Sports Medicine (2025) 55:1233–1264
https://doi.org/10.1007/s40279-025-02188-4

SYSTEMATIC REVIEW

Assessment of Aerobic Fitness and Repeated Sprint Ability in Elite Male Soccer: A Systematic Review of Test Protocols Used in Practice and Research

Nikolaos D. Asimakidis[1,2] · **Chris Bishop**[1] · **Marco Beato**[3] · **Anthony N. Turner**[1]

Accepted: 5 February 2025 / Published online: 12 April 2025

Abstract

Background Soccer requires players to cover distances around 10–12 km, with numerous consecutive sprints throughout the 90-min game. As such, aerobic fitness and repeated sprint ability (RSA) are crucial physical qualities for the modern soccer player to cope with the demands of the game. However, a comprehensive and systematic search of aerobic fitness and RSA assessment procedures in elite soccer has yet to be conducted.

Objectives The aims of this systematic review were to (1) identify the tests and outcome variables used to assess aerobic fitness and RSA of elite male soccer players, (2) provide normative values for the most common tests of aerobic fitness and RSA across different playing levels, and (3) report the reliability values of these aerobic fitness and RSA tests.

Methods A systematic review of the academic databases MEDLINE, CINAHL, SPORTDiscus, Web of Science, and OVID for studies published until August 2023 was conducted, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Studies were eligible for inclusion if (1) they were original research studies, published in a peer-reviewed journal, and written in English language; (2) they had the primary aim of assessing aerobic fitness and/or RSA; (3) players were male and older than 17 years of age (i.e. mean age of the group); and (4) their playing level was defined as 'professional', 'international', or 'elite'.

Results For aerobic fitness testing, 124 studies and 35 different tests were identified. Of those, 26 tests (74%) were field-based, whereas only nine (26%) were laboratory-based tests. The incremental treadmill test to exhaustion was the most commonly used aerobic fitness assessment method (56 studies, 45%), with maximal oxygen consumption ($\dot{V}O_{2max}$) (mL/kg/min) being the most prevalent outcome variable (49 studies, 87%). The YYIR1 and YYIR2 were also commonly used tests, identified in 22 (18%) and ten studies (8%), respectively. The most frequently reported outcome variable in both tests was distance in metres, reported in 20 studies (91%) for YYIR1 and in all ten studies (100%) for YYIR2. For RSA testing, 27 studies and 18 different tests were identified. Substantial variability in the identified RSA testing protocols was observed in terms of direction (linear vs. multidirectional), sprint repetitions (6–15), sprint distance (20–40 m), type of recovery (active vs. passive), and recovery duration (10–30 s). The 6 × 40-m shuttle sprint protocol with a 180° change of direction and 20 s passive recovery was the most common RSA test, employed in eight studies (29%).

Conclusions This systematic review provides a comprehensive overview of the testing methods used to assess aerobic fitness and RSA in elite male soccer players. A total of 35 different aerobic fitness tests and 18 RSA tests were identified, highlighting the diversity in methodologies used. The most prevalent aerobic test was the incremental treadmill testing to exhaustion, with a median $\dot{V}O_{2max}$ value of 58 mL/kg/min. Field-based tests were preferred due to their practicality, cost-efficiency, and ability to assess multiple athletes simultaneously. A substantial variability in RSA testing protocols was identified in terms of sprint directions, distances, repetitions, and recovery types. Future research should focus on establishing the diagnostic accuracy of the most commonly used aerobic fitness tests to inform their utility in practice and bridge the gap between current testing practices and optimal fitness evaluation.

Extended author information available on the last page of the article

Key Points

Assessing maximal oxygen consumption ($\dot{V}O_{2max}$) was most commonly done using incremental treadmill testing to exhaustion, with elite soccer players demonstrating a median value of 58.2 mL/kg/min.

The majority of the identified aerobic tests were field based (27 out of 36), with the Yo-Yo intermittent recovery level 1 and 2 tests most commonly used.

The 30–15 Intermittent Fitness Test and submaximal fitness protocols were identified as emerging trends, with the 30–15 Intermittent Fitness Test offering increased specificity and enhanced prescriptive ability, and the submaximal fitness testing being less disruptive to the training process.

The relevance of most repeated sprint ability tests is questionable, since they do not replicate actual match-play demands or effectively target the physiological systems they aim to evaluate.

Reliability and sensitivity studies within the same athlete cohorts are needed to determine the diagnostic accuracy of the most commonly used tests. Additionally, the development of a soccer-specific Participant Classification Framework is required to address the ambiguity in defining 'elite' and 'professional' players.

1 Introduction

Analyses of the physiological demands of soccer have revealed that elite soccer players run 10–12 km per game depending on playing position [1–3], mostly covered at low and moderate intensities [4]. Aerobic metabolism is the most prevalent source of energy during a game, contributing to a great extent of the total energy demands [5]. In particular, the average oxygen consumption ($\dot{V}O_2$) during a match is around 70–80% of maximal oxygen consumption ($\dot{V}O_{2max}$), with average heart rate (HR) typically corresponding to 80–90% of maximal values [6]. In addition, soccer players execute sprints at maximum or near-maximum speeds of short duration, typically lasting between 1 and 6 s, repeatedly throughout a 90-min game [7], with varying recovery periods in between [8, 9]. Previous research has shown a decline in running performance during the second half for both lower and higher intensity running [2, 10, 11]. Hence, a high aerobic capacity and the ability to recover quickly from successive sprints while maintaining maximal output during any subsequent sprints are essential qualities for effectively coping with the physical demands of the game [7, 12].

A higher level of aerobic capacity has been shown to be associated with a reduced injury risk [13] and a smaller fatigue-related deterioration of technical performance in soccer players ($r = -0.51$ to -0.65, $p < 0.05$) [14]. Furthermore, aerobic fitness can differentiate between level of play (i.e. professional vs. amateurs [15], sex [16], and age category) [17]. Differences exist in the aerobic performance of different playing positions, with midfielders generally exhibiting higher $\dot{V}O_{2max}$ values [18, 19], underscoring the different aerobic demands of each position. Likewise, several studies have shown that repeated sprint ability (RSA), which refers to the ability to perform multiple short sprints with a minimal decrement in performance [20], represents a distinguishing factor between professional and amateur soccer players, as well as playing positions [21–23]. Studies examining the correlations between aerobic fitness and RSA in soccer players have elicited mixed findings [24–27]. However, a recent meta-analysis showed that correlations between aerobic fitness and RSA are low to moderate ($r = 0.30$–0.52, $p < 0.05$) [28], which may imply that they should be assessed separately.

Aerobic fitness and RSA testing selection presents a significant challenge for researchers and practitioners, given the wide variety of available testing protocols [29, 30]. Complementary to the physiological and biomechanical demands of soccer [31], test selection should also be based on the reliability and sensitivity of an instrument to facilitate an accurate representation of an individual's performance and progress over time [32]. Traditionally, the evaluation of $\dot{V}O_{2max}$ with incremental exercise testing in a laboratory setting has been considered the gold-standard method of aerobic capacity assessment [33]. In addition to $\dot{V}O_{2max}$, submaximal measures such as running economy, lactate threshold, and ventilatory threshold – obtained during incremental treadmill testing – enable the nuanced understanding of an athlete's aerobic ability [34, 35]. These parameters are particularly relevant in soccer, where a great extent of the game is played at intensities below $\dot{V}O_{2max}$ [7], and where improvements in these variables have been shown to occur even without improvement in $\dot{V}O_{2max}$ [36]. However, laboratory-based assessments can be time-consuming and may fail to replicate the intermittent demands of field-based sports like soccer, thus reducing their ecological validity and specificity [30]. Besides greater specificity, field tests also offer the advantage of being easier to administer when working with large groups of athletes [30]. Furthermore, to address the logistical challenges of maximal testing in elite soccer, submaximal testing protocols have been suggested as a time-efficient and non-fatiguing alternative for evaluating aerobic adaptations [37]. On the other hand, the evaluation of RSA is performed through the implementation of sprints with various durations, distances, and directions (i.e. linear vs. shuttle) and includes the use of various measures, such as the best sprint time (RSA_{best}), mean sprint time (RSA_{mean}), total sprint time summed for all trials (RSA_{total}), as well as indicators of fatigue (i.e. performance decrement and fatigue index) [38]. Notably, the neuromuscular and physiological load imposed on the players during RSA testing varies between tests that employ a different number of sprints, type, and amount of recovery [20].

Despite the well-established importance of aerobic fitness and RSA in soccer, a comprehensive synthesis of the testing protocols used at the elite level is missing. Soccer, especially at higher levels, is characterized by unique physiological demands compared to other team sports [39]. Moreover, distinct physiological and performance differences exist between male and female soccer players [2, 40]. While Bok and Foster [30] conducted a narrative review on the applicability of field aerobic fitness tests in soccer, offering valuable insights into test selection, an in-depth summary of the testing protocols used in scientific literature was not within the scope of their study. Previous systematic reviews have investigated either the testing protocols used to assess RSA [38] or the measurement properties of RSA tests [29, 41], although none of them have explicitly focused on the assessment methods employed in elite soccer. In addition, the investigation of normative values for both aerobic fitness and RSA is of high practical value, as it can supply practitioners with benchmarks to evaluate players' fitness levels relative to elite-level standards. Previous research has shown differences in aerobic performances between regular first team players and elite youth players striving to make the transition to the first team [16, 17, 42]. By reporting normative values for both regular first team and elite youth players, a better contextualization of physical performance can be achieved, providing a clearer understanding of where the players stand relative to their competitive level. Having benchmark data like these facilitates a more strategic approach to athletic development, talent identification, and individualized training programming. Furthermore, examining the reliability of the identified tests and outcome variables is critical for determining the accuracy and the consistency of these measurement tools. Reliable tests provide practitioners with an increased confidence in the precision of the results, as well as in the interpretation of the performance changes over time [43]. By synthesizing the findings from multiple studies performed in high-level male soccer populations, this systematic review can serve as a valuable resource for practitioners and researchers alike, to understand current practices, historical trends, and areas requiring future investigation. Ultimately, the development of more robust and standardized testing practices can be promoted for both aerobic fitness and RSA. Consequently, the aims of this systematic review were to (1) identify the tests and outcome variables used to assess aerobic fitness and RSA of elite male soccer players, (2) provide normative values for the most common tests of aerobic fitness and RSA across different playing levels, and (3) report the reliability values of these aerobic fitness and RSA tests.

2 Methods

2.1 Design and Search Strategy

A systematic review was performed following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [44]. The academic databases MEDLINE, CINAHL, SPORTDiscus, Web of Science, and OVID were searched from the earliest record (i.e. January 1982) to August 2023, to identify English-language, peer-reviewed, original research studies that evaluated aerobic fitness and/or RSA, in elite male soccer players. Key words used for the identification of the studies are shown in Table 1. Search levels 1–5 were all linked by the Boolean operator 'AND', whereas search terms within each search level were joined with 'OR' or 'NOT'. All search results were extracted and imported into a reference management software (RefWorks, ProQuest LLC, Ann Arbor, Michigan, US).

2.2 Study Selection

Following the removal of duplicates, two reviewers (NA and CB) independently screened all titles and abstracts against the inclusion and exclusion criteria of the review. Studies that did not meet the inclusion criteria were removed. Any conflicts were addressed through discussion, or via the third reviewer (AT). The full texts of the articles that were included during this process were subsequently reviewed for eligibility. In addition to the systematic search, reference lists of the included papers were reviewed to identify potentially eligible articles. To fulfil the first objective of the review, studies were eligible for inclusion if they (1) were original research studies, published in a peer-reviewed journal, and written in the English language; (2) had the primary aim to assess aerobic fitness and/or RSA; (3) players were male and older than 17 years of age (i.e. mean age of the group), which was in line with a previous systematic review and a survey study on fitness testing [29, 45] and to minimize any potential influence of maturation [46]; and (4) their playing level was defined as 'professional', 'international', or 'elite'. These playing levels correspond to tiers 3–5 (i.e. highly trained/national level, elite/international level, world class) of the Participant Classification Framework proposed by McKay et al. [47]. Conversely, studies were excluded from the review if they (1) were narrative or systematic reviews and/

Table 1 Search strategy terms

Search 1	Search 2	Search 3	Search 4	Search 5
Soccer OR Football NOT ('American football' OR 'Australian Rules football' OR rugby OR 'Gaelic Football')	Male OR men	Adult OR senior	Professional OR elite	Fitness testing OR physical characteristics OR testing OR physical performance OR physical qualities OR physical profile OR fitness OR physical fitness OR aerobic* OR repeated sprint ability

or meta-analyses; (2) assessed physical characteristics as a result of other research objectives (i.e. fatigue, recovery, nutrition, and genome); (3) the sample consisted of different team sports; (4) players were semi-professional; (5) players were younger than 17 years of age; or (6) reported tests included the use of a ball. For the second objective, studies were eligible if they reported the mean result of the tests under consideration and clearly distinguished between different groups (i.e. professional vs. amateurs, adult men vs. youth, male vs. female). As such, only normative data for elite male soccer players older than 17 years old were recorded. For the third objective, studies were included if they provided information about reliability statistics (i.e. within-day and/or between-day) of the sample used in the study and had a clear description of the procedures that had taken place.

2.3 Assessment of Methodological Quality

The methodological quality of the included articles was assessed using a modified version of the Downs and Black [48] rating scale. This checklist has been used previously in systematic reviews with similar research objectives [49, 50] and can be adapted to the scope and the needs of the systematic review [51]. Eleven questions (1–4, 6, 7, 10, 11, 16, 18, 20) from the traditional version of the checklist were considered relevant to the specific aims of this systematic review, and therefore used to grade the methodological quality of the included studies (Supplementary Table S1 of the Electronic Supplementary Material [ESM]). For the purposes of this review, question 4 was directed to whether the testing procedures in each study were clearly described. Each question was scored as either a '1' (yes) or a '0' (no or unable to determine). Scores were summed for each study, with a total score of '11' representing the highest possible score.

2.4 Data Extraction

Data were extracted and documented in a Microsoft Excel 365 spreadsheet (Microsoft Corporation, Redmond, Washington, USA). Data extracted from each study consisted of the research design, publication details (authors and year of publication), sample information (number of participants, age of the sample, playing level), tests administered to assess aerobic fitness and/or RSA, outcome measures derived from each test, and normative values from each test. Where available, reliability values (i.e. intraclass correlation coefficient [ICC], coefficient of variation [CV], standard error of measurement [SEM], minimal detectable change [MDC], Pearson's r and Cronbach's alpha [α]) were also recorded. Playing level was divided into two categories: (1) senior professionals, representing players that were regular members of the first team of a professional soccer club and/or a national team's senior squad, and (2) elite youth, which included players over 17 years old who were members of the youth department of a professional soccer club (but not yet regular members of the first team), were members of a junior national team squad, or were defined as 'elite' by the authors of the study. According to McKay et al.'s [47] Participant Classification Framework, senior professionals encompass athletes from tiers 3–5 (i.e. national level to world class), while elite youth players fall within tier 3 (i.e. national level/highly trained). In studies with more than one group of players, only the groups with a mean age of 17 years or older were included for subsequent analysis. In terms of reporting normative values, the mean of each group (i.e. senior professionals vs. elite youth) was recorded. For studies with multiple groups of the same playing level, the mean and pooled standard deviation were reported. In intervention studies, only the baseline values were recorded to eliminate any intervention bias – noting that the purpose of this review was not to undertake a meta-analysis evaluating training effects. When a repeated-measures, no intervention study design was implemented, such as seasonal variation studies, the most recent testing point was recorded, in line with a recent similar systematic review in rugby union players [49] and to capture the latest performance level, unless the most recent point was taken after a congested fixture or a detraining period.

3 Results

3.1 Identification and Selection of Articles

Figure 1 illustrates the flowchart of the selection process. The initial search of databases identified 3427 articles. After removing the duplicates (1006 articles), the titles and abstracts of 2421 articles were screened. A total of 138 articles were retained for eligibility assessment through full-text review. Twelve additional studies were identified through manually searching reference lists for full-text eligibility assessment. Following full-text screening, 131 were included for the aim of identifying the tests and outcome variables used to assess aerobic fitness and RSA in elite male soccer. In addition, 63 of those were included for the purpose of reporting normative values for the most common aerobic fitness and RSA tests, whereas only 19 studies reported reliability data.

3.2 Characteristics of Included Studies

Supplementary Table S2 of the ESM shows the assessment of quality scores, with the 11 assessed items ranging from 6 to 10. Supplementary Table S3 of the ESM provides a summary of characteristics of the studies included in this systematic review. The range of sample sizes was 12–927, with a median of 24 participants. Ninety-two studies included senior professionals as participants, 29 included elite youth, while ten studies involved a group of both. The age range of the samples involved in the studies was 17.0–28.6 years, with a median age of 23.8 years. In terms of study design, 55 studies (42%) used a cross-sectional design, 47 (35.9%) used a repeated-measures design, 18 (13.7%) were intervention studies, seven (5.3%) were reliability studies, and six (4.6%) were validity studies. The studies took place in 32 different countries, with Spain (12.2%), Italy (8.4%), England (6.9%), Brazil (6.9%), and Greece (6.9%) being the most frequently identified countries.

