Advances in technology and knowledge have provided various options with respect to assessing speed, and practitioners can now perform in-depth assessment of speed qualities in the field, potentially aiding training monitoring and prescription. We recommend the use of short sprint split times as a benchmarking tool, in combination with Sprint force-velocity-power assessment to facilitate appropriate individualized training prescription.

**Stretch-shortening cycle performance:**
Strength is defined as the ability to exert force, under a variety of biomechanical conditions (17). While ‘maximal strength’ in isolation may have limited direct application to soccer performance, the role of maximal strength in developing ‘explosive’ or ‘impulsive’ athletes is important (101). Under Newtonian law, impulse (force x time) is equal to a change in momentum of a body and is a vector quantity, with both direction and magnitude. The application of force throughout the duration of ground contact represents the impulse applied, which is proportionate to the change in momentum experienced (e.g., ground contacts during sprinting, jumping, and cutting/changing direction). Maximal neuromuscular efforts have the goal of maximizing the impulse which determines the resultant velocity as per the impulse-momentum relationship ($Ft/m = \Delta v$). For example, when accelerating in a linear, forward, direction towards a ball, a player is required to transmit an impulse back and downwards quickly. The ability to apply the same total force in a shorter period, or more force in the same period of time could thus be advantageous in reaching the ball before an opponent (61). Therefore, assessing stretch-shortening cycle function through the measurement of maximal impulse, force and velocity are highly relevant.
Jump assessments provide a simple method to estimate maximal vertical impulse, with countermovement jump testing most frequently reported in the literature (22,44). Jump performance is generally assessed through jump height (estimation of centre of mass displacement) (66). Jump height is a useful and reliable metric that describes the outcome of the vertical reaction force and resultant impulse in understandable units for players and coaches. Estimation of jump height from take-off velocity using a force plate is considered the gold standard method (39), however the flight time method has enabled a variety of different instruments to be developed for estimation of jump height in the field. Flight time and / or jump height, calculated using optical measuring systems such as Optojump (Microgate) or mobile applications (MyJump) has shown strong associations ($r = 0.96 – 0.995$) with force platforms (2,18,37,76). These methods have also demonstrated strong reliability (ICCs 0.93 – 0.97; CV 3.3 – 4.2%). Typical mean flight time derived countermovement jump (no arms) height for elite players is ~30 cm in females (32) and ~40 cm in males (47). Nevertheless, there appears to be value in moving beyond this metric to gain better understanding jump strategy and / or force-velocity profile.

Jump height is a result of the magnitude of vertical force applied into the ground and duration of which the force is applied, i.e., vertical propulsive impulse (64). Thus, an athlete can achieve the same jump height either by applying a greater force over a shorter time or visa-versa, with the former being potentially advantageous in soccer (95). Furthermore, higher jump heights will be achieved when a countermovement is permitted, in comparison to jumps without a countermovement (e.g., squat jumps), which is a result of increased propulsive forces (97). Force-time analysis using force plates (64) could be beneficial for identifying these strategies and quantifying the stretch-shortening cycle such as, countermovement (unweighting and breaking) and propulsive phase force, time, or impulse. This allows practitioners to understand more about a players’ neuromuscular or stretch shortening cycle function (64) and provides valuable insight into individualising training programmes. For example, a coach may use such information to identify players who require a greater eccentric or concentric focus within their physical development programme, or those who may benefit from focussing on increasing absolute force production or the rate of force production. However, there is an array of potential metrics ranging in their validity and reliability (99) and it is beyond the scope of this paper to provide and in-depth overview. We recommend that practitioners consider the key variables of interest beforehand rather than taking blanket approach to the analysis and follow published guidelines, for example McMahon et al. (64). For practitioners without force-plates, slow-motion video analysis could be an alternative to understand the time-period in which forces are applied and thus move beyond jump height.
If push-off distance is controlled in a jump, power is equal to force multiplied by velocity and a players’ jump force-velocity-power profile can be derived using similar principles to those outlined for sprinting (65). This requires the player to perform squat jumps or countermovement jumps using a range of loading conditions. Like sprint force-velocity-power testing, theoretical maximum force, velocity, and maximum power can be estimated. It is suggested that an optimal force-velocity profile is one in which an athlete’s maximum power is achieved at a load equal to bodyweight, and that deviations from this profile has implications for training prescription (65). These methods have been shown to be reliable and valid (53,80,81) and can be performed using photocell devices or mobile applications (i.e., MyJump 2) without the need for expensive force-platforms (2,24,66,88). When applied to the countermovement jump, high between-trial reliability has been reported in athletes, with high reproducibility of rank order (ICCs >0.95) and low standard error of the estimates of (CV <1.0%) for jump height, force, velocity, and power (54), but the short-term (i.e., week-week) reliability has recently been questioned. It was recently reported that there is a high standard error of the estimates across devices (force plate, encoder and flight time) with high errors and low ICCs for velocity (Countermovement jump CV, 11.8 to 17.5%; ICC, 0.19 – 0.69, Squat jump CV, 8.6 to 17.4%; ICC, 0.54 – 0.79) and the slope of the force-velocity profile (Countermovement jump CV, 15.5 to 26.7%; ICC, 0.40 – 0.78, Squat jump CV, 13.9 to 29.3%; ICC, 0.36 – 0.76) using a counter movement jump (57). Given the disparity in the literature and that differences in methodologies are likely to influence reliability (51), we recommend practitioners choosing to use force-velocity profiling follow the procedures outlined by Morin and Samozino (65) carefully and consider assessing the short-term (i.e., week-week) reliability in their population.

