Soccer is a multifaceted game requiring a complex interaction of multiple physical abilities. Elite soccer players rarely demonstrate exceptional ability or capacity in one physical domain, yet they are often highly competent in several different areas. When analyzing soccer performance, it can be very difficult to differentiate the various physical factors due to significant crossover and interactions between abilities. Individual game physiology varies based on technical and tactical demands, and specific requirements and characteristics of each position. Large variations also exist across individuals and playing levels, in terms of game demands and fatigue. With this in mind, both training and testing protocols should be individualized to each specific player.

Strength and conditioning professionals are expected to support players of various ages, abilities, and genders; therefore, any assessment or training intervention must be carefully matched with the specific group and individual profiles. The focus of this article is to describe the needs of soccer athletes and then provide assessments for testing endurance.

BASIC PHYSIOLOGY OF SOCCER
Although decisive moments are defined by anaerobic activities such as sprints, jumps, and contests for the ball, aerobic metabolism still dominates so that soccer has a high endurance component (14). Endurance is generally understood in terms of ability to resist fatigue. Fatigue in soccer can be described as short term relating to immediate activities, or longer term resulting from the cumulative effect of work rate demands towards the conclusion of the match. Endurance performance in soccer is usually measured using the total distance covered in the match. Although this is a reasonable indicator, total distance does not clearly differentiate the varying intensities at which that distance was achieved (6). This issue is slowly being addressed with increased access to motion tracking devices. A well trained aerobic system has a positive relationship with overall distance covered, duration on the ball, and repeated sprint ability during a match (19).

FITNESS ASSESSMENT AND TESTING
It is important to reaffirm that tests selected accurately target the physiology and main performance related abilities in the sport. All tests also have a natural variability in results, and coaches must be mindful of falsely interpreting small changes in scores as positive or negative (measurement error). In addition to options for calculating worthwhile change that are discussed extensively elsewhere, coaches should consider what constitutes a worthwhile change and what level of change is meaningful (10).

Physiological demands of intermittent sports are difficult to reproduce in the laboratory and the use of sport-specific field testing is an accepted and valid approach to physical fitness assessment in soccer (5,6). Field-based testing is popular as it enables multiple players to be tested either together or in a relatively short time, and it can take place in a normal training environment. Basic, well-established field tests can be used to assess key endurance abilities related to soccer. Analysis within
the context of real play or related scenarios designed to replicate game play continue to be developed. Specific field-based endurance tests have been explored that incorporate forwards, backwards, and sideways running along with turning and jumping (5). Further specificity to soccer includes ball dribbling and a 290-m soccer circuit track (7).

Contemporary methods are now providing much improved data on previous notational and observational approaches. The use of multiple cameras, Global Position Systems (GPS), and time motion videos are just three ways in which soccer physiology and performance is now being analyzed.

**TESTING AEROBIC ENDURANCE**
Assessing or measuring aerobic endurance is achieved via establishing rate of maximal oxygen consumption (VO2max). Laboratory tests using step-like or ramped protocols with incremental intensities can be used for accurate measure of VO2max and parameters related to lactate, as well as running economy. Researchers suggest that a VO2max greater than 60 ml/kg/min is required at elite levels of soccer (15). Commonly used field tests include the multi-stage fitness test (MSFT), Loughborough intermittent shuttle test (LIST), yo-yo intermittent recovery test, and Hoff test.

**MULTI-STAGE FITNESS TEST (MSFT)** (FIGURE 1)
A commonly used field test for aerobic endurance is the MSFT, which was originally devised by Ramsbottom, Brewer, and Williams. MSFT is easy to administer and reproduce, and involves common activities in soccer such as deceleration, turning, and acceleration (13).

The MSFT protocol uses a prerecorded audio program with a series of timed beeps. The participant performs shuttle runs between the cones in time with the beeps of the program. The program progresses through a series of levels with running speeds increasing at each level. This test correlates well with VO2max; however, recording total distance covered during the program rather than estimating VO2max from the results may be a better strategy in this situation (18).

**LOUGHBOROUGH INTERMITTENT SHUTTLE TEST (LIST)** (FIGURE 1)
The LIST is a variation on the shuttle run test designed for intermittent team sports and uses the same basic setup used for the MSFT (11). The LIST test has two parts and uses a prerecorded audio program to provide the signals that control the speed of the participants.

The first part of the test begins with the participant between cones set up for 20-m shuttles to help determine their speed. Their speed can be calculated based on predetermined fitness level and specific sport. The audio beeps control the participant’s speed during each bout. The participant then performs 15-min bouts of the following cycle:

- 3 x 20-m shuttle walk
- 1 x 15-m sprint
- 3 x 20-m running
- 3 x 20-m jog (approximately 11 cycles in 15 min)
- Rest for 3 min and repeat for 5 bouts

The second part of the LIST test consists of the participant moving straight to intermittent shuttles alternating between jogging and running speed. The participant performs these shuttles until failing to stay with the audio for two consecutive beeps or 10 min expires, whichever comes first. An alternative modification for soccer players would be to skip the second part of the test and to perform six cycles of the first part of the LIST test, which would amount to 90 min of exercise.