3.3 Tests and Outcome Variables Used to Assess Aerobic Fitness

Aerobic fitness was investigated in 124 studies (94.7%) (Tables 2 and 3). Thirty-five different tests were used to assess aerobic fitness, demonstrating the multitude of different assessment methods available. Of those, 26 tests (74%) were field-based, whereas only nine (26%) were laboratory-based tests. Incremental treadmill test to exhaustion was the most commonly used aerobic fitness assessment method (56 studies, 45%), with $\dot{V}O_{2max}$ (mL/kg/min) being the most prevalent outcome variable (49 studies, 87%). Besides this, Yo-Yo intermittent recovery test level 1 (YYIR1) and level

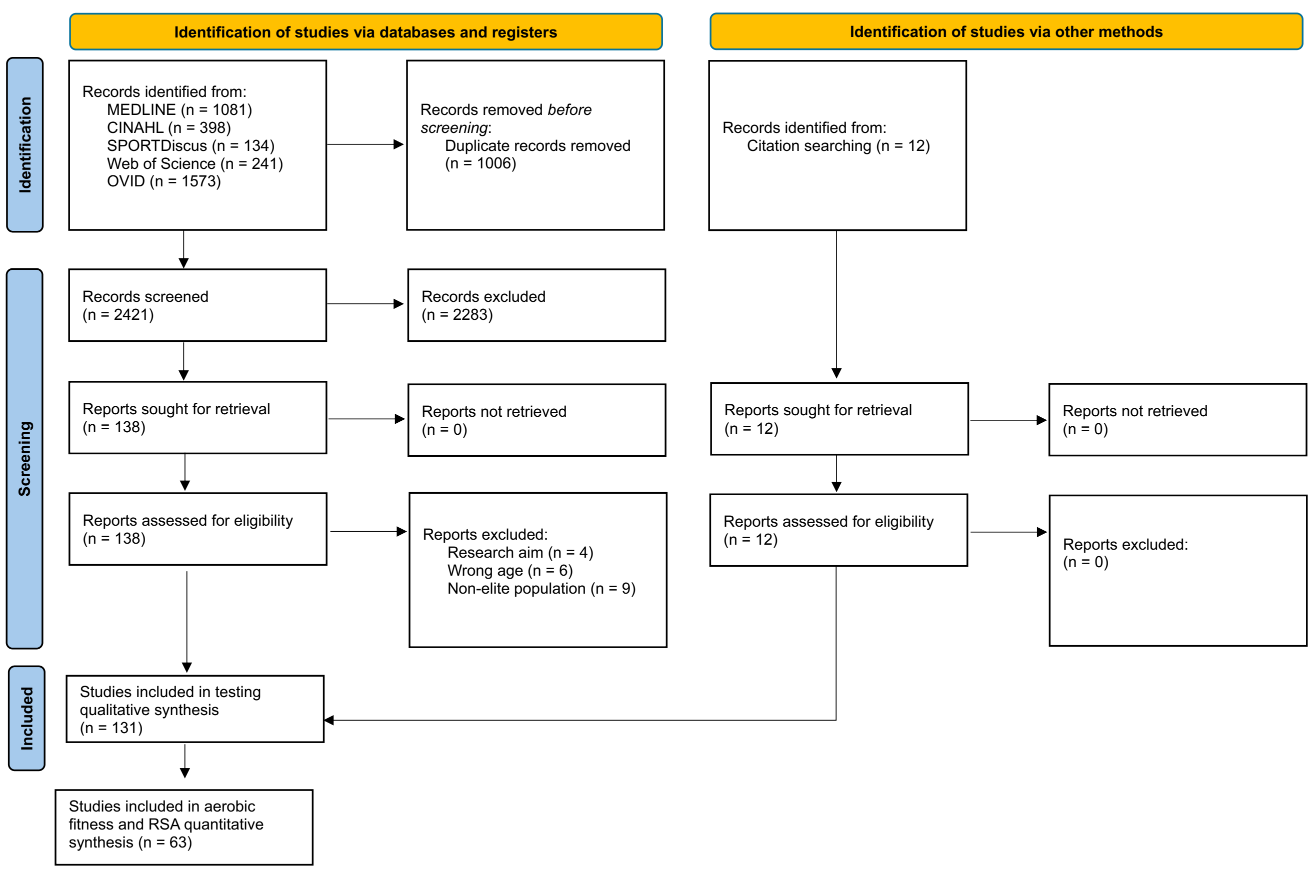

Fig. 1 Flow of selection process of eligible studies for qualitative and quantitative synthesis

2 (YYIR2) were the other two most frequently used tests, identified in 22 (18%) and ten studies (8%), respectively. Distance in metres was the most common outcome variable in both tests, reported in 20 studies (91%) in YYIR1 and in ten studies (100%) in YYIR2.

To enhance clarity and structure, the identified tests were categorized into maximal and submaximal assessments. A total of 21 maximal tests were identified, 18 of which were field based (Table 2). These were further categorized into continuous protocols (ten tests) and intermittent protocols (eight tests). The identified maximal continuous field tests were the VAMEVAL test, the 20-m multistage fitness test (beep test), the University of Montreal Track Test (UMTT) and its modified version, the 1000-m and the 1500-m time trials, a progressive maximal field test to exhaustion, the Conconi test, an incremental running test, and the Cooper test. The identified maximal intermittent field tests were the YYIR1 and YYIR2 tests, the Yo-Yo intermittent endurance test level 2 (YYIE2), the 30–15 Intermittent Fitness Test (30–15 IFT), a modified version of the YYIR1, an intermittent endurance running soccer specific test, an interval shuttle run test, and the Bangsbo test. Notably, five of the maximal tests, including the incremental treadmill test to exhaustion, the YYIR1 and YYIR2, the 2-phase progressive treadmill test, and the incremental endurance test, also assessed submaximal outcome variables. These variables included threshold parameters (e.g. lactate threshold, anaerobic threshold, ventilatory threshold), performance at specific intensities (e.g. $\dot{V}O_2$ and HR at certain velocities), and running economy, providing additional insights into aerobic performance.

In addition to the maximal tests, 14 submaximal tests were identified, comprising eight field-based tests and six laboratory-based tests (Table 3). The field-based submaximal test included the 6-min submaximal YYIR1, the submaximal YYIE2, the 4-min submaximal warm-up test, the 4-stage submaximal intermittent running test, the Mognoni test, the change of direction (COD) economy test, the constant speed running test, and the high-intensity intermittent test. The laboratory-based submaximal tests included the modified lactate threshold treadmill test, the submaximal lactate threshold treadmill test, the submaximal treadmill test, the square-wave treadmill protocol, the 4 × 6 submaximal running test at 75% maximal aerobic speed (MAS), and the 10-min run on treadmill (60% of peak speed).

3.4 Tests and Outcome Variables used to Assess Repeated Sprint Ability (RSA)

RSA was assessed in 27 studies (20.6%) (Table 4). A total of 18 different tests were used to assess RSA ability with 17 (95%) of those being running-based, whereas one was performed on a cycle ergometer. In terms of running-based tests, 11 tests (65%) included linear sprint tests, while six (35%) included at least one COD ranging from 45 to 180°. Sprint repetitions ranged from 6 to 15, sprint distances from 20 to 40 m, and duration of recovery period from 10 to 30 s. Overall, active recovery was the most prevalent recovery type (14 tests, 78%), whereas the remaining four (22%) incorporated passive recovery. The 6 × 40-m (20 + 20 m, 180° COD) shuttle sprint protocol with 20 s passive recovery was the most commonly used RSA test (eight studies, 29%), with RSA_{best} in seconds (eight studies, 100%), RSA_{mean} in seconds (eight studies, 100%), and percentage of performance decrement (eight studies, 100%), representing the most frequently examined outcome variables. The 6 × 20-m sprint protocol with 25 s active recovery (used in three studies, 11%), evaluating RSA_{best}, RSA_{mean}, RSA_{total}, and percentage of performance decrement, and a 7 × 30-m sprint protocol with 25 s active recovery (three studies, 11%), assessing RSA_{best}, RSA_{mean}, fatigue index in seconds, RSA_{total}, and percentage of performance decrement, were the other two most frequently used RSA tests.

3.5 Normative Values for Aerobic Fitness in Elite Male Soccer Players

Table 5 presents the normative values for $\dot{V}O_{2max}$ obtained in incremental treadmill testing to exhaustion. $\dot{V}O_{2max}$ values ranged from 51.5 to 65.5 mL/kg/min in senior professionals (37 studies, 84%), while the observed range in elite youth was 54.9 to 63.5 mL/kg/min (seven studies, 16%). Table 6 provides the normative values for YYIR1 and YYIR2. In terms of YYIR1, senior professionals achieved distances ranging from 1348 to 2520 m (14 studies, 78%), whereas distances in elite youth ranged from 2054 to 3150 m (six studies, 33%). For YYIR2, senior professionals reached distances ranging from 613 to 1300 m (seven studies, 70%), whilst distances in elite youth ranged from 815 to 1147 m (five studies, 50%). Table 7 provides normative values for other frequently used field tests in elite male soccer players. For the VAMEVAL test, MAS values in senior professionals ranged from 15.9 to 19.6 km/h (five studies, 62%). Regarding the YYIE2, senior professionals achieved distances ranging from 1640 to 2364 m (five studies, 62%), while distances in elite youth were between 1394 and 2892 m (two studies, 25%). In the 20-m multistage fitness test (beep test), senior professionals achieved distances ranging from 1981 to 2595 m (three studies, 50%). Lastly, the final velocity in 30–15 IFT ranged from 19.0 to 20.1 km/h in senior professionals (two studies, 33%), whereas the single study identified in elite youth players reported a final velocity of 19.5 km/h.

Table 2 Maximal aerobic tests and outcome variables

Test	Test type	Outcome variable	Reference
Incremental treadmill Decltest to exhaustion	Laboratory	$\dot{V}O_{2max}$ (mL/kg/min)	[15, 18, 22, 34, 36, 56, 59, 62, 67, 83–90, 112, 116, 120, 130, 131, 133, 135, 140, 143, 149, 159, 160, 162–166, 168, 173, 175–177, 179, 183–185, 188, 192, 198–201]
		HR_{max} (b/min)	[18, 34, 56, 59, 62, 67, 84, 89, 112, 135, 149, 159, 166, 175, 179, 192, 200]
		Velocity at $\dot{V}O_{2max}$ (km/h)	[19, 120, 135, 143, 173, 176, 177, 179, 192]
		Blood lactate concentration (mmol/L)	[18, 62, 88, 112, 135, 149, 166, 192]
		$\dot{V}O_{2max}$ (mL/lbm/min)	[190]
		$\dot{V}O_{2max}$ (L/min)	[19, 184]
		$\dot{V}O_{2peak}$ (mL/kg/min)	[195]
		$\dot{V}O_2$ at 12 km/h (mL/kg/min)*	[59]
		$\dot{V}O_2$ at respiratory compensation point (L/min)*	[184]
		$\dot{V}O_2$ at respiratory compensation point (mL/kg/min)*	[184]
		$\dot{V}O_2$ at ventilatory threshold (mL/kg/min)*	[36]
		$\dot{V}O_2$ at lactate threshold (mL/kg/min)*	[36]
		$\dot{V}O_2$ at anaerobic threshold (mL/kg/min)*	[59, 84, 185]
		$\dot{V}CO_{2max}$ (mL/kg/min)	[56]
		Lactate threshold (mmol/L)*	[34, 151]
		Velocity at lactate threshold (km/h)*	[34, 151, 198]
		HR at lactate threshold (b/min)*	[34, 151]
		Ventilatory threshold*	[120, 135]
		Velocity at 2 mmol/L (km/h)*	[61, 62, 130, 165, 197]
		Velocity at 2.5 mmol/L (km/h)*	[61]
		Velocity at 3 mmol/L (km/h)*	[61]
		Velocity at 4 mmol/L (km/h)*	[61, 62, 130, 160, 164, 165, 176, 189, 197]
		Ventilatory threshold 1 (mL/kg/min)*	[143]
		Ventilatory threshold 2 (mL/kg/min)*	[143, 188]
		$\%\dot{V}O_{2max}$ at ventilatory threshold 1 (%)*	[86, 143]
		$\%\dot{V}O_{2max}$ at ventilatory threshold 2 (%)*	[86, 143]
		$\%\dot{V}O_{2max}$ at 4 mmol/L (%)*	[176]
		$\dot{V}O_2$ at 2 mmol/L (mL/kg/min)*	[62]
		$\dot{V}O_2$ at 4 mmol/L (mL/kg/min)*	[62]
		$\%HR_{max}$ at 4 mmol/L (%)*	[176]
		$\%\dot{V}O_{2max}$ at ventilatory threshold (%)*	[89, 160, 177]
		$\%\dot{V}O_{2max}$ at anaerobic threshold (%)*	[190, 200, 201]
		$\dot{V}O_2$ at ventilatory threshold (mL/kg/min)*	[160, 164]
		$\dot{V}O_{2rest}$ (mL/kg/min)	[86]
		Time to exhaustion (min)	[85, 87, 120, 133, 159, 173]

Table 2 (continued)

Test	Test type	Outcome variable	Reference
		Maximum speed (km/h)	[18, 56, 84, 159]
		Maximal ventilation (L/min)	[149]
		Running economy (mL/kg/min)*	[34, 133]
		Running economy (mL/lbm/min)*	[190]
		Time to reach a respiratory exchange ratio of 1 (s)*	[133]
		Respiratory compensation point*	[120]
		Maximal respiratory exchange ratio	[149, 175]
		HR at ventilatory threshold (b/min)*	[120]
		HR at 2 mmol/L (b/min)*	[61, 62, 197]
		HR at 2.5 mmol/L (b/min)*	[61]
		HR at 3 mmol/L (b/min)*	[61]
		HR at 4 mmol/L (b/min)*	[61, 62, 197]
		HR at 12 km/h (b/min)*	[59]
		HR at anaerobic threshold (b/min)*	[59, 84]
		HR at respiratory compensation point (b/min)*	[120]
		HR at $\dot{V}O_{2max}$ (b/min)	[120]
		Velocity at anaerobic threshold (km/h)*	[140] [56, 84, 88]
		Velocity at ventilatory threshold (km/h)*	[120, 135, 177]
		Velocity at ventilatory threshold 1 (km/h)	[143]
		Peak aerobic speed (km/h)	[116]
		Aerobic threshold (km/h)*	[116]
		Anaerobic threshold (km/h)*	[116]
		Velocity at respiratory compensation point (km/h)*	[120]
Yo-Yo intermittent recovery test level 1	Field	Distance (m)	[15–17, 24–26, 91, 92, 111, 114, 115, 117, 136, 137, 141, 148, 154, 164, 165, 181]
		HR_{max} (b/min)	[15, 110]
		Final stage velocity (km/h)	[136]
		HR at 2nd minute of the test (b/min)*	[25]
		HR at 4th minute of the test (b/min)*	[25]
		$\dot{V}O_{2max}$ (mL/kg/min)	[119]
Yo-Yo intermittent recovery test level 2	Field	Distance (m)	[15, 25, 27, 42, 93, 139, 155, 159, 173, 179]
		HR_{max} (b/min)	[15, 159]
		HR at 2nd minute of the test (b/min)*	[25]
		HR at 4th minute of the test (b/min)*	[25]
VAMEVAL test	Field	MAS (km/h)	[144, 152, 157, 169, 181]
		HR_{max} (b/min)	[144, 147, 152, 181]
		$\dot{V}O_{2max}$ (mL/kg/min)	[165, 169]
		Blood lactate concentration (mmol/L)	[147]
		Velocity at last stage (km/h)	[147]
		HR_{mean} (b/min)	[169]

Table 2 (continued)

Test	Test type	Outcome variable	Reference
		Time to exhaustion (min)	[121]
		Distance (m)	[181]
Yo-Yo intermittent endurance test level 2	Field	Distance (m)	[67, 94, 95, 167, 170, 174, 177, 180]
		HR_{max} (b/min)	[67, 167, 174]
		HR_{mean} (b/min)	[167, 174]
20-m multistage fitness test (beep test)	Field	Distance (m)	[26, 132, 134]
		MAS (km/h)	[134]
		HR_{max} (b/min)	[134, 194, 196]
		Number of runs	[196]
		Resting blood lactate concentration (mmol/L)	[134]
		Post-exercise blood lactate concentration (mmol/L)	[134]
		Time to exhaustion (min)	[134]
		$\dot{V}O_{2max}$ (mL/kg/min)	[134, 186, 194]
30–15 Intermittent Fitness Test	Field	Final velocity (km/h)	[13, 68, 121, 124, 138, 146]
		HR_{max} (b/min)	[121, 138]
Modified Yo-Yo intermittent recovery test level 1	Field	Distance (m)	[128]
University of Montreal Track Test	Field	Time to exhaustion (min)	[118]
		Distance (m)	[118]
		MAS (km/h)	[118, 193]
		HR_{max} (b/min)	[193]
		$\dot{V}O_{2max}$ (mL/kg/min)	[118]
		Anaerobic speed reserve (km/h)	[118]
Modified University of Montreal Track Test	Field	Final velocity (km/h)	[178, 187]
		MAS (km/h)	[182]
		HR_{max} (b/min)	[178]
		Blood lactate concentration (mmol/L))	[178]
2-phase progressive treadmill test	Laboratory	HR_{max} (b/min)	[113]
		Blood lactate concentration (mmol/L)	[113]
		Velocity at 4 mmol/L (km/h)*	[113]
1000-m time trial	Field	Time to completion (s)	[137]
1500-m time trial	Field	MAS (m/s)	[109]
Progressive maximal field test to exhaustion	Field	MAS (km/h)	[160]
Conconi test	Field	MAS (km/h)	[123]
Intermittent endurance running (INTER) soccer specific test	Field	Time to exhaustion (s)	[166]
		Distance (m)	[166]
		Peak blood lactate concentration (mmol/L)	[166]
		Mean blood lactate concentration (mmol/L)	[166]
		HR_{peak} (b/min)	[166]
		HR_{mean} of the last 15 s (b/min)	[166]
Incremental running test	Field	Velocity at lactate threshold (m/s)	[132]
Incremental endurance test	Laboratory	Velocity at 2 mmol/L (km/h)*	[125]
		Velocity at 4 mmol/L (km/h)*	[125, 168]
		HR_{max} (b/min)	[125]
		Velocity at lactate threshold (km/h)*	[168]
		HR at velocity at 2 mmol/L (%max)*	[125]

Table 2 (continued)

Test	Test type	Outcome variable	Reference
		HR at velocity at 4 mmol/L (%max)*	[125]
		Distance (m)	[125]
Interval shuttle run test	Field	Distance (m)	[125, 168]
		HR_{max} (b/min)	[125, 196]
		Number of runs	[196]
Cooper 12 min test	Field	Distance (m)	[200]
Bangsbo test	Field	Distance (m)	[192, 199]

Outcome variables marked with an asterisk (*) represent submaximal variables

HR heart rate, HR_{max} maximum heart rate, HR_{mean} average heart rate, HR_{peak} peak heart rate, *MAS* maximal aerobic speed, $\dot{V}CO_{2max}$ maximum carbon dioxide production, $\dot{V}O_2$ oxygen uptake, $\dot{V}O_{2max}$ maximum oxygen uptake, $\dot{V}O_{2peak}$ peak oxygen uptake, O_{2rest} ventilatory efficiency at rest

3.6 Normative Values for RSA in Elite Male Soccer Players

Table 8 shows the normative values for the most common RSA tests. For the 6 × 40-m (20 + 20 m) shuttle sprint protocol with 20 s passive recovery test, senior professionals achieved values ranging from 6.86 to 7.40 s for RSA_{best} (five studies, 62%), 7.12 to 8.07 s for RSA_{mean} (five studies, 62%), and 3.3% to 7.8% for performance decrement (five studies, 62%). Values in elite youth ranged from 7.02 to 7.38 s for RSA_{best} (three studies, 37%), 7.43 to 7.67 s for RSA_{mean} (three studies, 37%), and 3.7% to 6.6% for performance decrement (five studies, 62%). For 6 × 20-m sprints with 25 s active recovery test, values in senior professionals ranged from 2.89 to 3.14 s for RSA_{best} (three studies, 100%), 17.79 to 19.31 s for RSA_{total} (three studies, 100%), and 1.75% to 2.59% for performance decrement (three studies, 100%).