A final consideration is the measurement of “reactive strength” through drop or repeated jumps to assess stretch shortening cycle function and/or vertical stiffness in the sagittal plane (37,61). The reactive strength index (jump height or flight time / ground contact time) provides practitioners with important information about a players’ ability to transmit a given impulse in a short period of time (37,61). A recent meta-analysis describes moderate associations between reactive strength index and acceleration and top speed and large associations with change-of-direction performance (52). Drop vertical jumps from a 30 cm box are commonly used to measure reactive strength index (23,91). Furthermore, a simple measure of reactive strength is the 10 to 5 repeated jumps test (41) which, like the jump force-velocity profile can be performed using photocell devices or mobile applications. Jump height, ground contact time and reactive strength index derived from the 10 to 5 repeated jumps test are reliable metrics in team-sport athletes (ICCs >0.89 for a CV; between 4 and 10%) (23,91). These metrics are useful for tracking at least ‘moderate’ changes in performance and repeated
jumping provides reactive-strength indexes comparable to those from a 30 cm drop jump (23,91). While the countermovement jump provides an opportunity to evaluate “slow stretch-shortening cycle activity” (~>250 ms), a drop or repeated jump test allows an estimation of “fast stretch-shortening cycle” activity (~<250 ms) (23,97). Therefore, we recommend including both tests to assess stretch shortening cycle related physical qualities of soccer players. This is given the assumption the athlete executes the tests with correct technique and maximal intensity. For example, heel contact during drop or repeated jumping would alter the reaction force curve and the assumption of a fast stretch-shortening cycle activity (61). Practitioners may also consider using Jump force-velocity-power profiling (figure 1).

**Figure 1 near here**

Jump testing variables also have potential as proxy measures for neuromuscular fatigue in soccer players (35). These data can be collected quickly as part of a regular gym-based strength and conditioning session. However, countermovement jump height alone appears to lack sensitivity to identify fatigue (90) probably due to players’ altering their strategy to achieve the same outcome. For example, it has been shown that the countermovement jump takes longer to perform and with a reduced eccentric component (37). In contrast, force plate derived flight time: contraction time ratio for the countermovement jump (24) or drop jump reactive strength index have been shown to be a sensitive measure of fatigue status (37).

In summary, the evaluation of players’ ability to apply force, and specifically the impulse that can be transmitted over relatively short periods of time is important. We recommend practitioners consider countermovement jump and drop or repeated jump tests to estimate fast and slow-stretch shortening cycle function. We would also recommend the addition of Jump force-velocity-power profiling and/or force time analysis to identify individual characteristics as detailed in Figure 1.