**YO-YO INTERMITTENT RECOVERY TEST** (FIGURE 2)
The Yo-Yo Intermittent Recovery Test consists of 20-m shuttles similar to the MSFT, but instead there is a short recovery period following each shuttle run (2). Two speed profiles exist for this test: level 1 (speed 10 km/hr) targets the aerobic energy pathway and level 2 (speed 13 km/hr) targets both the aerobic and anaerobic pathways.

For this test, the participant begins at the middle of three cones. The prerecorded audio program signals the start of the test and the participant must perform a 20-m shuttle run between the cones in time with the beeps. Upon returning to the starting cone, the participant has 10 s of recovery to either walk or jog out to the 5-m cone and back to the starting cone before the beep signals the next shuttle. The participant’s inability to stay in time with the predetermined beeps on two consecutive occasions ends the test. Upon ending, the final point is marked and the total distance covered is calculated. The level 1 speed profile relates to on-field performance and an individual with a VO2max greater than 60 will cover in excess of 2,250 m on this test (30).

**HOFF TEST**
Developed by Hoff et al., the Hoff test is ideally marked out on half of a full-sized soccer field (7). The participant dribbles a ball in the direction of the arrows around a track. The dribbling track is designed to replicate various soccer skills to complete the 290-m lap. The participant completes the maximum number of circuits in 10 min. Elite players should cover more than 2,100 m on this test (18). Recent research also suggests that the Hoff test may be able to predict maximal lactate steady state (9).

**TESTING FOR MAXIMAL AEROBIC SPEED (MAS)**
MAS describes the minimum speed that elicits VO2max and may be indicative of a high anaerobic capacity (16). It has been suggested that MAS may be a critical factor in developing aerobic power in sports such as soccer (1). Interval training using MAS can be a useful approach for improving aerobic power (1).

Testing for MAS can be done by using a fixed distance shuttle run where participants cover as much distance as possible in 5 min (300 s) using an out and back shuttle method (1). To calculate
MAS, divide distance covered (meters) by the time (seconds). Researchers have suggested that a MAS of 4.4 – 4.8 m/s is common in high-level soccer players (1).

TESTING FOR REPEATED SPRINT ABILITY (RSA) (FIGURE 3)
Anaerobic endurance (i.e., RSA) is also a critical factor as soccer players are often expected to perform multiple, short duration near-maximal or maximal-effort activities with limited recovery. RSA has recently been of great interest in team sports (3). Initial evidence in soccer indicates a relationship between performance on an RSA test and the distance a player can cover at high intensity in a game (12).

RSA tests have used mixed protocols ranging up to 15 repetitions of 6 – 10 s effort with 23 – 30 s of recovery (3,12). However, it has been suggested that RSA tests should involve no more than eight sprints if 20 – 30 s recovery bouts are used to avoid speed decrement (4). A question has been raised regarding appropriate protocols for soccer-specific RSA tests concerning the protocol design in regards to the number of sprints required to induce a performance drop off (4).

Testing protocols for RSA in soccer should reflect game characteristics and analysis. For instance, a typical RSA adapted protocol for soccer might use 30-m sprints interspersed with 25-s active recovery (e.g., jogging) periods. When collecting the data, the following factors should be considered:

• Average time for all efforts
• Fatigue index: difference between first and last effort
• Percentage drop off: [mean sprint time ÷ best sprint time] x 100 (-100)

SOCcer-Specific TEST for REPEATED SPRINT ABILITY (FIGURE 4)
Bangsbo proposed a soccer-specific RSA test (2). This test uses a standard protocol for RSA testing as described previously. The participant runs as fast as they can from the starting cone to a finishing cone with a single sideways direction change, covering a distance of 34.2 m in total. The test consists of seven sprints of this 34.2 m course, with a 25-s recovery to walk back to the starting cone between sprints.

CONCLUSION
There are many factors that contribute to success for each individual soccer player, such as position, experience, abilities, and gender. Regardless of these aspects, utilizing assessments and testing for endurance can be a useful tool in training. These assessments and tests can be easily performed and may provide valuable performance measures for soccer-specific endurance abilities including areas of improvement and the effectiveness of the current training program.

REFERENCES


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**ABOUT THE AUTHOR**

Gary Stebbing studied sport and exercise science as an undergraduate and sport and performance psychology at the postgraduate level (PG Dip). He has been certified as a Certified Strength and Conditioning Specialist® (CSCS®) through the National Strength and Conditioning Association (NSCA) for 13 years. He trains clients for challenging objectives such as ultra-endurance and multi-day events. Since 1995, Stebbing has been a trainer and freelance performance and conditioning coach, including practicing, writing, and lecturing on coaching psychology, training, and conditioning for sport in the United Kingdom and Australia. Prior to this, he was a professional soccer player, spending 11 years in English leagues and captaining England at the U18 and U19 levels.