3.7 Reliability Data

Reliability statistics for the aerobic fitness and RSA tests are shown in Supplementary Tables S4 and S5 of the ESM. For the aerobic fitness tests, reliability statistics were reported in 11 studies (9.6%). The CV (eight studies, 72%), ICC (nine studies, 83%), SEM (three studies, 25%), and MDC (three studies, 25%) were the identified reliability metrics for aerobic fitness testing. YYIR2 was the test in which the greatest number of studies reported reliability values (three studies, 25%). For the total distance achieved in the YYIR2 test, the observed CV values ranged from 4.2% to 9.6%, with an ICC of 0.96, SEM of 34 m, and MDC 94.1 m. Although no study reported reliability values for the distance covered in the YYIR1, excellent reliability was reported for HR at the second (ICC 0.92, CV 4.1%) and fourth (ICC 0.93, CV 3.8%) minutes of the protocol. High levels of reliability were also reported for the 1000-m time trial (ICC 0.82, CV 1.06%, SEM 2.86 s, MDC 4.56 s). The HR_{ex} appeared to be more reliable than HR recovery in the 4-min submaximal warm-up test (ICC 0.95, CV 1.4% vs. ICC 0.84, CV 7.0%) and the 6-min submaximal version of YYIR1 (ICC 0.96, CV 1.6% vs. ICC 0.58–0.93, CV 3.9–19.5%).

For RSA tests, reliability values were reported in five studies (18%). The CV (five studies, 100%), ICC (four studies, 80%), and SEM (one study, 25%) were the reliability metrics reported for RSA tests. Both RSA_{total} (ICC 0.92, CV 0.7–2.7%) and RSA_{mean} (ICC 0.81–0.93, CV 0.8–1.8%) displayed good reliability. Conversely, the performance decrement score showed poor reliability levels (ICC 0.17, CV 30.2%, SEM 1.2%), rendering its utility in practice questionable.

4 Discussion

The aims of this systematic review were to (1) identify the tests and outcome variables used to assess aerobic fitness and RSA in elite male soccer players, (2) report normative values on the most common aerobic fitness and RSA tests, and (3) report reliability data for the identified tests and outcome variables. In total, 131 studies from 32 different countries were included in this review. A considerably larger number of studies (i.e. 124 vs. 27) assessed aerobic fitness compared to RSA, which is in agreement with the findings of a recent survey on fitness testing practices of elite male soccer practitioners [45]. This prevalence may be attributed to the fact that RSA research emerged later, with a 20-year gap between the first studies on aerobic fitness and RSA in our review. For aerobic fitness testing, 35 different testing protocols were identified, with the majority of them being field-based tests. However, the incremental treadmill test to exhaustion was the most used aerobic fitness test, followed by the YYIR1 and YYIR2. For RSA testing, 18 different tests were identified, comprising repeated linear sprints and involving at least one COD test, active and passive recovery, different sprint repetitions and distances, as well as recovery durations. The 6 × 40-m (20 + 20 m, 180° COD) shuttle

Table 3 Submaximal aerobic tests and outcome variables

Test	Test type	Outcome variable	Reference
Submaximal Yo-Yo intermittent recovery test level 1	Field	$\%HR_{max}$ (%) at 3 min	[110]
		$\%HR_{max}$ (%) at 6 min	[110]
		$\%HR_{max}$ (%) at 1 min of recovery	[110]
		$\%HR_{max}$ (%) at 2 min of recovery	[110]
		HR_{mean} during the last 30 s ($\%HR_{max}$)	[129]
		HR at 6 min (completion of test) (b/min)	[66]
		HR at 30 s after completion (b/min)	[66]
		HR at 60 s after completion (b/min)	[66]
		HR at 90 s after completion (b/min)	[66]
		HR at 120 s after completion (b/min)	[66]
		HRR at 30 s after completion ($\%HR_{max}$)	[66]
		HRR at 60 s after completion ($\%HR_{max}$)	[66]
		HRR at 90 s after completion ($\%HR_{max}$)	[66]
		HRR at 120 s after completion ($\%HR_{max}$)	[66]
Submaximal Yo-Yo intermittent endurance test level 2	Field	HRR at 4 min after completion ($\%HR_{max}$)	[67]
		HRR at 6 min after completion ($\%HR_{max}$)	[67]
Modified lactate threshold treadmill test	Laboratory	Velocity at 2 mmol/L (km/h)	[172]
		HR at 2 mmol/L (km/h)	[172]
		Velocity at 4 mmol/L (km/h)	[172]
		HR at 4 mmol/L (km/h)	[172]
Submaximal lactate threshold treadmill test	Laboratory	Velocity at first lactate inflection point (km/h)	[191]
		Velocity at 4 mmol/L (km/h)	[191]
Submaximal treadmill test	Laboratory	$\dot{V}O_2$ (mL/kg/min)	[171]
		Respiratory exchange ratio	[171]
		Respiratory rate	[171]
		HR at 9, 11, 14 km/h (b/min)	[171]
		Blood lactate concentration (mmol/L)	[171]
Submaximal warm-up test	Field	HR exercise (b/min)	[68, 126]
		HR recovery 60 s (b/min)	[68, 126]
		HR post 1 min (b/min)	[68, 126]
4-stage submaximal intermittent running test (around the field)	Field	Velocity at 3 mmol/L (km/h)	[142, 145, 150, 156]
		Blood lactate concentration at 12 km/h (mmol/L)	[150, 156]
		Blood lactate concentration at 13 km/h (mmol/L)	[150, 156]
		Individual anaerobic threshold (km/h)	[161]
Square-wave treadmill protocol	Laboratory	$\dot{V}O_2$ kinetics	[173]
Mognoni test	Field	Blood lactate concentration (mmol/L)	[123]
Change of direction economy test	Field	$\dot{V}O_2$ (L/min)	[83]
		Energetic cost (kcal/kg/km)	[83]
		Respiratory exchange ratio	[83]
		$\dot{V}CO_2$ (L/min)	[83]
		Minute ventilation (breaths/min)	[83]
		Mean HR of the last minute (b/min)	[83]
		Blood lactate concentration (mmol/L)	[83]
		Distance (m)	[125]
4 × 6 submaximal running at 75% MAS	Laboratory	$\dot{V}O_2$ kinetics	[179]
		Running economy (mL/kg/km)	[179]
		Respiratory exchange ratio	[179]
		HR during the final 30 s of each running bout ($\%HR_{max}$)	[179]
Constant speed running test	Field	Blood lactate concentration (mmol/L)	[122]
High-intensity intermittent test	Field	Blood lactate concentration (mmol/L)	[15, 22, 122]
10-min run on treadmill (60% of peak speed)	Laboratory	$\dot{V}O_2$ kinetics	[15, 22]

HR heart rate, HR_{max} maximum heart rate, HR_{mean} average heart rate, *HRR* heart rate recovery, *MAS* maximal aerobic speed, $\dot{V}CO_2$ carbon dioxide production, $\dot{V}O_2$ oxygen uptake, $\dot{V}O_2$ *kinetics* the rate which $\dot{V}O_2$ adjusts to a dynamic exercise challenge

Table 4 RSA tests and outcome variables

Test	Outcome variable	Reference
6×40-m (20+20) shuttle sprints with 20 s passive recovery	RSA_{best} (s)	[21, 22, 26, 83, 136, 153, 158, 187]
	RSA_{mean} (s)	[21, 22, 26, 83, 136, 153, 158, 187]
	RSA_{total} (s)	[158]
	Performance decrement (%)	[21, 22, 26, 83, 136, 153, 158, 187]
	Blood lactate concentration (mmol/L)	[83, 136]
6×20-m sprints with 25 s active recovery	RSA_{best} (s)	[23, 75, 171]
	RSA_{mean} (s)	[23, 75]
	RSA_{total} (s)	[23, 75, 171]
	Performance decrement (%)	[23, 75, 171]
7×30-m sprints with 25 s active recovery	RSA_{best} (s)	[139, 173]
	RSA_{mean} (s)	[139, 173]
	Fatigue index (s)	[173]
	RSA_{total} (s)	[24]
	Performance decrement (%)	[24, 139]
6×20-m sprints (with 4 changes of directions [100°] every 4 m) with 25 s active recovery	RSA_{best} (s)	[23, 75]
	RSA_{mean} (s)	[23, 75]
	RSA_{total} (s)	[23, 75]
	Performance decrement (%)	[23, 75]
	RSA/RCOD index	[23, 75]
8×30-m sprints with 25 s active recovery	RSA_{best} (s)	[92]
	RSA_{mean} (s)	[92]
	RSA_{total} (s)	[92]
	Performance decrement (%)	[92]
Bangsbo sprint test (7×34.2-m sprint with 3 changes of directions [45°] with 25 s active recovery)	RSA_{best} (s)	[127]
	RSA_{mean} (s)	[127]
	Fatigue index (s)	[127]
	Performance decrement (%)	[127]
15×40-m sprints with 30 s passive recovery	RSA_{total} (s)	[155]
	Performance decrement (%)	[155]
7×30-m sprints (completed on 20-s cycles)	RSA_{total} (s)	[27]
	Performance decrement (%)	[27]
10×20-m sprints with 15 s active recovery	RSA_{best} (s)	[179]
	RSA_{total} (s)	[179]
	Sprint fatigue index (%)	[179]
10×20-m sprints with 25 s active recovery	RSA_{best} (s)	
	RSA_{mean} (s)	[74]
	RSA_{total} (s)	[74]
	Performance decrement (%)	[74]
10×20-m sprints (with 4 changes of directions [100°] every 4 m) with 25 s active recovery	RSA_{best} (s)	[74]
	RSA_{mean} (s)	[74]
	RSA_{total} (s)	[74]
	Performance decrement (%)	[74]
	RSA/RCOD index	[74]
6×35-m sprints with 10 s active recovery	RSA_{best} (s)	[157]
	RSA_{total} (s)	[157]
	Performance decrement (%)	[157]
	Maximal sprinting speed (km/h)	[157]
7×35-m sprints with 25 s active recovery	RSA_{mean} 10 m (s)	[25]
	RSA_{mean} 20 m (s)	[25]
	RSA_{mean} (s)	[25]

Table 4 (continued)

Test	Outcome variable	Reference
6×40-m sprints (involving 3 changes of directions) with 25 s passive recovery	RSA_{best} (s)	[170]
	RSA^{total} (s)	[170]
	Performance decrement (%)	[170]
10×6-s cycle sprints with 24 s of passive recovery (60% of optimal resistive load)	Peak power (W)	[177]
	Relative peak power (W/lean leg volume)	[177]
	Mean power (W)	[177]
	Relative mean power (W/lean leg volume)	[177]
	Total work (kJ)	[177]
	Performance decrement (%)	[177]
8×20-m sprints with 20 s active recovery	RSA_{best} (s)	[186]
	RSA_{total} (s)	[186]
6×30-m shuttle sprints with 20 s passive recovery	RSA_{mean} (s)	[131]
6×30-m sprints with 30 s active recovery	RSA_{best} (s)	[140]
	RSA_{total} (s)	[140]
	Performance decrement (%)	[140]

RCOD repeated change of direction, *RSA* repeated sprint ability, RSA_{best} best sprint time, RSA_{mean} mean sprint time, RSA_{total} total sprint time

sprint protocol with 20 s passive recovery test was the most commonly used RSA test, followed by a 6×20-m sprint protocol with 25 s active recovery and a 7×30-m sprint protocol with 25 s active recovery.

4.1 Testing Methods and Outcome Variables

The significant aerobic demands and the need to repeatedly perform short sprints during a 90-min game [6, 7, 39] require the presence of increased aerobic capacity and RSA levels to support a consistent level of performance throughout the game [52]. A valid, reliable, and standardized evaluation of these physical attributes can allow for an objective assessment at both the individual and group level, enabling meaningful within- and between-athlete comparisons to be made [53, 54]. Ultimately, information gained from these assessments can form the basis for the prescription and implementation of tailored training interventions [32].

4.1.1 Aerobic Fitness Assessment

Incremental treadmill testing to exhaustion represents the most frequent testing method for aerobic assessment according to the results of this systematic review, with $\dot{V}O_{2max}$ being the main outcome variable of interest. A wide range of incremental treadmill testing protocols were used across the studies, varying in terms of initial speed, speed increments, and inclination levels, highlighting the lack of a universal standardized protocol [55]. The role of $\dot{V}O_{2max}$ in differentiating between playing standards is questionable, with research in elite soccer yielding equivocal results [15, 19, 34, 56], which may necessitate obtaining additional information from supplementary $\dot{V}O_{2max}$ variables [57, 58]. Based on this systematic review, maximum HR (b/min), velocity at $\dot{V}O_{2max}$ (km/h), and blood lactate concentration (mmol/L) represent the three most frequently used supplementary outcome variables to gain a more holistic view of an athlete's aerobic ability. Additionally, outcome variables related to running economy, such as $\dot{V}O_2$, velocity, and HR at the anaerobic [59, 60] and lactate thresholds [34, 36], as well as at specific intensities [61, 62], were also identified. Velocity at $\dot{V}O_{2max}$ integrates aerobic capacity and aerobic cost of running, providing a practical measure that can be used for exercise prescription [63]. Rebelo et al. [58] reported that only velocity at $\dot{V}_{2max}$ from incremental treadmill testing correlated with match high-intensity running in youth soccer players, whereas $\dot{V}O_{2max}$ showed no significant relationships. Blood lactate concentration provides insights into an athlete's aerobic ability, with the lactate threshold reflecting the point where lactate production exceeds lactate removal. Athletes with a higher lactate threshold can theoretically perform at higher average intensities without accumulating fatigue-inducing byproducts [34, 36].

Aerobic capacity testing under laboratory conditions may not be specific for intermittent sports such as soccer and is associated with certain limitations, including increased cost, the need for specialized equipment, increased time required for assessment, and limited accessibility. Hence, field testing has emerged as an attractive alternative, with the results of our systematic review demonstrating a higher preference for such assessment methods. Overall, the vast majority of

Table 5 Normative values for $\dot{V}O_{2max}$ (mL/kg/min) during incremental treadmill tests to exhaustion

Study	Playing standard	Playing position/subgroup	Protocol	$\dot{V}O_{2max}$ (mL/kg/min)
Boraczyński et al. [112]	Senior professionals	All	Continuous 3-min running stages (at 1% gradient) with initial speed set at 9 km/h increased by 1 km/h per stage until volitional exhaustion (failure) was reached	55.4 ± 5.3
Dolci et al. [83]	Elite youth	All	Running started at 10 km/h, and speed was increased by 2 km/h every 3 min until volition	63.5 ± 7.7
Parpa and Michaelides [85]	Senior professionals	All	Modified Heck incremental maximal protocol	57.7 ± 1.4
Enes et al. [116]	Senior professionals	All	The test started with 8 km/h with a progressive increase of 0.1 km/h every 6 s, with a steady slope of 1%	54.5 ± 3.8
Angoorani et al. [86]	Senior professionals	All	Bruce protocol → Running started at 1.7 mph (10% grade). The speed of running was subsequently increased to 2.5 mph, 3.4 mph, 4.2 mph, 5.0 mph, and 5.5 mph at 3-min intervals throughout the test. The inclination of the treadmill was also enhanced by 2% for each stage of test	55.3 ± 5.4
Colosio et al. [62]	Senior professionals	All (excluding goalkeepers)	Two-part step-incremental running test → The first, submaximal part of the protocol consisted of steps of 3 min starting from a speed of 8 km/h, which increased with 2 km/h after each step. When blood lactate concentration had passed the threshold of 4 mmol/L, the second, maximal part of the protocol started, and speed was increased by 1 km/h, while the slope of the treadmill was increased 0.5% every 30 s until volitional exhaustion	58.3 ± 3.8
Papadakis et al. [130]	Senior professionals	All	The initial speed of the incremental test was set at 10 km/h and was increased by 2 km/h every 3 min until volitional exhaustion	59.7 ± 3.7
Hoppe et al. [133]	Elite youth	U21 group U19 group	After a 4-min run at 10 km/h with 1% inclination, the latter was increased to 5% for further 4 min. Then, the speed was increased by 1 km/h every 2 min until maximal exhaustion was reached	55.0 ± 1.7 54.9 ± 1.3
Krespi et al. [131]	Elite youth	All	The starting speed was 3 km/h, with speed increments of 1 km/h every 60 s Participants walked the first 5 steps (up to 7 km/h) and continued running from 8 km/h until volitional exhaustion	56.2 ± 4.7
Bekris et al. [135]	Senior professionals	All		56.1
Meckel et al. [140]	Senior professionals	All	Treadmill's initial speed was 9 km/h with a 1% grade. The speed was increased by 1 km/h every minute until volitional exhaustion occurred. The grade was maintained at 1% throughout the entire test until volitional exhaustion	57.4 ± 5.4

Table 5 (continued)