**Agility/ Change of direction performance:**

Agility, “a rapid whole-body movement with change of velocity or direction in response to a stimulus” (87) has been identified as a key fitness component in soccer. However, the assessment of agility is complicated, with perceptual and change of direction abilities underpinning performance (72). To effectively assess agility, distinguishing between perceptual performance (i.e., reaction time) and movement time (or total time) is critical (68). Yet, doing so in an ecologically valid and reliable manner is problematic, limiting the usage of agility assessments in soccer (72,96). No consensus on the most appropriate agility test exists, and the methods that have been used, such as reaction to lights or audible cues are
sub-optimal (68,72). Consequently, practitioners generally opt to assess movement time through the means of assessing change of direction ability (i.e., changing direction in a pre-planned task).

Change of direction ability (COD) has traditionally been viewed within the context of total time to complete a specific course. Previously, Stewart and colleagues (89) assessed the between-trial reliability and factorial validity of five commonly used COD tests in team-sports players (male and female), reporting high reliability with low typical CVs for the Illinois agility test ($r = 0.89; CV 2.0\%$), L-Run ($0.94; 2.0\%$), Pro-agility test ($0.90; 2.2\%$) and T-test ($0.95; 2.0\%$).

Perhaps the most popular test in soccer; the 505-test, also possessed good reliability ($0.88; 2.4\%$) (89). A modified version of the 505-test (within which players do not complete a 10-m lead-in sprint) is often used to assess the COD ability of soccer players; however, the reliability of this test requires further exploration in senior players (92). Importantly, it has been demonstrated that the determinants of COD ability are test specific (19,79) and this should be considered by practitioners when selecting a COD test. Starting position, COD angle and entry speed have a marked impact of performance and the underlying kinematic and kinetic mechanisms (68), consequently, there is a lack of consensus on the most suitable COD test in soccer.

It has been suggested that COD tests that assess time taken to complete a given course may not be effective at isolating COD ability and are influenced by linear sprinting ability (68). The importance of measuring COD ability using a valid measure of the COD component has been emphasized, and failure to assess true COD ability may result in inappropriate training prescription (68). One proposed solution to isolate COD capacity, is the COD deficit. The COD deficit is calculated as the time differential between a 10-linear sprint and the 10-m 505 time (69). It has been demonstrated that although players with greater linear sprint capabilities display greater COD performance, they are likely to elicit great COD deficit which is indicative of lower efficiency (58). This data suggests that COD deficit provides a greater depth of information, but further work is needed with respect to reliability in senior players, given the unsatisfactory reliability reported in youth soccer players and the limited data available on senior players (92). Subsequently, the component parts of COD performance were further explored with deceleration deficit (i.e., ability to decelerate whilst accounting for linear speed capacity) being identified as a strategy to determine when deceleration ability may limit COD performance (21), however similarly to COD deficit, data for soccer players is limited.

Assessment of technical COD performance using kinematic and kinetic analysis techniques (i.e., 2-D and 3-D analysis) may present additional useful information for practitioners (68).
Technical information obtained from video analysis such as contact times or joint angles/positions allow more detailed training prescription with respect to performance and injury risk factors in soccer players. While such analysis has historically been time consuming and required specialist expensive software, the development of mobile applications that use high-speed cameras embedded within modern mobile phones and tablets such as CODTimer (1) or Dartfish Express™ has streamlined this process by allowing slow-motion video to be analysed in the field whilst reducing cost. Furthermore, the CODTimer App has been demonstrated to have good between trial reliability for total time taken (CV 2.6-3.5%) and validity in comparison to timing gates \(r = 0.96\); SEE 0.03s) in soccer players (1). The use of App technology presents a contemporary option for the assessment of COD ability, however, may be prioritised with special cases where in-depth analysis is needed to avoid unnecessary time cost.

As summarised by Nimphius et al. (68), given the nuanced requirements of changing direction in different circumstances (e.g., angle of turns, entry velocity, starting position) a single comprehensively valid and reliable test of COD ability test for team-sports players is not available. Therefore, understanding the strengths and limitations of selected tests, and how the practitioner intends to use the data to enhance training prescription or profile players is critical. For example, where a practitioner desires insight on a players deceleration capacity, using a shuttle-based test (such as the 505-test or a 5 m shuttle sprint) may be more appropriate than a test focussing more on manoeuvrability. There is evidence to suggest that much of the variance in COD performance can be determined through linear regression of other capacities such as short sprint and reactive strength performance (32), however further work in this area is needed. Based on current evidence, practitioners are advised to use tests which are short in nature to isolate COD performance, but must be aware of the limitations of their chosen tests.

**Scheduling of testing**

Table 1. displays a proposed season testing schedule for elite male and female soccer players, with reference to which tests we recommend using and at which points of the season. While considering the testing schedule practitioners should adopt a cost-benefit approach. Therefore, we have suggested the scheduling of tests (i.e., sprint and FVP) only when data would inform the training prescription process, thus justifying the time-cost and additional loading. For example, we chose not to include FVP testing at the end of the season where it is unlikely to influence prescription in off-season programmes which are often unsupervised and favour general preparation (including aerobic conditioning).
Position specific normative data for outfield players, along with test-retest reliability (coefficient of variation CV%) and smallest worthwhile changes scores (where available) for the proposed tests are presented for male and female players, respectively, in tables 2 and 3. While it is beyond the scope of this review to discuss data interpretation in detail, we encourage practitioners to consider the minimal detectable change for groups and individuals with respect to the test error and the minimal practically important difference, or smallest worthwhile change. Practical examples of using these approaches in combination are presented by Turner et al. (94) and Weakley et al. (100).

The traditional approach to testing in soccer has been to complete a battery of tests, which are scheduled based on the physiological demands of each. As summarised by Turner et al. (96) this approach would often lead to practitioners using the following order: resting and non-fatiguing tests (resting heart rate, body composition, flexibility and jump tests) followed by agility tests, power/strength tests, sprint tests, anaerobic capacity tests and finishing with an aerobic capacity test. Furthermore, the recovery interval between tests should be based on the time-course recovery of key metabolic substrates, with a minimum of 3 minutes recommended (96).

Guidance on this traditional approach using the recommended tests is displayed in table 4. We have also provided guidance on a more flexible approach to scheduling testing across a training week, which compliments player training schedules without occupying a full training day. By using this approach, practitioners may be able to use testing to complement daily training outcomes according to the periodization of a given micro-cycle. Tables 5. and 6. display examples of how testing can be integrated across an ‘in-season’ and ‘pre-season’ training week, to compliment player training schedules and allow for more regular assessments. It is important emphasize that the integration of this approach to testing should only be used during a 1-game week, given the additional focus on recovery and tactical preparation needed in a multi-game week.
In summary, this article aimed to provide practitioners with a contemporary overview of fitness testing practices for professional/well-trained soccer players. While adhering to the basic testing principles of reliability, validity and practicality are key, we propose that the key aims of fitness testing in soccer should be to enhance training prescription on a squad/individual level and have therefore suggested the most practical tests to do this. The testing protocols outlined present evidence-based practices, that might allow practitioners to take advantage of theoretical and technological advances that have occurred over the last decade in sport science. Each of the tests recommended can facilitate the development of individualized training programmes, and with a view to enhancing the physical profile of well-trained male and female soccer players. We also highlighted an alternative approach to the scheduling of testing in a full-time training environment. While traditional practice has been to schedule a ‘testing day’ which may be necessitated in some environments, the use of a multi-day ‘micro-dosing’ approach might allow for a time-efficient and complimentary testing battery that can be integrated into player programmes whilst limiting interference with training practices.

Conflicts of Interest and Source of Funding.

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Table Captions:

Table 1. Proposed testing schedule for professional soccer players.

Table 2. Normative fitness testing data for elite male soccer players. Note: SWC values are presented using a distribution approach (0.2 x standard deviation) only when alternative methods (such as expert opinion or anchoring) have not been considered. Where robust estimates have been made in raw units we have reported these as such.

Table 3. Normative fitness testing data for elite female soccer players. Note: SWC values are presented using a distribution approach (0.2 x standard deviation) only when alternative methods (such as expert opinion or anchoring) have not been considered. Where robust estimates have been made in raw units we have reported these as such.

Table 4. Example of traditional testing battery with suggested testing order and rest periods.