Study	Playing standard	Playing position/subgroup	Protocol	$\dot{V}O_{2max}$ (mL/kg/min)
Almeida et al. [143]	Senior professionals	Control group	Modified Heck incremental maximal protocol	56.9 ± 4.2
Michaelides et al. [87]	Senior professionals	First Division group	Modified Heck incremental maximal protocol	57.0 ± 5.5
		Second Division group		52.2 ± 5.4
Sapp et al. [149]	Elite youth	All	All players ran at a speed of 12.9 km/h or 13.7 km/h. The players ran at a 0.5% incline for the first 2 min of the test, after which incline increased 2% every subsequent 2 min until volitional exhaustion	56.9 ± 5.1
Wells et al. [159]	Senior professionals	All		57.3 ± 4.5
Manzi et al. [160]	Senior professionals	All	4–5 submaximal exercise bouts at an initial running speed of 9 km/h followed by a maximal incremental test to volitional fatigue. The treadmill running velocity was increased during the submaximal test by 1 km/h every 5 min. Once capillary blood lactate concentrations were elevated above 4 mmol/L, the treadmill speed was increased by 0.5 km/h every 30 s until exhaustion	59.2 ± 4.3
Koundourakis et al. [162]	Senior professionals	All	Initial speed was set at 10 km/h, and it was held constant for 3 min. Thereafter, speed was increased by 2 km/h every 3 min until 16 km/h, and then speed was increased 2 km/h every 2 min until volitional exhaustion	60.1 ± 3.3
Koundourakis et al. [163]	Senior professionals	All	Initial speed was set at 10 km/h, and it was held constant for 3 min. Thereafter, speed was increased by 2 km/h every 3 min until 16 km/h, and then speed was increased 2 km/h every 2 min until volitional exhaustion	58.0 ± 3.2
Manzi et al. [164]	Senior professionals	All	Starting speed of 10 km/h and speed increments of 1 km/h/min until exhaustion	61.2 ± 4.1
Castagna et al. [165]	Senior professionals	All	4–5 submaximal exercise bouts at an initial running speed of 9 km/h followed by a maximal incremental test to volitional fatigue. The treadmill running velocity was increased during the submaximal test by 1 km/h every 5 min. Once capillary blood lactate concentrations were elevated above 4 mmol/L, the treadmill speed was increased by 0.5 km/h every 30 s until exhaustion	61.4 ± 4.1
Aandstad and Simon [166]	Senior professionals	All	Running started at 12 km/h (5.2% inclination). Treadmill speed was increased by 1 km/h every minute until volitional exhaustion	59.9 ± 2.1
Hoppe et al. [168]	Senior professionals	All	After a 4-min run at 10 km/h with 1% inclination, the inclination was increased to 5% for 4 min. The treadmill speed was than increased every 2 min by increments of 1 km/h until exhaustion was reached	58.2 ± 4.9

Table 5 (continued)

Study	Playing standard	Playing position/subgroup	Protocol	$\dot{V}O_{2max}$ (mL/kg/min)
Boone et al. [88]	Senior professionals	All (excluding goalkeepers)	The incremental exercise consisted of steps of 3 min starting from a speed of 8 km/h, and the speed was increased with 2 km/h after each step (1.5% slope)	58.5 ± 3.0
Signorelli et al. [59]	Senior professionals	All	After 1 min at 5.5 km/h, speed was increased to 8 km/h and thereafter increased by 0.1 km/h every 7.5 s (0.8 km/h per min) until exhaustion	63.3 ± 6.2
Angius et al. [56]	Senior professionals	All	Linear increase in running velocity of 1 km/h every minute, starting at a speed of 8 km/h up to exhaustion	55.2 ± 4.6
Wells et al. [173]	Senior professionals	All (professional group)		56.5 ± 2.9
Helgerud et al. [175]	Senior professionals	All	Players started at 11 km/h and kept there for 5 min. The speed of the treadmill was then increased by 1 km/h every minute to a level that brought the participant to exhaustion within 5–6 min	60.5 (51.7–67.1)
Kalapotharakos et al. [176]	Senior professionals	All	Initial speed was set at 10 km/h, and it was held constant for 3 min. Thereafter, speed was increased by 2 km/h every 3 min until 16 km/h, and then speed was increased 2 km/h every 2 min until volitional exhaustion	61.2 ± 2.3
Bogdanis et al. [177]	Senior professionals	All	Speed was increased by 0.5 km/h every minute, starting from a speed of 10–12 km/h	51.5 ± 1.7
Ziogas et al. [34]	Senior professionals	First division group	The initial speed of the incremental test was set at 10 km/h and was increased by 2 km/h/min every 3 min until volitional exhaustion	58.8 ± 3.3
		Second division group		56.4 ± 3.7
		Third division group		57.6 ± 3.2
Rampinini et al. [15]	Senior professionals	All	Starting speed at 10 km/h, with increments of 1 km/h/min until volitional exhaustion (4% inclination)	58.5 ± 3.8
Rampinini et al. [22]	Senior professionals	All	Starting speed at 10 km/h, with increments of 1 km/h/min until volitional exhaustion (4% inclination)	58.5 ± 4.0
Sotiropoulos et al. [183]	Senior professionals	All	The speed started at 10 km/h, and was increased by 1 km/h every 2 min until volitional exhaustion	57.8 ± 2.6
Sporis et al. [18]	Senior professionals	All	1-min incremental maximal exercise test	60.1 ± 2.3
Voutselas et al. [188]	Senior professionals	All	Protocol started with 15-min warm-up at 50% of their $\dot{V}O_{2max}$ (of previously estimated $\dot{V}O_{2max}$ tests) followed by a 3-min rest, after which the athletes started to run at approximately 60% of their $\dot{V}O_{2max}$. Intensity was increased by 0.5 km/h every 1 min until volitional exhaustion	52.3 ± 5.0
Chamari et al. [192]	Elite youth	All	Participants ran for 3 min at 9 km/h. The speed was then increased by 1 km/h every minute until exhaustion, which occurred within 10–15 min	61.1 ± 4.6

Table 5 (continued)

Study	Playing standard	Playing position/subgroup	Protocol	$\dot{V}O_{2max}$ (mL/kg/min)
Edwards et al. [36]	Senior professionals	All	A series of incremental steps, which increased in speed every 3.5 min to a maximum of 4.03 m/s. After the final 3 min stage at 4.03 m/s was completed, the incline of the treadmill was increased by 2% every minute	62.1 ± 4.9
Helgerud et al. [198]	Elite youth	All	Treadmill speed started at 11 km/h and kept there for 5 min. The speed of the treadmill was then increased by 1 km/h every minute to a level that brought the participant to exhaustion within 5–6 min (constant inclination at 5.5%)	58.2 ± 4.4
Casajús [84]	Senior professionals	All	The test began at a 3% grade and a speed of 8 km/h. The grade was held constant, and the speed increased 1 every min until exhaustion	65.5 ± 8.0
Al-Hazzaa et al. [89]	Senior professionals	All	Following a 6-min warm-up period, the athlete began running while the treadmill speed was gradually increased until a velocity of 15.5 km/h was reached, after which the treadmill velocity was kept constant and the inclination was increased by 2% every 2 min until volitional exhaustion	56.8 ± 4.8
Wisløff et al. [90]	Senior professionals	All	The speed of the treadmill was increased every minute to a level that brought the participant close to exhaustion after approximately 5 min. Inclination was constant at 3°. Immediately after $\dot{V}O_{2max}$ determination, each participant ran for 2 min at an exercise intensity of 50–60% of $\dot{V}O_{2max}$ directly followed by a supramaximal intensity run, resulting in exhaustion after ≈ 3 min	63.8 ± 4.1
Bangsbo and Lindquist [199]	Senior professionals	All	The initial treadmill speed was 18 km/h, and it was increased 2 km/h every 2 min until the participant was exhausted	60.8 ± 1.3
Chin et al. [200]	Senior professionals	All	After a 10-min warm-up at 8.0 km/h (0% grade), the participant began running at a velocity of 12.1 km/h (0% grade). Every 2 min thereafter, the grade was increased by 2.5% until volitional exhaustion	59.1 ± 4.9
Rhodes et al. [201]	Elite youth	All	After a 10-min warm-up at 8.0 km/h (0% grade), the participant began running at a velocity of 12.1 km/h (0% grade). Each minute thereafter the treadmill velocity was increased by 0.8 km/h until volitional exhaustion	58.7 ± 4.1

Data are presented as mean ± standard deviation

$\dot{V}O_{2max}$ maximum oxygen uptake

Table 6 Normative values for distance (m) during YYIR1 and YYIR2

Study	Test	Playing standard	Playing position/subgroup	Distance (m)
Akyildiz et al. [114]	YYIR1	Senior professionals	All	2083 ± 404
Schons et al. [115]	YYIR1	Senior professionals	All (men)	2271 ± 744
Arregui-Martin et al. [117]	YYIR1	Elite youth	All	2716 ± 242
Owen et al. [91]	YYIR1	Senior professionals	All	1349 ± 167
Saidi et al. [136]	YYIR1	Senior professionals	All	2520 ± 363
Clancy et al. [137]	YYIR1	Elite youth	All	2138 ± 293
Rago et al. [141]	YYIR1	Senior professionals	All	2260 ± 277
Rodríguez-Fernández et al. [92]	YYIR1	Senior professionals	Senior professionals group	2368 ± 265
		Elite youth	Elite youth group	2054 ± 289
Pareja-Blanco et al. [148]	YYIR1	Senior professionals	All	1500 ± 419
Pareja-Blanco et al. [26]	YYIR1	Senior professionals	All	1558 ± 362
Noon et al. [154]	YYIR1	Elite youth	All	3150 ± 269
Ingebrigtsen et al. [25]	YYIR1	Senior professionals	All	1736 ± 443
Manzi et al. [164]	YYIR1	Senior professionals	All	2366 ± 409
Castagna et al. [165]	YYIR1	Senior professionals	All	2390 ± 409
Chaouachi et al. [24]	YYIR1	Elite youth	All	2289 ± 409
Wong et al. [181]	YYIR1	Senior professionals	All	1525 ± 63
Rampinini et al. [15]	YYIR1	Senior professionals	All	2231 ± 294
Mujika et al. [16]	YYIR1	Senior professionals	All	2414 ± 456
		Elite youth	All	2092 ± 260
Lockie et al. [27]	YYIR2	Elite youth	All	1062 ± 371
Enright et al. [139]	YYIR2	Elite youth	All	920 ± 156
Stevens et al. [93]	YYIR2	Senior professionals	Senior professionals group	1300 ± 210
		Elite youth	Elite youth group	1147 ± 244
Iaia et al. [155]	YYIR2	Elite youth	All	958 ± 208
Wells et al. [159]	YYIR2	Senior professionals	All	893 ± 42
Ingebrigtsen et al. [25]	YYIR2	Senior professionals	All	613 ± 174
Wells et al. [173]	YYIR2	Senior professionals	All	966 ± 153
Christensen et al. [179]	YYIR2	Senior professionals	All	891 ± 131
Rampinini et al. [15]	YYIR2	Senior professionals	All	958 ± 99
Krustrup et al. [42]	YYIR2	Senior professionals	International elite group	1050
		Elite youth	Elite U19	815

Data are presented as mean ± standard deviation

YYIR1 Yo-Yo intermittent recovery test level 1, *YYIR2* Yo-Yo intermittent recovery test level 2

the identified aerobic fitness tests were field based (26 vs. nine studies), which may be attributed to their reduced cost compared to laboratory testing, the ease of administration that allows for a large number of athletes to be assessed at once, and their practical relevance [30]. More specifically, field tests of different types were identified, such as continuous straight-line running (e.g. VAMEVAL test, Mognoni test, Conconi test), shuttle (e.g. 20-m multistage fitness test), intermittent shuttle (e.g. Yo-Yo intermittent tests, 30–15 IFT), and submaximal (e.g. submaximal warm-up test). Notably, intermittent tests are characterized by greater anaerobic demands compared to continuous running tests, with significantly higher blood lactate levels and faster end-test velocities [63]. Among the identified field tests, YYIR1 and YYIR2 were the most used. It is vital to recognize that the frequency of use does not necessarily equate to the superiority of a test, and that each protocol carries inherent strengths and limitations that must be considered before selection.

YYIR1 and YYIR2 tests involve running 2 × 20-m shuttles at increased speeds controlled by audio signals, interspersed with 10 s of active recovery. Consequently, their intermittent nature may better reflect the demands of the sport. The difference between these two versions lies in their initial speed (10 km/h in YYIR1 vs. 13 km/h in YYIR2) and the speed increases, which are more conservative in YYIR1 [64]. These differences pose distinct physiological demands, with YYIR2 presenting a greater blood lactate accumulation and anaerobic contribution [15, 42]. Hence, YYIR1 and YYIR2 should not be used interchangeably. Interestingly, the YYIR1 seems to be preferred

Table 7 Normative values for MAS (km/h) during VAMEVAL, distance (m) during YYIE2, distance (m) during 20-m multistage fitness test (beep test), and final velocity (km/h) during 30–15 IFT

Study	Test	Playing standard	Playing position/subgroup	MAS (km/h)	Distance (m)	Final velocity (km/h)
Fessi et al. [144]	VAMEVAL	Senior professionals	All	17.6 ± 2.3		
Fessi et al. [152]	VAMEVAL	Senior professionals	All	17.8 ± 0.9		
Brocherie et al. [157]	VAMEVAL	Senior professionals	All	17.1 ± 1.3		
Lago-Ballesteros [169]	VAMEVAL	Senior professionals	All	19.6 ± 0.8		
Wong et al. [181]	VAMEVAL	Senior professionals	All	15.9 ± 0.2		
Bradley et al. [94]	YYIE2	Senior professionals	Premier League group		2364 ± 478	
			Championship group		2268 ± 567	
			League 1 group		2226 ± 432	
Rebelo et al. [95]	YYIE2	Elite youth	All		1394 ± 421	
Silva et al. [167]	YYIE2	Senior professionals	All		1776 ± 358	
Gibson et al. [170]	YYIE2	Elite youth	U19 group		2892 ± 484	
Silva et al. [174]	YYIE2	Senior professionals	All		1640 ± 196	
Bogdanis et al. [177]	YYIE2	Senior professionals	All		1658 ± 156	
Henderson et al. [180]	YYIE2	Senior professionals	All		2183 ± 401	
Radzimiński et al. [132]	20-m multistage fitness test (beep test)	Senior professionals	All		2561 ± 264	
Boraczyński et al. [134]	20-m multistage fitness test (beep test)	Senior professionals	All		2595 ± 257	
Pareja-Blanco et al. [26]	20-m multistage fitness test (beep test)	Senior professionals	All		1981 ± 309	
Rabbani et al. [124]	30–15 IFT	Senior professionals	First team group			19.0 ± 1.0
		Elite youth	U19 group			19.5 ± 0.7
Campos-Vazquez et al. [146]	30–15 IFT	Senior professionals	All			20.1 ± 0.8

Data are presented as mean ± standard deviation

30–15 IFT 30–15 intermittent fitness test, *MAS* maximal aerobic speed, *YYIE2* Yo-Yo intermittent endurance test level 2

in elite soccer players compared to YYIR2 (22 vs. ten studies). This preference could be attributed to its better suitability in evaluating aerobic adaptations due to the greater involvement of the aerobic system [64]. Rampinini et al. [15] demonstrated a strong correlation between YYIR1 and $\dot{V}O_{2max}$ ($r = 0.74$, $p < 0.05$) in professional soccer players, while YYIR2 showed only moderate correlations with $\dot{V}O_{2max}$ ($r = 0.47$, $p < 0.05$). However, Bangsbo et al. [64] reported a wide variability in YYIR1 performance among individuals with similar $\dot{V}O_{2max}$ values. This suggests that YYIR1 performance reflects additional physiological qualities, such as recovery ability and anaerobic contribution, which are not captured by aerobic capacity alone. Therefore, YYIR1 and YYIR2 should not be used to estimate $\dot{V}O_{2max}$, as they are not accurate measures of maximal aerobic capacity. Instead, their utility lies in assessing soccer-specific intermittent endurance, reflecting a player's ability to sustain repeated high-intensity efforts. YYIR1 has been found to significantly differentiate between professionals and amateurs (2231 ± 294 vs. 1827 ± 292, $p = 0.002$, effect size [ES] = 1.14) [15], adult and youth ($p < 0.05$, ES = 1.21) [17], as well as male and female soccer players (2414 ± 456 vs. 1224 ± 255 m, $p < 0.01$) [16]. However, the YYIR1 and YYIR2 tests have limited suitability for training prescription of high-intensity interval training (HIIT), due to their distance-focused nature. This is not in alignment with the time-defined nature of HIIT sessions, which require the athlete to maintain a certain intensity over a prescribed time interval. Additionally, although Bok and Foster [30] demonstrated a high sensitivity to change for both YYIR1 (signal-to-noise ratio [SNR] = 2.7) and YYIR2 (SNR = 2.5), these values are considerably lower compared to the 30–15 IFT (SNR = 5.1).

The 30–15 IFT, which consists of 30-s shuttle runs interspersed with 15-s passive recovery periods and an increase in velocity by 0.5 km/h at the end of each 45-s stage, was used in six studies in our review. Notably, all of these studies were conducted within the last 7 years, potentially

Table 8 Normative values for RSA_{best} (s), RSA_{mean} (s), RSA_{total} (s), and performance decrement (%) for common RSA tests

Study	Test	Playing standard	Playing position/sub-group	RSA_{best} (s)	RSA_{mean} (s)	RSA_{total} (s)	Performance decrement (%)
Dolci et al. [83]	6 × 40-m (20 + 20) shuttle sprints with 20 s passive recovery	Elite youth	All	7.13 ± 0.29	7.43 ± 0.23		3.7 ± 0.01
Saidi et al. [136]	6 × 40-m (20 + 20) shuttle sprints with 20 s passive recovery	Senior professionals	All	7.40 ± 0.40	8.07 ± 0.30		7.8 ± 4.7
Spineti et al. [153]	6 × 40-m (20 + 20) shuttle sprints with 20 s passive recovery	Elite youth	All	7.02 ± 0.17	7.48 ± 0.16		6.6 ± 2.0
Pareja-Blanco et al. [26]	6 × 40-m (20 + 20) shuttle sprints with 20 s passive recovery	Senior professionals	All	7.36 ± 0.18	7.60 ± 0.17		3.3 ± 1.5
Haddad et al. [158]	6 × 40-m (20 + 20) shuttle sprints with 20 s passive recovery	Elite youth	All	7.38 ± 0.14	7.67 ± 0.15	46.01 ± 0.91	3.9 ± 1.6
Rampinini et al. [22]	6 × 40-m (20 + 20) shuttle sprints with 20 s passive recovery	Senior professionals	All	6.86 ± 0.13	7.17 ± 0.09		4.5 ± 1.9
Impellizzeri et al. [21]	6 × 40-m (20 + 20) shuttle sprints with 20 s passive recovery	Senior professionals	All	6.88 ± 0.19	7.12 ± 0.17		3.3 ± 1.5
Rampinini et al. [187]	6 × 40-m (20 + 20) shuttle sprints with 20 s passive recovery	Senior professionals	All	7.00 ± 0.19	7.25 ± 0.17		3.3 ± 1.6
Wong et al. [75]	6 × 20-m sprints with 25 s active recovery	Senior professionals	All	2.89 ± 0.09	2.97 ± 0.11	17.79 ± 0.64	1.75 ± 0.98
		Elite youth	U19 group	2.93 ± 0.09	2.99 ± 0.10	17.91 ± 0.58	2.51 ± 1.17
Owen et al. [171]	6 × 20-m sprints with 25 s active recovery	Senior professionals	All	3.08 ± 0.11		18.96 ± 0.68	2.43 ± 1.42
Wong et al. [23]	6 × 20-m sprints with 25 s active recovery	Senior professionals	All	3.14 ± 0.09	3.22 ± 0.08	19.31 ± 0.47	2.59 ± 1.02
Enright et al. [139]	7 × 30-m sprints with 25 s active recovery	Elite youth	All	4.33 ± 0.19	4.58 ± 0.15		10.6 ± 4.3
Chaouachi et al. [24]	7 × 30-m sprints with 25 s active recovery	Elite youth	All			31.21 ± 1.13	4.0 ± 1.1

Data are presented as mean ± standard deviation

RSA repeated sprint ability, RSA_{best} best sprint time, RSA_{mean} mean sprint time, RSA_{total} total sprint time

highlighting an emerging trend. In line with this, a recent survey of the current fitness testing practices of practitioners working in applied elite soccer settings showed that the 30–15 IFT was the most commonly used aerobic test [45]. The final velocity in km/h represents the main outcome variable, which reflects a combination of aerobic and anaerobic capacities, COD ability, and the inter-effort recovery ability, making it more appropriate for the prescription of short HIIT formats [65]. Other commonly used field tests employed in elite soccer included the YYIE2 (eight studies), the VAMEVAL test (eight studies), and the 20-m multistage fitness test (six studies). The VAMEVAL test has been reported to possess high criterion-related validity, with a correlation coefficient of $r = 0.96$ and a standard error of estimate of 2.8 mL/kg/min, rendering it a suitable field test for the evaluation of $\dot{V}O_{2max}$ [30]. In addition, its continuous nature supports its use in the prescription of long format HIIT sessions, with the MAS representing the most frequently used outcome variable in systematic reviews. Similarly, the 20-m multistage fitness test exhibits criterion-related validity with a correlation coefficient of $r = 0.85$–0.91 and a standard error of estimate ranging from 3.5 to 5.9 mL/kg/min, depending on the population tested. While it is less precise than the VAMEVAL in $\dot{V}O_{2max}$ estimation, its criterion-related validity is higher than the YYIR1, YYIR2, and 30–15 IFT for estimating $\dot{V}O_{2max}$ in certain populations [30]. It should be noted though that many of these findings are largely dependent on the population assessed. However, we failed to find any studies examining criterion-related validity in elite soccer players.

The demanding training schedules and the fixture congestion encountered during the in-season phase in elite soccer environments pose significant challenges in the administration of aerobic fitness testing due to their fatiguing nature. Consequently, submaximal fitness tests have emerged as practical solutions, possibly owing to their short duration, non-disruptive and non-fatiguing nature [37]. This systematic review identified ten submaximal protocols, six of which were field based. Of particular advantage is that submaximal field protocols can be integrated into the training session as part of the warm-up, allowing a more frequent assessment of an individual's training status. The submaximal YYIR1 [66], the submaximal YYIE2 [67], and the submaximal warm-up test [68] are viable short-duration (< 6 min) options, with the use of HR during exercise (HR_{ex}) representing a reliable outcome variable (ICC 0.95–0.96, CV 1.4–1.6%). In addition, the HR_{ex} and the HR 1 min post-test from the submaximal warm-up test demonstrated significant large inverse relationships with the final velocity achieved in the 30–15 IFT (i.e. $r = -0.50$ and $r = -0.76$, respectively) [68].

Selecting the appropriate test is essential for accurate assessment and effective training prescription. To measure maximal aerobic capacity, laboratory testing remains the most accurate method. However, among field tests, the VAMEVAL is preferable due to the stronger criterion-related validity for $\dot{V}O_{2max}$ compared to other options. While $\dot{V}O_{2max}$ is a widely used measure, it represents only a limited aspect of a player's working capacity and is less relevant to sports with predominant intermittent demands like soccer. If the goal is to assess a player's ability to perform repeated high-intensity efforts with brief recoveries, the Yo-Yo intermittent recovery (IRTs) and the 30–15 IFT represent the most suitable options. However, due to its enhanced prescriptive capabilities, the 30–15 IFT seems to be the most appropriate choice for evaluating soccer-specific endurance [69]. Ultimately, submaximal fitness testing allows for the ongoing evaluation of fitness and fatigue, facilitating informed adjustments to training loads as required.

4.1.2 RSA Assessment

The results of this systematic review revealed that RSA is being assessed to a considerably smaller extent than aerobic fitness in elite soccer. Logistical constraints, such as the time-consuming nature of RSA testing and the need for multiple staff members to ensure the adherence to the testing protocols, may limit its potential inclusion into a testing battery [12]. In particular, a wide variety of RSA tests were employed, including varying modes of exercise (overground sprinting vs. cycling), directions (linear vs. multidirectional), distances (20–40 m), repetitions (6–15), types of recovery (active vs. passive), and recovery durations (10–30 s), reflecting the complexity in RSA testing and the lack of a gold-standard testing protocol in elite soccer.

Linear RSA and RSA with CODs have been found to represent two separate attributes, as the shared variance between them is < 50% [23]. Although it could be assumed that the inclusion of CODs in RSA testing is of high relevance in sports where a vast number of directional changes occur, such as soccer [70, 71], linear RSA tests were the most frequently used modality. More specifically, 11 tests investigated linear RSA testing, whereas six tests assessed RSA involving at least one COD. Notably, the neuromuscular and metabolic systems are taxed in different ways, as the physiological load has been found to be higher in the presence of CODs in RSA testing due to higher accumulation of blood lactate [72]. In addition, the number and the angle of CODs can have a significant impact on the imposed neuromuscular load, with higher demands placed during sharper COD angles [73]. Consequently, the selection of an RSA test requires careful consideration of these aforementioned factors. In the context of the distinct demands of linear RSA and RSA with CODs, the RSA/repeated change of direction (RCOD) index, defined as the time of linear RSA divided by the time of RSA with CODs, was identified in this systematic review as a measure aiming to inform training focus in terms of linear RSA or RSA with CODs [23, 74, 75]. However, the practical application of the RSA/RCOD index may be limited due to the need to perform two different RSA tests, which is time consuming and potentially difficult to implement consistently in practice. In addition, the inherent limitations associated with its ratio-based nature may complicate its interpretation and reliability [76].

The recovery duration lasted between 10 and 30 s in the identified studies, with active recovery, mostly in the form of low-intensity jogging, being the type of recovery used in the majority of tests. The predominant use of active recovery may be attributed to its relevance to the soccer demands, where high-intensity bouts are interspersed with low-intensity activity [7, 39]. Active recovery has been shown to improve the rate of waste removal, due to enhanced blood flow, which can promote the buffering of hydrogen ions and the restoration of pH levels [77–79].

In terms of sprinting distances, the most used distances were 20 m, used by six tests, and 30 m, used by four tests, which may reflect the actual match-play sprint requirements, as it has been observed that the vast majority of sprint bouts during a soccer game are shorter than 30 m [7]. Although sprint repetitions ranged from 6 to 15, six repetitions were the most frequently used, identified in six different testing protocols. In instances where the total work is identical, the number of repetitions and sprint distances can influence the elicited physiological responses, as has been previously shown [60]. In particular, the ability to eliminate the decline in repeated sprint performance is more dependent on aerobic metabolism in a protocol with a higher number of repetitions and shorter distances (e.g. 12 × 20 m) compared to a protocol where a lower number of repetitions and longer distances are employed (e.g. 6 × 40 m).

The 6 × 40-m (20 + 20 m, 180° COD) shuttle sprint protocol with 20 s passive recovery was identified as the most commonly used RSA test in this systematic review, used in eight studies. RSA_{best}, RSA_{mean}, and performance decrement were the most frequently used outcome variables in this test. Despite its popularity, the use of passive recovery in this test may limit its ecological validity, given that low-intensity activities are performed during recovery periods in soccer matches [7]. Furthermore, the longer duration of each repetition, which is approximately 7 s, may introduce a greater reliance on anaerobic glycolysis, as opposed to the shorter duration sprint, where the energy requirements are being met by the phosphocreatine (PCr) system [20]. When considering all RSA test measures identified in this review, performance decrement (%), which is the ratio of RSA_{mean} to RSA_{best}, was used in 14 tests (22 studies, 81%), RSA_{total} in 14 tests (14 studies, 52%), RSA_{best} in 13 tests (21 studies, 78%), and RSA_{mean} in ten tests (18 studies, 67%), and these represent the most frequent outcome variables used in RSA testing in elite soccer. Nevertheless, concerns about the reliability of performance decrement, which is an indicator of an individual's ability to sustain sprint performance over successive sprints, have been previously reported in the literature [29, 41], and were in line with the results of the only study providing between-day reliability values on this measure in an elite soccer sample (ICC 0.17[90% CI: − 0.18 to 0.49], CV 30.2 [90% CI: 23.6–42.7]) [21].

It has been suggested that RSA testing protocols should align with the specific demands of soccer to enhance ecological validity [80, 81]. Recommendations from a recent systematic review [38] suggest that optimal RSA protocols should consist of seven sprints (to limit pacing strategies), involve distances of 30 m to engage top-speed ability, and incorporate active recovery periods that enable the achievement of work-to-rest ratios of 1:4 to 1:5, to effectively challenge the anaerobic energy system without complete PCr recovery between sprints. Based on these guidelines, the majority of the identified tests do not seem to align with these recommendations. The 7 × 30-m sprints with 25 s active recovery and the 7 × 30-m sprint completed on 20-s cycles represent the exception to this, which may suggest a more ecologically valid assessment. The introduction of a 180° turn in these protocols could further enhance their ecological validity by better replicating the demands of soccer.

In summary, RSA assessment seems to require a comprehensive understanding of the physiological responses elicited by different testing protocols. Selection of sprint distances, repetitions, the inclusion of CODs, their angle and number, and the type of recovery are all critical factors that should be considered due to their distinct neuromuscular and physiological requirements.

4.2 Normative Values for Aerobic Fitness and RSA Tests

To our knowledge, this is the first systematic review collecting the normative values of common aerobic fitness and RSA tests in elite soccer players. In this way, in-depth insights into the aerobic fitness and RSA levels of high-performing soccer players can be acquired, enabling individual and group comparisons to be made, and measurable and realistic performance targets to be set. Furthermore, an understanding of the physical standards of elite performers can be valuable to the practitioners working with developmental soccer players, as it can lay the foundation for a structured long-term athletic development plan [82]. For a thorough investigation of the values reported from each study on $\dot{V}O_{2max}$ from incremental treadmill testing, YYIR1 and YYIR2, VAMEVAL, YYIE2, 20-m multistage fitness test (beep test), 30–15 IFT, and the three most common RSA tests, readers are referred to Tables 5, 6, 7, and 8.

In terms of $\dot{V}O_{2max}$, senior professionals (58.3 mL/kg/min) displayed a nearly identical median value to elite youth soccer players (57.5 mL/kg/min). However, caution should be exercised concerning these findings due to a smaller number of studies in elite youth populations. Unfortunately, none of the studies performed a direct comparison between these two groups within the same setting under similar testing conditions, which would have enhanced the comparability of the results. Signorelli et al. [59] compared younger (17–22 years old) and older (27–36 years old) Brazilian first division senior professionals, finding no significant differences between the two different groups (older group 63.2 ± 6.2 vs. younger group 62.7 ± 6.1). This could suggest that the high aerobic capacity is largely established early in a player's professional career and remains stable with minimal improvement over time. The highest value identified in the elite youth group was 63.5 mL/kg/min, recorded in an Australian sample [83], whereas the highest value among senior professionals was 65.5 mL/kg/min, found in Spanish first division players [84]. In addition, eight studies in this review provided position-specific $\dot{V}O_{2max}$ data [18, 62, 85–90]. Midfielders demonstrated the highest $\dot{V}O_{2max}$ values, with a median of 59.7 mL/kg/min, which is indicative of the high aerobic levels required of midfield players in elite soccer. In contrast, defenders demonstrated the lowest $\dot{V}O_{2max}$ levels, with a median of 56.4 mL/kg/min. Four studies further differentiated between centre-backs and full-backs, revealing median $\dot{V}O_{2max}$ values of 54.8 mL/kg/min for centre-backs and 56.6 mL/kg/min for full-backs. Forwards exhibited a comparable median value of 56.8 mL/kg/min.

These differences highlight the distinct aerobic demands of each position, which should be considered in programme design and the talent identification process.

In the YYIR1 test, senior professionals demonstrated a median distance of 2245 m (range 1348–2520) across 14 studies, which is similar to the elite youth group's median distance of 2213 m (range 2054–3150), derived from six studies. Interestingly, the study reporting the lowest YYIR1 distance (1349 m) was from a high-level soccer club, where 80% of the players were representing their respective national teams [91]. This counterintuitive finding may be attributed to accumulated fatigue, as top-level players often participate in multiple competitions simultaneously, resulting in limited recovery times between matches. To facilitate a more accurate comparison between senior professionals and elite youth players while minimizing the influence of confounding variables (e.g. environmental conditions, differences in testing order, and timing of the day or season), we identified two studies that directly compared these groups. Both studies demonstrated a superior performance in senior professionals (2368 ± 265 m vs. 2054 ± 289 m [92] and 2414 ± 456 m vs. 2092 ± 260 m, $p < 0.05$ [16]). Similarly, the results for the YYIR2 distance were identical across the studies, for both senior professionals (median 958 m, range 613–1330) and the elite youth group (median 958 m, range 815–1147). However, when individual studies directly compared these two groups, a higher performance of senior professionals was observed, as shown by both Stevens et al. [93] (1300 ± 210 m vs. 1147 ± 244 m, ES = 0.67) and Krustrup et al. [42] (1050 vs. 815 m, $p < 0.05$). These findings suggest that although elite youth players exhibit high levels of aerobic ability, senior professionals have a greater high-intensity intermittent endurance ability, possibly due to increased number of years of exposure to high-intensity training and match-play. For the YYIE2 test, Bradley et al. [94] reported small, non-significant differences between Premier League (2364 ± 478 m), Championship (2268 ± 567 m), and League 1 senior players (2226 ± 432 m), suggesting comparable aerobic fitness levels across professional tiers. Elite youth players, on the other hand, outperformed non-elite counterparts across all playing positions in terms of YYIE2 distance, with effect sizes ranging from moderate to large (0.6–1.5) [95]. Finally, the single study comparing senior professionals and elite youth in the 30–15 IFT found slightly higher final velocities for elite youth players (19.5 ± 0.7 vs. 19.0 ± 1.0 km/h, ES = 0.39).

In terms of the 6 × 40-m (20 + 20 m) shuttle sprint protocol with 20 s passive recovery test, senior professionals outperformed elite youth soccer players, with a lower median value in terms of RSA_{best} (7.00 vs. 7.13 s) and RSA_{mean} (7.25 vs. 7.48 s). One study provided position-specific data, illustrating that full-backs displayed the best RSA performance (RSA_{best} 6.83 s; RSA_{mean} 7.18 s), whereas defenders had the worst (RSA_{best} 7.01 s; RSA_{mean} 7.40 s) [21]. This finding reflects the unique physical demands of the full-back position, owing their role in both offensive (e.g. overlapping runs) and defensive (e.g. recovery runs) situations within the match-play. Practitioners should consider these position-specific differences when designing RSA development training interventions.

Despite the practical utility of these normative values to drive evidence-informed training processes, certain limitations should be acknowledged in their interpretation and implementation. While aggregate data provide a broad overview, this approach may fail to capture nuanced methodological differences across studies. Consequently, variability in testing protocols and conditions may influence the comparability of the results and limit the generalization of these findings. For instance, the unequal number of studies in each group (e.g. 14 studies for senior professionals versus six studies for elite youth in YYIR1 test) may lead to a bias in the representativeness of the results and misleading conclusions. Factors such as different running surfaces [96], starting methods, distances behind the start line [97], and measurement equipment [98] have been shown to introduce substantial variability in the final outcome of a sprint test. These elements can have a major influence on the outcome measures derived from an RSA test, and as such, consideration of them is necessary. Similarly for $\dot{V}O_{2max}$, the values reported by each study should be interpreted, and subsequently used, with caution, due to the variability in the employed protocols. Factors such as stage length, speed increments, percentage of inclination, and total duration can have significant implications on the final $\dot{V}O_{2max}$ value [55]. More specifically, Astorino et al. [99] demonstrated that incremental treadmill protocols lasting approximately 7–10 min can optimize $\dot{V}O_{2max}$ compared to longer protocols (> 13 min), which elicited a lower $\dot{V}O_{2max}$ value. These factors highlight the need for universally standardized testing procedures to enhance the reliability and applicability of normative data. Until then, we recommend that practitioners exercise caution when comparing their results to different studies and ensure that any comparisons are made in context, by taking into account the specific testing conditions used.

4.3 Reliability Data

The testing selection process should be influenced by the reliability or repeatability of a test [43, 100], as well as its sensitivity to detect small but important changes in performance [101]. Reliability represents a fundamental concept in the overall testing process, especially in high-performance sport where a limited amount of training adaptation is expected to occur [54]. A test with high variability fails to accurately represent an individual's true performance, compromising the confidence in the precision of the results. It is important that the reliability levels of a test and its relevant outcome variables are determined within the specific cohort of interest, due to differences in the skill levels and training status of different populations [102, 103]. This systematic review found that a limited number of studies reported reliability data for aerobic fitness ($n=11$) and RSA tests ($n=5$), highlighting a gap in the literature, which may be attributable to the challenges associated with conducting test–retest procedures in elite environments.