Table 5. Example Integration of testing into a weekly schedule for professional soccer players (1-game week)

Table 6. Example Integration of testing into a weekly schedule for professional soccer players (Pre-Season)
Figure Captions:

Figure 1: Our recommended jump testing approach. The green spine represents core tests which can be administered quickly/efficiently. The amber tests demonstrate opportunities to undertake additional testing, for a more detailed understanding of players.
Table 1. Proposed testing schedule for professional soccer players

<table>
<thead>
<tr>
<th>Test</th>
<th>Pre-Season</th>
<th>Start-Season</th>
<th>Mid-Season</th>
<th>End-Season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprint (10-30 m)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>CMJ</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>RSI</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>30:15 Test</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Sprint FVP</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Jump FVP</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Submaximal Warm-up</td>
<td></td>
<td></td>
<td></td>
<td>Weekly testing*</td>
</tr>
</tbody>
</table>

* Weekly when no maximal testing.

RSI, Reactive Strength Index; FVP, Force-velocity-power; CMJ, Countermovement Jump.

Table 2. Normative fitness testing data for elite male soccer players

<table>
<thead>
<tr>
<th></th>
<th>Defenders</th>
<th>Midfielders</th>
<th>Attackers</th>
<th>CV (%)</th>
<th>SWC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Speed</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10m (s) [47]</td>
<td>1.53 ± 0.05</td>
<td>1.55 ± 0.06</td>
<td>1.50 ± 0.06</td>
<td>1.6</td>
<td>0.01</td>
</tr>
<tr>
<td>30m (s) [47]</td>
<td>3.93 ± 0.04</td>
<td>3.96 ± 0.04</td>
<td>3.86 ± 0.05</td>
<td>1.6</td>
<td>0.03</td>
</tr>
<tr>
<td>40m (s) [47]</td>
<td>5.06 ± 0.04</td>
<td>5.11 ± 0.04</td>
<td>4.98 ± 0.05</td>
<td>0.7</td>
<td>0.03</td>
</tr>
<tr>
<td>F₀ (N·kg⁻¹) [43]</td>
<td>8.4 ± 0.6</td>
<td>8.3 ± 0.5</td>
<td>8.6 ± 0.6</td>
<td>3.0</td>
<td>0.1</td>
</tr>
<tr>
<td>V₀ (m·s⁻¹) [43]</td>
<td>9.3 ± 0.4</td>
<td>9.2 ± 0.4</td>
<td>9.3 ± 0.4</td>
<td>1.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Pmax (W·kg⁻¹) [43]</td>
<td>19.4 ± 1.6</td>
<td>19.1 ± 1.5</td>
<td>20.1 ± 1.6</td>
<td>2.7</td>
<td>0.3</td>
</tr>
<tr>
<td>RF (%) [43]</td>
<td>47.2 ± 1.5</td>
<td>47.0 ± 1.4</td>
<td>47.9 ± 1.5</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td><strong>Aerobic fitness</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-15 IFT (km·hr⁻¹) [#]</td>
<td>20.5 ± 0.5</td>
<td>21.5 ± 0.5</td>
<td>21.0 ± 0.5</td>
<td>&lt;5</td>
<td>1.0</td>
</tr>
<tr>
<td>MAS (km·hr⁻¹) [98]</td>
<td>16.3 ± 0.8</td>
<td>16.4 ± 0.9</td>
<td>16.2 ± 1.0</td>
<td>1-3</td>
<td>0.3</td>
</tr>
<tr>
<td><strong>Strength/Power</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CMJ (No Arms) cm [47]</td>
<td>39.5 ± 5.0</td>
<td>37.5 ± 3.7</td>
<td>40.0 ± 4.9</td>
<td>3.1</td>
<td>1.0</td>
</tr>
<tr>
<td>RSI (m·s⁻¹) [37]</td>
<td>&gt;2.0</td>
<td>&gt;2.0</td>
<td>&gt;2.0</td>
<td>6-7</td>
<td>~0.06</td>
</tr>
<tr>
<td>F₀ (N·kg⁻¹) [53]</td>
<td>36.7 ± 5.7*</td>
<td>36.7 ± 5.7*</td>
<td>36.7 ± 5.7*</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>V₀ (m·s⁻¹) [53]</td>
<td>3.2 ± 0.6*</td>
<td>3.2 ± 0.6*</td>
<td>3.2 ± 0.6*</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Pmax (W·kg⁻¹) [53]</td>
<td>28.9 ± 3.2*</td>
<td>28.9 ± 3.2*</td>
<td>28.9 ± 3.2*</td>
<td>0.6</td>
<td></td>
</tr>
</tbody>
</table>