The CV, representing the within-subject variation by dividing the standard deviation by the mean, was the most reported reliability metric for both aerobic fitness and RSA testing. A CV value of less than 10% is widely acknowledged as acceptable, yet this threshold may be arbitrary [104], as 'highly' variable outcome measures may be sensitive to change [105]. Consequently, a good understanding of the context at hand is required. The CV appears to be of great practical relevance to practice, as it can be used for the interpretation of performance changes [43]. In addition, the ICC represented the second most reported reliability metric for both physical qualities. The ICC refers to the between-subject variation (i.e. whether an individual maintains their ranking across repeated trials), and as such, is affected by group homogeneity. An ICC value of ≥ 0.75 is considered as 'good', whereas an ICC ≥ 0.90 is considered as 'excellent' [106]. Based on the generally accepted ICC and CV values, all the aerobic tests and outcome variables show good to excellent reliability, except the heart recovery at 30 s (ICC 0.58 [95% CI: 0.51–0.90], CV 19.5%) and 60 s (ICC 0.68 [95% CI: 0.56–0.93], CV 12.2%) after the completion of the submaximal YYIR1 [66]. The same was true for RSA tests, except for performance decrement in the 6 × 40-m (20 + 20 m) shuttle sprints with 25 s passive recovery (ICC 0.17 [90% CI: − 0.18 to 0.49], CV 30.2%) [21].

For aerobic testing, the 1000-m time trial demonstrated high reliability, with a low CV of 1.6% and an SEM of 2.86 s, making it a suitable tool for estimating MAS and prescribing aerobic conditioning intervals. In contrast, the YYIR2 test, while within acceptable CV range (4.2–9.6%) displayed higher variability compared to the 1000-m time trial and showed values similar to the YYIE2 (CV 3.9%). Despite the popularity of YYIR1 for assessing elite soccer players, we were unable to find a single study reporting reliability for the distance covered. Consequently, future research should focus on investigating the YYIR1 distance in elite soccer samples. Additionally, the Iintermittent endurance running (INTER) test, designed to replicate soccer-specific match demands by including shuttle runs, agility sprints, and straight-line sprints, demonstrated high reliability levels for both exercise tolerance time (ICC 0.75, CV 2.5%) and distance covered (ICC 0.79, CV 2.6%). For submaximal aerobic tests, the use of HR_{ex} seems to be well-justified for monitoring physiological adaptations in elite soccer players, considering the excellent reliability levels (ICC 0.95–0.96, CV 1.4–1.6%). On the other hand, the high variability of heart rate recovery (HRR) (ICC 0.58–0.93, CV 3.9–19.5%) may limit its usability as a reliable fitness indicator. When assessing RSA, practitioners are encouraged to prioritize metrics such as the RSA_{total} and RSA_{mean} over performance decrement measures, given the lack of accuracy and consistency of the latter.

Overall, it seems that a greater awareness needs to be adopted on the concept of reliability. A description of the procedures generating the reliability data is generally lacking, especially in relation to the between-day context (i.e. number of participants, days between the two assessments, etc.). It should be acknowledged that the test–retest process on different days (typically 3–7 days apart) captures the day-to-day fluctuations in an athlete's performance due to normal biological variation, which is paramount to accurately identifying true performance changes. In contexts requiring high precision, such as elite sports, stricter reliability benchmarks (e.g. CV ≤ 5%, ICC ≥ 0.90) may be more appropriate. However, there is currently no consensus on these stricter thresholds, and further research is needed to establish standardized guidelines. In addition, complementary tools such as Bland–Altman plots and analysis of variance (ANOVA) can provide information on the agreement and differences between trials that are not captured by ICC and CV, thus offering a more thorough understanding of a test's reliability. However, it is crucial to understand that the reliability determines the 'noise' of an outcome variable, and additional information on the typical variation over time ('signal') must be considered to draw meaningful conclusions on the utility of a test and its associated outcome variables. Ultimately, practitioners are recommended to establish their context-specific reliability measures, since the characteristics of each setting and athlete sample are distinct.

4.4 Limitations and Directions for Future Research

Although this systematic review provided a comprehensive picture of aerobic fitness and RSA testing in elite soccer, certain limitations should be acknowledged. Firstly, it should be emphasized that the frequency of use of a fitness test in the literature should not be mistaken as an indicator of its effectiveness and its superiority. In addition, the terms 'elite' and 'professional' are often used interchangeably across the literature, leading to ambiguity and inconsistencies in participant classification. However, it is likely that these terms are used differently in different geographical regions and leagues. For example, the criteria for 'elite' performance in a top-tier European league may vary significantly from those in a smaller or developing soccer nation.

This can be considered both as a limitation and a reflection of the existing soccer literature, highlighting the need for standardized terminology moving forward. While the Participant Classification Framework by McKay et al. [47] provides a solid foundation for categorizing athletes, it does not fully address the nuanced factors associated with soccer. Consequently, a soccer-specific classification system is needed to reflect the specifics of the sport's hierarchical leagues structures, youth development pathways, and varying levels of professionalism across different regions. The variability in testing conditions, such as the different incremental test protocols with varying speeds and durations, as well as the different running surfaces in field-based testing, including natural and artificial turf, is an additional challenge in the establishment of universal normative standards, complicating the direct comparison of results across studies and limiting the generalizability of the findings. Lastly, due to the heterogeneity of testing methods identified in the present literature review, it was not possible to carry out a meta-analysis.

Areas requiring further investigation were identified in this systematic review. The development of a standardized process for assessing aerobic fitness and RSA would help to establish robust normative values and facilitate meaningful comparisons between different contexts. This standardization should not be limited to test selection and administration, but also include guidelines on data analysis, interpretation, and visualization to enhance overall consistency. In addition, the value of RSA testing has been questioned, due to the rare occurrences of repeated sprint sequences in a soccer match [107, 108]. As such, specific protocols evaluating repeated acceleration ability should be developed. Furthermore, greater emphasis on the concept of reliability is recommended, and a shift towards its consideration as an integral part of the reporting of results. Reliability studies using some of the most frequently identified tests such as YYIR1, 30–15 IFT, and 20-m multistage fitness test in elite soccer players should be performed. Longitudinal research should also aim to determine the sensitivity of these tests and their outcome variables. Combined with reliability data from the same athlete cohort, the signal-to-noise ratio can be quantified to provide an accurate evaluation of diagnostic ability and practical utility of each test. Such an approach will optimize the use of resources (e.g. time, staff, financial), reduce unnecessary testing, and produce quality data to inform decision making. Ultimately, this will support the establishment of fitness assessments tailored to the specific needs of elite soccer players.

5 Conclusion

The current systematic review provides a comprehensive overview of all tests and outcome variables used in elite male soccer to assess aerobic fitness and RSA (as shown in the infographic in Fig. 2), offering a valuable resource for researchers and practitioners. It should be noted that the frequency of use in the literature does not imply the superiority or effectiveness of these tests. The identification of 35 different aerobic fitness tests and 18 RSA tests illustrates the diverse methodologies employed in both research and practice, potentially influenced by differing testing philosophies, equipment accessibility, and logistical constraints. Field-based tests are predominantly utilized due to their practicality, cost-efficiency, and ability to assess multiple athletes simultaneously. The determination of a player's $\dot{V}O_{2max}$ using incremental treadmill testing represents the main choice for aerobic fitness testing, although significant variability across protocols was observed. A value of 58 mL/kg/min represents the median across studies, with only minimal differences between senior professionals and elite youth soccer players. Midfielders exhibited the highest $\dot{V}O_{2max}$ values (59.7 mL/kg/min), while centre-backs presented the lowest (54.8 mL/kg/min). These normative values can serve as preliminary benchmarks for fitness evaluation and talent identification, yet caution is warranted due to methodological inconsistencies. YYIR1 and YYIR2 were also frequently used, potentially due to their historical precedence as the first field test enabling the assessment of soccer-specific intermittent endurance. Despite their widespread use, practitioners should acknowledge the limitations of these tests. An emerging trend towards the use of the 30–15 IFT and submaximal protocols has been identified, possibly due to the enhanced prescriptive ability and specificity of the former, and the minimal invasiveness of the latter, enabling its regular in-season use in elite applied soccer environments. For RSA assessment, the identified tests varied in terms of modes direction (linear vs. multidirectional), distances (20–40 m), repetitions (6–15), types of recovery (active vs. passive), and recovery durations (10–30 s). The 6 × 40-m (20 + 20 m, 180° COD) shuttle sprints with 20 s passive recovery test was the most commonly used RSA test, with performance decrement, RSA_{total}, and RSA_{mean} being the main outcome variables used. Due to its low reliability, practitioners should avoid using the performance decrement. Additionally, the vast majority of the identified RSA tests failed to replicate the match-specific demands or to sufficiently challenge the relevant physiological systems, highlighting a gap between current testing practices and actual match-play requirements. Future research should

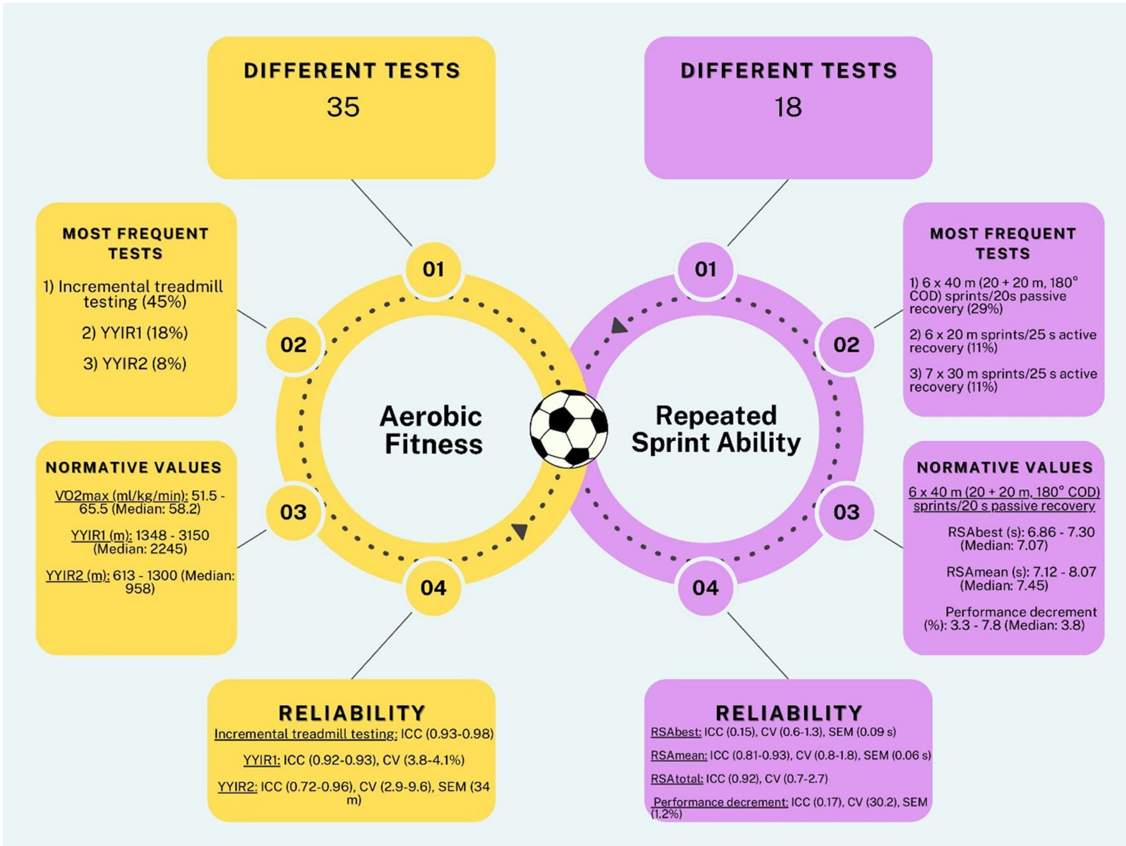

Fig. 2 Aerobic fitness and RSA testing in elite male soccer. *COD* change of direction, *CV* coefficient of variation, *ICC* intraclass correlation coefficient, *RSA* repeated sprint ability, RSA_{best} best sprint time, RSA_{mean} mean sprint time, RSA_{total} total sprint time, *SEM* standard error of measurement, $\dot{V}O_{2max}$ maximum oxygen uptake, *YYIR1* Yo-Yo intermittent recovery test level 1, *YYIR2* Yo-Yo intermittent recovery test level 2

prioritize determining the reliability and sensitivity (i.e. SNR) of the most common tests in elite soccer cohorts. Combined with their validity, this will enable a robust critical evaluation of these protocols, bridging the gaps between current practices and optimal fitness assessment.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s40279-025-02188-4.

Declarations

Funding At no point was funding received by any of the authors for the writing of this article.

Conflict of Interest Nikolaos D. Asimakidis, Chris Bishop, Marco Beato, and Anthony N. Turner declare they have no conflicts of interest relevant to the content of this review.

Ethics Approval Not applicable.

Consent to Participate Not applicable.

Authors' Contributions NA, CB, and AT conceived the idea for this review. All authors contributed to the establishment of the search criteria and the refinement of final methodology. NA, CB, and AT conducted the literature search. All authors collectively interpreted the results of the systematic review. NA wrote the first draft of the manuscript. CB, MB, and AT revised the manuscript. All authors read and approved the final version.

Data Availability Statement The dataset generated and analysed during the current study are available from the corresponding author on reasonable request.

References

1. Allen T, Taberner M, Zhilkin M, Rhodes D. Running more than before? The evolution of running load demands in the English Premier League. Int J Sports Sci Coach. 2023;19:174795412311645.
2. Bradley PS. 'Setting the Benchmark' part 1: the contextualised physical demands of positional roles in the FIFA World Cup Qatar 2022. Biol Sport. 2024;41:261–70.
3. Zhang W, Gong B, Tao R, Zhou F, Ruano MÁG, Zhou C. The influence of tactical formation on physical and technical performance across playing positions in the Chinese super league. Sci Rep. 2024;14:2538.
4. Bradley PS, Sheldon W, Wooster B, Olsen P, Boanas P, Krustrup P. High-intensity running in English FA Premier League soccer matches. J Sports Sci. 2009;27:159–68.
5. Bangsbo J, Mohr M, Krustrup P. Physical and metabolic demands of training and match-play in the elite football player. J Sports Sci. 2006;24:665–74.
6. Bangsbo J, Iaia FM, Krustrup P. Metabolic response and fatigue in soccer. Int J Sports Physiol Perform. 2007;2:111–27.
7. Stølen T, Chamari K, Castagna C, Wisløff U. Physiology of soccer: an update. Sports Med. 2005;35:501–36.
8. Carling C, Le Gall F, Dupont G. Analysis of repeated high-intensity running performance in professional soccer. J Sports Sci. 2012;30:325–36.
9. Di Mascio M, Bradley PS. Evaluation of the most intense high-intensity running period in English FA Premier League Soccer matches. J Strength Cond Res. 2013;27:909–15.
10. Vigne G, Gaudino C, Rogowski I, Alloatti G, Hautier C. Activity profile in elite Italian soccer team. Int J Sports Med. 2010;31:304–10.
11. Russell M, Sparkes W, Northeast J, Cook CJ, Love TD, Bracken RM, et al. Changes in acceleration and deceleration capacity throughout professional soccer match-play. J Strength Cond Res. 2016;30:2839–44.
12. Turner AN, Stewart PF. Repeat sprint ability. Strength Cond J. 2013;35:37–41.
13. Malone S, Owen A, Mendes B, Hughes B, Collins K, Gabbett TJ. High-speed running and sprinting as an injury risk factor in soccer: can well-developed physical qualities reduce the risk? J Sci Med Sport. 2018;21:257–62.
14. Rampinini E, Impellizzeri FM, Castagna C, Azzalin A, Bravo DF, Wisløff U. Effect of match-related fatigue on short-passing ability in young soccer players. Med Sci Sports Exerc. 2008;40:934–42.
15. Rampinini E, Sassi A, Azzalin A, Castagna C, Menaspà P, Carlomagno D, et al. Physiological determinants of Yo-Yo intermittent recovery tests in male soccer players. Eur J Appl Physiol. 2010;108:401–9.
16. Mujika I, Santisteban J, Impellizzeri FM, Castagna C. Fitness determinants of success in men's and women's football. J Sports Sci. 2009;27:107–14.
17. Kobal R, Loturco I, Gil S, Cal Abad CC, Cuniyochi R, Barroso R, et al. Comparison of physical performance among Brazilian elite soccer players of different age-categories. J Sports Med Phys Fitness. 2016;56:376–82.
18. Sporis G, Jukic I, Ostojic SM, Milanovic D. Fitness profiling in soccer: physical and physiologic characteristics of elite players. J Strength Cond Res. 2009;23:1947–53.
19. Tønnessen E, Hem E, Leirstein S, Haugen T, Seiler S. Maximal aerobic power characteristics of male professional soccer players, 1989–2012. Int J Sports Physiol Perform. 2013;8:323–9.
20. Girard O, Mendez-Villanueva A, Bishop D. Repeated-sprint ability—part I: factors contributing to fatigue. Sports Med. 2011;41:673–94.
21. Impellizzeri F, Rampinini E, Castagna C, Bishop D, Ferrari Bravo D, Tibaudi A, et al. Validity of a repeated-sprint test for football. Int J Sports Med. 2008;29:899–905.
22. Rampinini E, Sassi A, Morelli A, Mazzoni S, Fanchini M, Coutts AJ. Repeated-sprint ability in professional and amateur soccer players. Appl Physiol Nutr Metab. 2009;34:1048–54.
23. Wong DP, Chan GS, Smith AW. Repeated-sprint and change-of-direction abilities in physically active individuals and soccer players: training and testing implications. J Strength Cond Res. 2012;26:2324–30.
24. Chaouachi A, Manzi V, Wong DP, Chaalali A, Laurencelle L, Chamari K, et al. Intermittent endurance and repeated sprint ability in soccer players. J Strength Cond Res. 2010;24:2663–9.
25. Ingebrigtsen J, Brochmann M, Castagna C, Bradley PS, Ade J, Krustrup P, et al. Relationships between field performance tests in high-level soccer players. J Strength Cond Res. 2014;28:942–9.
26. Pareja-Blanco F, Suarez-Arrones L, Rodríguez-Rosell D, López-Segovia M, Jiménez-Reyes P, Bachero-Mena B, et al. Evolution of determinant factors of repeated sprint ability. J Hum Kinet. 2016;54:115–26.
27. Lockie RG, Moreno MR, Orjalo AJ, Stage AA, Liu TM, Birmingham-Babauta SA, et al. Repeated-sprint ability in division I collegiate male soccer players: positional differences and relationships with performance tests. J Strength Cond Res. 2019;33:1362–70.
28. Ulupınar S, Özbay S, Gençoğlu C, Hazır T. Low-to-moderate correlations between repeated sprint ability and aerobic capacity: a systematic review and meta-analysis. Strength Cond J. 2023;45:462–74.
29. Altmann S, Ringhof S, Neumann R, Woll A, Rumpf MC. Validity and reliability of speed tests used in soccer: a systematic review. Mirkov D, editor. PLoS ONE. 2019;14: e0220982.
30. Bok D, Foster C. Applicability of field aerobic fitness tests in soccer: which one to choose? JFMK. 2021;6:69.
31. Turner A, Walker S, Stembridge M, Coneyworth P, Reed G, Birdsey L, et al. A testing battery for the assessment of fitness in soccer players. Strength Cond J. 2011;33:29–39.
32. Weakley J, Black G, McLaren S, Scantlebury S, Suchomel TJ, McMahon E, et al. Testing and profiling athletes: recommendations for test selection, implementation, and maximizing information. Strength Cond J [Internet]. 2023. https://doi.org/10.1519/SSC.0000000000000784.
33. DiMenna FJ, Jones AM. Aerobic performance assessment. Performance Assessment in Strength and Conditioning. London and New York: Routledge; 2019. p. 212–39.
34. Ziogas GG, Patras KN, Stergiou N, Georgoulis AD. Velocity at lactate threshold and running economy must also be considered along with maximal oxygen uptake when testing elite soccer players during preseason. J Strength Cond Res. 2011;25:414–9.
35. Dolci F, Hart NH, Kilding A, Chivers P, Piggott B, Spiteri T. Movement economy in soccer: current data and limitations. Sports. 2018;6:124.
36. Edwards AM, Clark N, Macfadyen AM. Lactate and ventilatory thresholds reflect the training status of professional soccer players where maximum aerobic power is unchanged. J Sports Sci Med. 2003;2:23–9.
37. Shushan T, McLaren SJ, Buchheit M, Scott TJ, Barrett S, Lovell R. Submaximal fitness tests in team sports: a theoretical framework for evaluating physiological state. Sports Med. 2022;52:2605–26.