F₀, Maximal theoretical force; V₀ Maximal theoretical velocity; Pmax, Maximal Power; RF, Ratio of Force; MAS, Maximal Aerobic speed; CMJ, Countermovement jump height; RSI, Reactive strength index; 30-15, 30-15 Intermittent fitness test; SWC, Smallest worthwhile change (Calculated as 0.2 x between subject standard deviations); CV, Coefficient of variation.

* Denotes that position specific data was not available. #, Unpublished observations in from Premier League football clubs.
**Table 3. Normative fitness testing data for elite female soccer players**

<table>
<thead>
<tr>
<th></th>
<th>Defender</th>
<th>Midfielders</th>
<th>Attackers</th>
<th>CV (%)</th>
<th>SWC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Speed</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10m (s) [48]</td>
<td>1.69 ± 0.07</td>
<td>1.70 ± 0.07</td>
<td>1.68 ± 0.09</td>
<td>2.9</td>
<td>0.02</td>
</tr>
<tr>
<td>30m (s) [48]</td>
<td>4.40 ± 0.06</td>
<td>4.44 ± 0.06</td>
<td>4.34 ± 0.08</td>
<td>2.6</td>
<td>0.03</td>
</tr>
<tr>
<td>40m (s) [48]</td>
<td>5.71 ± 0.06</td>
<td>5.76 ± 0.06</td>
<td>5.62 ± 0.08</td>
<td>3.0</td>
<td>0.03</td>
</tr>
<tr>
<td><strong>CV (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SWC</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Speed</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10m (s) [48]</td>
<td>2.90 ± 0.02</td>
<td>2.90 ± 0.02</td>
<td>2.90 ± 0.02</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>30m (s) [48]</td>
<td>0.03 ± 0.01</td>
<td>0.03 ± 0.01</td>
<td>0.03 ± 0.01</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>40m (s) [48]</td>
<td>0.1 ± 0.01</td>
<td>0.1 ± 0.01</td>
<td>0.1 ± 0.01</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td><strong>Aerobic fitness</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-15 IFT (km·hr⁻¹) [85]</td>
<td>18.7 ± 0.4</td>
<td>19.5 ± 0.5</td>
<td>19.3 ± 0.4</td>
<td>&lt; 3.0</td>
<td>1.0</td>
</tr>
<tr>
<td>MAS (km·hr⁻¹) [50]</td>
<td>15.0 ± 0.9</td>
<td>14.4 ± 0.9</td>
<td>14.4 ± 1.2</td>
<td>1-3</td>
<td>0.2</td>
</tr>
<tr>
<td><strong>Strength/Power</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CMJ (No Arms) cm [48]</td>
<td>29.6 ± 4.0</td>
<td>28.4 ± 3.9</td>
<td>30.5 ± 4.5</td>
<td>3.3</td>
<td>1.0</td>
</tr>
<tr>
<td>RSI (m·s⁻¹) [29]</td>
<td>&gt;1.2 ± 1.2</td>
<td>&gt;1.2 ± 1.2</td>
<td>&gt;1.2 ± 1.2</td>
<td>10</td>
<td>0.09</td>
</tr>
<tr>
<td>F₀ (N·kg⁻¹) [53]</td>
<td>32.9 ± 3.6*</td>
<td>32.9 ± 3.6*</td>
<td>32.9 ± 3.6*</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>V₀ (m·s⁻¹) [53]</td>
<td>3.0 ± 0.3*</td>
<td>3.0 ± 0.3*</td>
<td>3.0 ± 0.3*</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Pmax (W·kg⁻¹) [53]</td>
<td>24.7 ± 0.9*</td>
<td>24.7 ± 0.9*</td>
<td>24.7 ± 0.9*</td>
<td>0.2</td>
<td></td>
</tr>
</tbody>
</table>

F₀, Maximal theoretical force; V₀, Maximal theoretical velocity; Pmax, Maximal Power; RF, Ratio of Force; MAS, Maximal Aerobic speed; CMJ, Countermovement jump height; RSI, Reactive strength index; 30-15, 30-15 Intermittent fitness test; Smallest worthwhile change (Calculated as 0.2 x between subject standard deviations); CV, Coefficient of variation.