38. Kyles A, Oliver JL, Cahill MJ, Lloyd RS, Pedley J. Linear and Change of Direction Repeated Sprint Ability Tests: A Systematic Review. J Strength Cond Res. 2023;37:1703–17.
39. Dolci F, Hart NH, Kilding AE, Chivers P, Piggott B, Spiteri T. Physical and energetic demand of soccer: a brief review. Strength Cond J. 2020;42:70–7.
40. Datson N, Drust B, Weston M, Jarman IH, Lisboa PJ, Gregson W. Match physical performance of elite female soccer players during international competition. J Strength Cond Res. 2017;31:2379–87.
41. Lopes-Silva JP, Ferreira Da Silva Santos J, Abbiss CR, Franchini E. Measurement properties and feasibility of repeated sprint ability test: a systematic review. Strength Cond J. 2019;41:41–61.
42. Krustrup P, Mohr M, Nybo L, Majgaard Jensen J, Jung Nielsen J, Bangsbo J. The Yo-Yo IR2 test: physiological response, reliability, and application to elite soccer. Med Sci Sports Exerc. 2006;38:1666–73.
43. Hopkins WG. Measures of reliability in sports medicine and science. Sports Med. 2000;30:1–15.
44. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, The PRISMA, et al. statement: an updated guideline for reporting systematic reviews. BMJ. 2020;2021: n71.
45. Asimakidis ND, Bishop CJ, Beato M, Mukandi IN, Kelly AL, Weldon A, et al. A survey into the current fitness testing practices of elite male soccer practitioners: from assessment to communicating results. Front Physiol. 2024;15:1376047.
46. Oliver JL, Harrison CB. Aerobic and anaerobic training for young athletes. Strength and Conditioning for Young Athletes: Science and Application. 2nd ed. New York and London: Routledge; 2020. p. 248–64.
47. McKay AKA, Stellingwerff T, Smith ES, Martin DT, Mujika I, Goosey-Tolfrey VL, et al. Defining training and performance caliber: a participant classification framework. Int J Sports Physiol Perform. 2022;17:317–31.
48. Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. J Epidemiol Community Health. 1998;52:377–84.
49. Owen C, Till K, Weakley J, Jones B. Testing methods and physical qualities of male age grade rugby union players: a systematic review. Cortis C, editor. PLoS ONE. 2020;15: e0233796.
50. Morrison M, Martin DT, Talpey S, Scanlan AT, Delaney J, Halson SL, et al. A systematic review on fitness testing in adult male basketball players: tests adopted, characteristics reported and recommendations for practice. Sports Med. 2022;52:1491–532.
51. Jarvis P, Turner A, Read P, Bishop C. Reactive strength index and its associations with measures of physical and sports performance: a systematic review with meta-analysis. Sports Med. 2022;52:301–30.
52. Turner AN, Stewart PF. Strength and conditioning for soccer players. Strength Cond J. 2014;36:1–13.
53. Turner AN, Parmar N, Jovanovski A, Hearne G. Assessing group-based changes in high-performance sport. Part 2: Effect sizes and embracing uncertainty through confidence intervals. Strength Cond J. 2021;43:68–77.
54. Turner A. But did my athlete improve? Assessing performance changes when N = 1. Prof Strength Cond. 2022;63:27–31.
55. Beltz NM, Gibson AL, Janot JM, Kravitz L, Mermier CM, Dalleck LC. Graded exercise testing protocols for the determination of VO_2 max: historical perspectives, progress, and future considerations. J Sports Med. 2016;2016:1–12.
56. Angius L, Olla S, Pinna M, Mura R, Marongiu E, Roberto S, et al. Aerobic and anaerobic capacity of adult and young professional soccer players. Sport Sci Health. 2012;8:95–100.
57. Mclaughlin JE, Howley ET, Bassett DR, Thompson DL, Fitzhugh EC. Test of the classic model for predicting endurance running performance. Med Sci Sports Exerc. 2010;42:991–7.
58. Rebelo A, Brito J, Seabra A, Oliveira J, Krustrup P. Physical match performance of youth football players in relation to physical capacity. Eur J Sport Sci. 2014;14:S148–56.
59. Signorelli G, Perim R, Santos T, Araujo C. A pre-season comparison of aerobic fitness and flexibility of younger and older professional soccer players. Int J Sports Med. 2012;33:867–72.
60. Meckel Y, Machnai O, Eliakim A. Relationship among repeated sprint tests, aerobic fitness, and anaerobic fitness in elite adolescent soccer players. J Strength Cond Res. 2009;23:163–9.
61. Guner R, Kunduracioglu B, Ulkar B, Ergen E. Running velocities and heart rates at fixed blood lactate concentrations in elite soccer players. Adv Therapy. 2005;22:613–20.
62. Colosio AL, Lievens M, Pogliaghi S, Bourgois JG, Boone J. Heart rate-index estimates aerobic metabolism in professional soccer players. J Sci Med Sport. 2020;23:1208–14.
63. Haydar B, Haddad HA, Ahmaidi S, Buchheit M. Assessing inter-effort recovery and change of direction ability with the 30–15 Intermittent Fitness Test. J Sports Sci Med. 2011;10:346–54.
64. Bangsbo J, Iaia FM, Krustrup P. The Yo-Yo intermittent recovery test: a useful tool for evaluation of physical performance in intermittent sports. Sports Med. 2008;38:37–51.
65. Buchheit M. The 30–15 Intermittent Fitness Test: Accuracy for Individualizing Interval Training of Young Intermittent Sport Players. J Strength Cond Res. 2008;22:365–74.
66. Owen C, Jones P, Comfort P. The reliability of the submaximal version of the Yo-Yo intermittent recovery test in elite youth soccer. Journal of Trainology. 2017;6:31–4.
67. Bradley PS, Mohr M, Bendiksen M, Randers MB, Flindt M, Barnes C, et al. Sub-maximal and maximal Yo–Yo intermittent endurance test level 2: heart rate response, reproducibility and application to elite soccer. Eur J Appl Physiol. 2011;111:969–78.
68. Rabbani A, Kargarfard M, Twist C. Reliability and validity of a submaximal warm-up test for monitoring training status in professional soccer players. J Strength Cond Res. 2018;32:326–33.
69. Buchheit M, Dikmen U, Vassallo C. The 30–15 Intermittent Fitness Test—two decades of learnings. Sport Perf Sci Rep. 2021;1:1–13.
70. Bloomfield J, Polman R, O'Donoghue P. Physical demands of different positions in FA Premier League Soccer. J Sports Sci Med. 2007;6:63–70.
71. Morgan OJ, Drust B, Ade JD, Robinson MA. Change of direction frequency off the ball: new perspectives in elite youth soccer. Sci Med Football. 2022;6:473–82.
72. Buchheit M, Bishop D, Haydar B, Nakamura FY, Ahmaidi S. Physiological responses to shuttle repeated-sprint running. Int J Sports Med. 2010;31:402–9.
73. Dos'Santos T, Thomas C, Comfort P, Jones PA. The effect of angle and velocity on change of direction biomechanics: an angle-velocity trade-off. Sports Med. 2018;48:2235–53.
74. Dellal A, Wong DP. Repeated Sprint and Change-of-Direction Abilities in Soccer Players: Effects of Age Group. J Strength Cond Res. 2013;27:2504–8.
75. Wong DP, Hjelde GH, Cheng C-F, Ngo JK. Use of the RSA/RCOD Index to Identify Training Priority in Soccer Players. J Strength Cond Res. 2015;29:2787–93.
76. Bishop C, Shrier I, Jordan M. Ratio data: understanding pitfalls and knowing when to standardise. Symmetry. 2023;15:318.
77. Devlin J, Paton B, Poole L, Sun W, Ferguson C, Wilson J, et al. Blood lactate clearance after maximal exercise depends on active recovery intensity. J Sports Med Phys Fitness. 2014;54:271–8.
78. Mota MR, Dantas RAE, Oliveira-Silva I, Sales MM, Da Costa Sotero R, Espíndola Mota Venâncio P, et al. Effect of self-paced active recovery and passive recovery on blood lactate

removal following a 200 m freestyle swimming trial. OAJSM. 2017;8:155–60.
79. Duque-Vera IL, Urrutia-Illera IMa, Ramírez-Forero BI. Comparison of active and passive recovery using local heat in lactate removal in cyclists. J Study Sports Athletes Educ. 2022;16:277–89.
80. Gabbett TJ. The development of a test of repeated-sprint ability for elite women's soccer players. J Strength Cond Res. 2010;24:1191–4.
81. Fernandes-Da-Silva J, Castagna C, Teixeira AS, Carminatti LJ, Francini L, Póvoas SCA, et al. Ecological and construct validity of a repeated sprint test in male youth soccer players. J Strength Cond Res. 2021;35:2000–9.
82. Lloyd RS, Oliver JL. The youth physical development model: a new approach to long-term athletic development. Strength Cond J. 2012;34:61–72.
83. Dolci F, Kilding AE, Spiteri T, Chivers P, Piggott B, Maiorana A, et al. Modulators of change-of-direction economy after repeated sprints in elite soccer players. Int J Sports Physiol Perform. 2021;16:1649–55.
84. Casajús JA. Seasonal variation in fitness variables in professional soccer players. J Sports Med Phys Fitness. 2001;41:463–9.
85. Parpa K, Michaelides M. Anthropometric characteristics and aerobic performance of professional soccer players by playing position and age. hm. 2022;23:44–53.
86. Angoorani H, Basharkhah A, Mazaherinezhad A, Nazari A. Evaluation of cardiorespiratory fitness and its correlation with team performance, player position and physical characteristics in the Soccer Premium League of Iran. Asian J Sports Med 2021;12:e109724.
87. Michaelides M, Parpa K, Zacharia AI. Preseason maximal aerobic power in professional soccer players among different divisions. J Strength Cond Res. 2018;32:356–63.
88. Boone J, Vaeyens R, Steyaert A, Bossche LV, Bourgois J. Physical fitness of elite belgian soccer players by player position. J Strength Cond Res. 2012;26:2051–7.
89. Al-Hazzaa HM, Almuzaini KS, Al-Refaee SA, Sulaiman MA, Dafterdar MY, Al-Ghamedi A, et al. Aerobic and anaerobic power characteristics of Saudi elite soccer players. J Sports Med Phys Fitness. 2001;41:54–61.
90. Wisløff U, Helgerud J, Hoff J. Strength and endurance of elite soccer players. Med Sci Sports Exerc. 1998;30:462–7.
91. Owen AL, Newton M, Shovlin A, Malone S. The use of small-sided games as an aerobic fitness assessment supplement within elite level professional soccer. J Hum Kinet. 2020;71:243–53.
92. Rodríguez-Fernández A, Sánchez-Sánchez J, Ramirez-Campillo R, Rodríguez-Marroyo JA, Villa Vicente JG, Nakamura FY. Effects of short-term in-season break detraining on repeated-sprint ability and intermittent endurance according to initial performance of soccer player. Padulo J, editor. PLoS ONE. 2018;13: e0201111.
93. Stevens TGA, De Ruiter CJ, Beek PJ, Savelsbergh GJP. Validity and reliability of 6-a-side small-sided game locomotor performance in assessing physical fitness in football players. J Sports Sci. 2016;34:527–34.
94. Bradley PS, Carling C, Gomez Diaz A, Hood P, Barnes C, Ade J, et al. Match performance and physical capacity of players in the top three competitive standards of English professional soccer. Hum Mov Sci. 2013;32:808–21.
95. Rebelo A, Brito J, Maia J, Coelho-e-Silva M, Figueiredo A, Bangsbo J, et al. Anthropometric characteristics, physical fitness and technical performance of under-19 soccer players by competitive level and field position. Int J Sports Med. 2012;34:312–7.
96. Brechue WF, Mayhew JL, Piper FC. Equipment and running surface alter sprint performance of college football players. J Strength Cond Res. 2005;19:821–5.
97. Weakley J, McCosker C, Chalkley D, Johnston R, Munteanu G, Morrison M. Comparison of sprint timing methods on performance, and displacement and velocity at timing initiation. J Strength Cond Res [Internet]. 2022. https://doi.org/10.1519/JSC.0000000000004223.
98. Van Den Tillaar R, Haugen ME, Falch HN. A comparison of sprint mechanical parameters measured with timing gates and a laser gun. Front Sports Act Living. 2022;4: 877482.
99. Astorino TA, Rietschel JC, Tam PA, Taylor K, Freedman TP, Sakarya CE. Reinvestigation of optimal duration of VO2max testing. J Exerc Physiol. 2004;7:1–8.
100. Atkinson G, Nevill AM. Statistical methods for assessing measurement error (Reliability) in variables relevant to sports medicine. Sports Med. 1998;26:217–38.
101. Currell K, Jeukendrup AE. Validity, reliability and sensitivity of measures of sporting performance. Sports Med. 2008;38:297–316.
102. Darrall-Jones JD, Jones B, Roe G, Till K. Reliability and usefulness of linear sprint testing in adolescent rugby union and league players. J Strength Cond Res. 2016;30:1359–64.
103. Howarth DJ, Cohen DD, McLean BD, Coutts AJ. Establishing the noise: interday ecological reliability of countermovement jump variables in professional rugby union players. J Strength Cond Res. 2022;36:3159–66.
104. Turner A, Brazier J, Bishop C, Chavda S, Cree J, Read P. Data analysis for strength and conditioning coaches: using excel to analyze reliability, differences, and relationships. Strength Cond J. 2015;37:76–83.
105. Mercer RAJ, Russell JL, McGuigan LC, Coutts AJ, Strack DS, McLean BD. Finding the signal in the noise—interday reliability and seasonal sensitivity of 84 countermovement jump variables in professional basketball players. J Strength Cond Res. 2023;37:394–402.
106. Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. J Chiropr Med. 2016;15:155–63.
107. Taylor JM, Macpherson TW, Spears IR, Weston M. Repeated sprints: an independent not dependent variable. Int J Sports Physiol Perform. 2016;11:693–6.
108. Buchheit M, Mendez-villanueva A, Simpson BM, Bourdon PC. Repeated-sprint sequences during youth soccer matches. Int J Sports Med. 2010;31:709–16.
109. Unnithan VB, Drust B, Brow C, Bakhshi A, Mason L, Weston M. Influence of the COVID-19 pandemic on changes in aerobic fitness and injury incidence in elite male soccer players. J Sports Med Phys Fitness 2023;63:155–161.
110. Wezenbeek E, Denolf S, Bourgois JG, Philippaerts RM, De Winne B, Willems TM, et al. Impact of (long) COVID on athletes' performance: a prospective study in elite football players. Ann Med. 2023;55:2198776.
111. Guerra MA, Caldas LC, Souza HL, Tallis J, Duncan MJ, Guimarães-Ferreira L. The effects of physical fitness on postactivation potentiation in professional soccer athletes. J Strength Cond Res. 2022;36:1643–7.
112. Boraczyński MT, Laskin JJ, Gajewski J, Podstawski RS, Brodnicki MA, Boraczyński TW. Effects of two low-volume high-intensity interval training protocols in professional soccer: sprint interval training versus small-sided games. J Sports Med Phys Fitness. 2022;63:23–33.
113. Manzi V, Annino G, Savoia C, Caminiti G, Padua E, Masucci M, et al. Relationship between aerobic fitness and metabolic power metrics in elite male soccer players. Biol Sport. 2022;39:599–606.
114. Akyildiz Z, Güler AH, Çene E, Palucci Vieira LH, Aquino R, Clemente FM. Effects of a competitive half-season on the aerobic capacity and match running performance of Turkish

elite professional soccer players. Proceedings of the Institution of Mechanical Engineers, Part P: J Sports Eng Technol. 2022;3:175433712211017.