* Denotes that position specific data was not available.

**Table 4. Example of traditional testing battery with suggested testing order and rest periods.**

<table>
<thead>
<tr>
<th>Test</th>
<th>Rest Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthropometry Assessments</td>
<td>None</td>
</tr>
<tr>
<td>CMJ or Jump FVP</td>
<td>3-5 minutes between Reps/Tests</td>
</tr>
<tr>
<td>RSI (e.g., 30-cm Drop Jump)</td>
<td></td>
</tr>
<tr>
<td>Sprint FVP or 30-m Sprints (10 and 30-m Splits)</td>
<td>3-5 minutes between Reps/Tests</td>
</tr>
<tr>
<td>Change of direction test (if selected)</td>
<td>3-5 minutes between Reps/Tests</td>
</tr>
<tr>
<td>e.g. 505 test</td>
<td></td>
</tr>
<tr>
<td>30:15 Intermittent Fitness Test</td>
<td>NA</td>
</tr>
</tbody>
</table>

CMJ = Countermovement jump; RSI = Reactive Strength Index test; FVP = Force-velocity-power
Table 5. Example Integration of testing into a weekly schedule for professional soccer players (1-game week)

<table>
<thead>
<tr>
<th>Time</th>
<th>MD+2</th>
<th>MD+3</th>
<th>MD-3</th>
<th>MD-2</th>
<th>MD-1</th>
<th>MD</th>
<th>MD+1</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM</td>
<td>Submaximal</td>
<td>Jump</td>
<td>Extensive</td>
<td>Sprint FVP</td>
<td>Tactical/</td>
<td>Game</td>
<td>Recovery</td>
</tr>
<tr>
<td></td>
<td>WUT</td>
<td>FVP/RSI</td>
<td>Intensive</td>
<td>Speed/Power</td>
<td>Reactivity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PM</td>
<td>Recovery</td>
<td>Strength</td>
<td>Tactical</td>
<td>Strength</td>
<td>Recovery</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

WUT, Warm-up test; FVP, Force-velocity-power; RSI, Reactive Strength Index test; MD, Matchday.

Table 6. Example Integration of testing into a weekly schedule for professional soccer players (Pre-Season)

<table>
<thead>
<tr>
<th>Time</th>
<th>Mon</th>
<th>Tues</th>
<th>Weds</th>
<th>Thurs</th>
<th>Fri</th>
<th>Sat</th>
<th>Sun</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM</td>
<td>CMJ + 30-15</td>
<td>RSI</td>
<td>Extensive</td>
<td>Technical</td>
<td>Sprint 30-m</td>
<td>Extensive</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Technical</td>
<td>Intensive</td>
<td></td>
<td></td>
<td>Intensive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PM</td>
<td>Strength</td>
<td>Technical</td>
<td>Strength</td>
<td>Recovery</td>
<td>Strength</td>
<td>Recovery</td>
<td></td>
</tr>
</tbody>
</table>

CMJ, Countermovement Jump; RSI, Reactive Strength Index test; 30-15, 30-15 Intermittent fitness test.
Additional testing

Force (load) – velocity – power profile
Evaluates if a players’ peak power occurs at, below or above body weight
Informs training focus (alongside core tests)
For example, should the player target maximal force production or force production at higher velocities

Core tests
Counter-movement jump
(maximal vertical impulse)
Drop or repeated jump
(reactive strength / fast SSC capabilities)
Informs training target
Reactive strength or maximal impulse

Counter-movement jump force / time analysis
(slow SSC capabilities)
Impulse characteristics (force and time)
Breaking versus propulsive phases?

Additional analysis
Informs training focus (alongside core tests)
For example: concentric or eccentric or plyometric focus?
Should training target an increased impulse or decrease time period in which the impulse is applied or rate of force application?