115. Schons P, Birk Preissler AA, Oliveira R, Brito JP, Clemente FM, Droescher De Vargas G, et al. Comparisons and correlations between the anthropometric profile and physical performance of professional female and male soccer players: Individualities that should be considered in training. Int J Sports Sci Coach. 2022;18:174795412211316.
116. Enes A, Oneda G, Alves DL, Palumbo DDP, Cruz R, Moiano Junior JVM, et al. Determinant factors of the match-based internal load in elite soccer players. Res Q Exerc Sport. 2021;92:63–70.
117. Arregui-Martin MA, Garcia-Tabar I, Gorostiaga EM. Half soccer season induced physical conditioning adaptations in elite youth players. Int J Sports Med. 2020;41:106–12.
118. Azcárate U, Los Arcos A, Jiménez-Reyes P, Yanci J. Are acceleration and cardiovascular capacities related to perceived load in professional soccer players? Res Sports Med. 2020;28:27–41.
119. Querido SM, Clemente FM. Analyzing the effects of combined small-sided games and strength and power training on the fitness status of under-19 elite football players. J Sports Med Phys Fitness. 2020;60:1–10.
120. Michaelides MA, Parpa KM, Zacharia AI. Effects of an 8-week pre-seasonal training on the aerobic fitness of professional soccer players. J Strength Condi Res 2021;35:2783–2789.
121. Silva AF, González-Fernández FT, Ceylan HI, Silva R, Younesi S, Chen Y-S, et al. Relationships between fitness status and blood biomarkers in professional soccer Players. Taiar R, editor. J Healthc Eng. 2022;2022:1–13.
122. Martin M, Rampinini E, Bosio A, Azzalin A, McCall A, Ward P. Relationships between internal and external load measures and fitness level changes in professional soccer players. Res Q Exerc Sport. 2022;94:1–13.
123. Saccà M, Bondi D, Balducci F, Petri C, Mazza G. Intra- and Inter-seasonal fitness and training load variations of elite U20 soccer players. Res Q Exerc Sport. 2022;94:940–7.
124. Rabbani A, Wong DP, Clemente FM, Kargarfard M. Internal training load and fitness profile between adult team versus junior team soccer players. Kinesiology (Zagreb, Online). 2021;53:71–7.
125. Cardoso De Araújo M, Baumgart C, Jansen CT, Freiwald J, Hoppe MW. Sex differences in physical capacities of German Bundesliga soccer players. J Strength Cond Res. 2020;34:2329–37.
126. Rabbani A, Kargarfard M, Twist C. Fitness monitoring in elite soccer players: group vs. individual analyses. J Strength Cond Res. 2020;34:3250–7.
127. Jorge G, Garrafoli MT, Cal Abad CC. Seasonal repeated sprint ability with change of direction variations in U17 and u20 elite brazilian soccer players: a comparative study. J Strength Cond Res. 2020;34:1431–9.
128. Grazioli R, Loturco I, Baroni BM, Oliveira GS, Saciura V, Vanoni E, et al. Coronavirus disease-19 quarantine is more detrimental than traditional off-season on physical conditioning of professional soccer players. J Strength Cond Res. 2020;34:3316–20.
129. Rago V, Krustrup P, Martín-Acero R, Rebelo A, Mohr M. Training load and submaximal heart rate testing throughout a competitive period in a top-level male football team. J Sports Sci. 2020;38:1408–15.
130. Papadakis L, Tymvios C, Patras K. The relationship between training load and fitness indices over a pre-season in professional soccer players. J Sports Med Phys Fit. 2020;60:329–37.
131. Krespi M, Sporiš G, Trajković N. Effects of two different tapering protocols on fitness and physical match performance in elite junior soccer players. J Strength Cond Res. 2020;34:1731–40.
132. Radzimiński Ł, Szwarc A, Padron-Cabo A, Jastrzębski Z. Correlations between body composition, aerobic capacity, speed level and distance covered during the official matches in professional soccer players. J Sports Med Phys Fit. 2019;60:257–62.
133. Hoppe MW, Barnics V, Freiwald J, Baumgart C. Contrary to endurance, power associated capacities differ between different aged and starting-nonstarting elite junior soccer players. Perroni F, editor. PLoS ONE. 2020;15: e0232118.
134. Boraczyński M, Boraczyński T, Podstawski R, Wójcik Z, Gronek P. Relationships between measures of functional and isometric lower body strength, aerobic capacity, anaerobic power, sprint and countermovement jump performance in professional soccer players. J Hum Kinet. 2020;75:161–75.
135. Bekris E, Mylonis E, Gissis I, Katis A, Metaxas T, Komsis S, et al. Variation of aerobic performance indices of professional elite soccer players during the annual macrocycle. J Sports Med Phys Fitness 2019;59:1628–1634.
136. Saidi K, Zouhal H, Rhibi F, Tijani JM, Boullosa D, Chebbi A, et al. Effects of a six-week period of congested match play on plasma volume variations, hematological parameters, training workload and physical fitness in elite soccer players. Clemente FM, editor. PLoS ONE. 2019;14: e0219692.
137. Clancy C, Green P, Curnyn S, Donaldson E, Ring N. The concurrent validity and between-session reliability of a 1000m time trial for the assessment of aerobic fitness in elite development soccer players. Sports Perf Sci Rep. 2020;1:1–3.
138. Rabbani A, Kargarfard M, Castagna C, Clemente FM, Twist C. Associations between selected training-stress measures and fitness changes in male soccer players. Int J Sports Physiol Perform. 2019;14:1050–7.
139. Enright K, Morton J, Iga J, Lothian D, Roberts S, Drust B. Reliability of “in-season” fitness assessments in youth elite soccer players: a working model for practitioners and coaches. Sci Med Football. 2018;2:177–83.
140. Meckel Y, Doron O, Eliakim E, Eliakim A. Seasonal variations in physical fitness and performance indices of elite soccer players. Sports. 2018;6:14.
141. Rago V, Silva JR, Mohr M, Barreira D, Krustrup P, Rebelo AN. The inter-individual relationship between training status and activity pattern during small-sided and full-sized games in professional male football players. Sci Med Football. 2018;2:115–22.
142. Los Arcos A, Martins J. Physical fitness performance of young professional soccer players does not change during several training seasons in a Spanish elite reserve team: club study, 1996–2013. J Strength Cond Res. 2018;32:2577–83.
143. Almeida AMD, Santos Silva PR, Pedrinelli A, Hernandez AJ. Aerobic fitness in professional soccer players after anterior cruciate ligament reconstruction. PLoS ONE. 2018;13: e0194432.
144. Fessi MS, Farhat F, Dellal A, Malone JJ, Moalla W. Straight-line and change-of-direction intermittent running in professional soccer players. Int J Sports Physiol Perform. 2018;13:562–7.
145. Castillo D, Los Arcos A, Martínez-Santos R. Aerobic endurance performance does not determine the professional career of elite youth soccer players. J Sports Med Phys Fitness 2018;58:392–398.
146. Campos-Vazquez MA, Toscano-Bendala FJ, Mora-Ferrera JC, Suarez-Arrones LJ. Relationship between internal load indicators and changes on intermittent performance after the preseason in professional soccer players. J Strength Cond Res. 2017;31:1477–85.
147. Requena B, García I, Suárez-Arrones L, Sáez De Villarreal E, Naranjo Orellana J, Santalla A. Off-season effects on functional performance, body composition, and blood parameters in top-level professional soccer players. J Strength Cond Res. 2017;31:939–46.

148. Pareja-Blanco F, Sánchez-Medina L, Suárez-Arrones L, González-Badillo JJ. Effects of velocity loss during resistance training on performance in professional soccer players. Int J Sports Physiol Perform. 2017;12:512–9.
149. Sapp RM, Aronhalt L, Landers-Ramos RQ, Spangenburg EE, Wang MQ, Hagberg JM. Laboratory and match physiological data from an elite male collegiate soccer athlete. J Strength Cond Res. 2017;31:2645–51.
150. Yanci J, Los AA. Monitoring perceived respiratory and muscular exertions and physical fitness in young professional soccer players during a 32-week period. Kinesiology (Zagreb, Online). 2017;49:153–60.
151. Cerda-Kohler H, Burgos-Jara C, Ramírez-Campillo R, Valdés-Cerda M, Báez E, Zapata-Gómez D, et al. Analysis of agreement between 4 lactate threshold measurements methods in professional soccer players. J Strength Cond Res. 2016;30:2864–70.
152. Fessi MS, Zarrouk N, Filetti C, Rebai H, Elloumi M, Moalla W. Physical and anthropometric changes during pre and in-season in professional soccer players. J Sports Med Phys Fit. 2016;56:1163–70.
153. Spineti J, Figueiredo T, Bastos DE, Oliveira V, Assis M, Fernandes DE, Oliveira L, Miranda H, et al. Comparison between traditional strength training and complex contrast training on repeated sprint ability and muscle architecture in elite soccer players. J Sports Med Phys Fitness. 2016;56:1269–78.
154. Noon MR, James RS, Clarke ND, Akubat I, Thake CD. Perceptions of well-being and physical performance in English elite youth footballers across a season. J Sports Sci. 2015;33:2106–15.
155. Iaia FM, Fiorenza M, Perri E, Alberti G, Millet GP, Bangsbo J. The effect of two speed endurance training regimes on performance of soccer players. Sandbakk O, editor. PLoS ONE. 2015;10:e0138096.
156. Arcos AL, Martínez-Santos R, Yanci J, Mendiguchia J, Méndez-Villanueva A. Negative associations between perceived training load, volume and changes in physical fitness in professional soccer players. J Sports Sci Med. 2015;14:394–401.
157. Brocherie F, Girard O, Forchino F, Al Haddad H, Dos Santos GA, Millet GP. Relationships between anthropometric measures and athletic performance, with special reference to repeated-sprint ability, in the Qatar national soccer team. J Sports Sci. 2014;32:1243–54.
158. Haddad M, Dridi A, Chtara M, Chaouachi A, Wong DP, Behm D, et al. Static stretching can impair explosive performance for at least 24 hours. J Strength Cond Res. 2014;28:140–6.
159. Wells C, Edwards A, Fysh M, Drust B. Effects of high-intensity running training on soccer-specific fitness in professional male players. Appl Physiol Nutr Metab. 2014;39:763–9.
160. Manzi V, Impellizzeri F, Castagna C. Aerobic Fitness Ecological Validity in Elite Soccer Players: A Metabolic Power Approach. J Strength Cond Res. 2014;28:914–9.
161. Arcos AL, Yanci J, Mendiguchia J, Salinero JJ, Brughelli M, Castagna C. Short-term training effects of vertically and horizontally oriented exercises on neuromuscular performance in professional soccer players. Int J Sports Physiol Perform. 2014;9:480–8.
162. Koundourakis NE, Androulakis N, Spyridaki EC, Castanas E, Malliaraki N, Tsatsanis C, et al. Effect of different seasonal strength training protocols on circulating androgen levels and performance parameters in professional soccer players. Hormones. 2014;13:104–18.
163. Koundourakis NE, Androulakis NE, Malliaraki N, Tsatsanis C, Venihaki M, Margioris AN. Discrepancy between exercise performance, body composition, and sex steroid response after a six-week detraining period in professional soccer players. Novelli G, editor. PLoS ONE. 2014;9: e87803.
164. Manzi V, Bovenzi A, Franco Impellizzeri M, Carminati I, Castagna C. Individual training-load and aerobic-fitness variables in premiership soccer players during the precompetitive season. J Strength Cond Res. 2013;27:631–6.
165. Castagna C, Impellizzeri FM, Chaouachi A, Manzi V. Preseason variations in aerobic fitness and performance in elite-standard soccer players: a team study. J Strength Cond Res. 2013;27:2959–65.
166. Aandstad A, Simon EV. Reliability and validity of the soccer specific INTER field test. J Sports Sci. 2013;31:1383–92.
167. Silva JR, Magalhães J, Ascensão A, Seabra AF, Rebelo AN. Training status and match activity of professional soccer players throughout a season. J Strength Cond Res. 2013;27:20–30.
168. Hoppe MW, Baumgart C, Sperlich B, Ibrahim H, Jansen C, Willis SJ, et al. Comparison between three different endurance tests in professional soccer players. J Strength Cond Res. 2013;27:31–7.
169. Lago-Ballesteros J. Seasonal variations in body composition and fitness parameters according to individual percentage of training completion in professional soccer players. 2013;
170. Gibson N, Currie J, Johnston R, Hill J. Relationship between measures of aerobictness, speed and repeated sprint ability in full and part time youth soccer players. J Sports Med Phys Fit. 2013;53:9–16.
171. Owen AL, Wong DP, Paul D, Dellal A. Effects of a periodized small-sided game training intervention on physical performance in elite professional soccer. J Strength Cond Res. 2012;26:2748–54.
172. Akubat I, Patel E, Barrett S, Abt G. Methods of monitoring the training and match load and their relationship to changes in fitness in professional youth soccer players. J Sports Sci. 2012;30:1473–80.
173. Wells CM, Edwards AM, Winter EM, Fysh ML, Drust B. Sport-specific fitness testing differentiates professional from amateur soccer players where VO2max and VO2 kinetics do not. J Sports Med Phys Fitness. 2012;52:245–54.
174. Silva JR, Magalhães JF, Ascensão AA, Oliveira EM, Seabra AF, Rebelo AN. Individual match playing time during the season affects fitness-related parameters of male professional soccer players. J Strength Cond Res. 2011;25:2729–39.
175. Helgerud J, Rodas G, Kemi OJ, Hoff J. Strength and endurance in elite football players. Int J Sports Med. 2011;32:677–82.
176. Kalapotharakos VI, Ziogas G, Tokmakidis SP. Seasonal aerobic performance variations in elite soccer players. J Strength Cond Res. 2011;25:1502–7.
177. Bogdanis GC, Papaspyrou A, Souglis AG, Theos A, Sotiropoulos A, Maridaki M. Effects of two different half-squat training programs on fatigue during repeated cycling sprints in soccer players. J Strength Cond Res. 2011;25:1849–56.
178. Faude O, Kellmann M, Ammann T, Schnittker R, Meyer T. Seasonal changes in stress indicators in high level football. Int J Sports Med. 2011;32:259–65.
179. Christensen PM, Krustrup P, Gunnarsson TP, Kiilerich K, Nybo L, Bangsbo J. V˙O2 kinetics and performance in soccer players after intense training and inactivity. Med Sci Sports Exerc. 2011;43:1716–24.
180. Henderson G, Barnes CA, Portas MD. Factors associated with increased propensity for hamstring injury in English Premier League soccer players. J Sci Med Sport. 2010;13:397–402.
181. Wong P, Chaouachi A, Chamari K, Dellal A, Wisloff U. Effect of preseason concurrent muscular strength and high-intensity interval training in professional soccer players. J Strength Cond Res. 2010;24:653–60.
182. López-Segovia M, Palao Andrés JM, González-Badillo JJ. Effect of 4 months of training on aerobic power, strength, and acceleration in two under-19 soccer teams. J Strength Cond Res. 2010;24:2705–14.

183. Sotiropoulos A, Travlos AK, Gissis I, Souglis AG, Grezios A. The effect of a 4-week training regimen on body fat and aerobic capacity of professional soccer players during the transition period. J Strength Cond Res. 2009;23:1697–703.
184. Bravo D, Impellizzeri F, Rampinini E, Castagna C, Bishop D, Wisloff U. Sprint vs. interval training in football. Int J Sports Med. 2008;29:668–74.
185. Clark NA, Edwards AM, Morton RH, Butterly RJ. Season-to-season variations of physiological fitness within a squad of professional male soccer players. J Sports Sci Med. 2008;7:157–65.
186. Aziz A, Mukherjee S, Chia M, Teh K. Validity of the running repeated sprint ability test among playing positions and level of competitiveness in trained soccer players. Int J Sports Med. 2008;29:833–8.
187. Rampinini E, Bishop D, Marcora S, Ferrari Bravo D, Sassi R, Impellizzeri F. Validity of simple field tests as indicators of match-related physical performance in top-level professional soccer players. Int J Sports Med. 2007;28:228–35.
188. Voutselas V, Papanikolaou Z, Soulas D, Famisis K. Years of training and hamstring-quadriceps ratio of soccer players. Psychol Rep. 2007;101:899–906.
189. Kalapotharakos VI, Strimpakos N, Vithoulka I, Karvounidis C, Diamantopoulos K, Kapreli E. Physiological characteristics of elite professional soccer teams of different ranking. J Sports Med Phys Fitness. 2006;46:515–9.
190. Chamari K. Appropriate interpretation of aerobic capacity: allometric scaling in adult and young soccer players. Br J Sports Med. 2005;39:97–101.
191. McMillan K. Lactate threshold responses to a season of professional British youth soccer. Br J Sports Med. 2005;39:432–6.
192. Chamari K, Hachana Y, Ahmed YB, Galy O, Sghaïer F, Chatard J-C, et al. Field and laboratory testing in young elite soccer players. Br J Sports Med. 2004;38:191–6.
193. Dupont G, Akakpo K, Berthoin S. The effect of in-season, high-intensity interval training in soccer players. J Strength Cond Res. 2004;18:584–9.
194. Ostojic SM. Elite and nonelite soccer players: preseasonal physical and physiological characteristics. Res Sports Med. 2004;12:143–50.
195. Arnason A, Sigurdsson SB, Gudmundsson A, Holme I, Engebretsen L, Bahr R. Physical fitness, injuries, and team performance in soccer. Med Sci Sports Exerc. 2004;36:278–85.
196. Lemmink KAPM, Verheijen R, Visscher C. The discriminative power of the Interval Shuttle Run Test and the Maximal Multistage Shuttle Run Test for playing level of soccer. J Sports Med Phys Fitness. 2004;44:233–9.
197. Ozcakar L. Comprehensive isokinetic knee measurements and quadriceps tendon evaluations in footballers for assessing functional performance. Br J Sports Med. 2003;37:507–10.
198. Helgerud J, Engen LC, Wisloff U, Hoff J. Aerobic endurance training improves soccer performance. Med Sci Sports Exerc. 2001;33:1925–31.
199. Bangsbo J, Lindquist F. Comparison of various exercise tests with endurance performance during soccer in professional players. Int J Sports Med. 1992;13:125–32.
200. Chin MK, Lo YS, Li CT, So CH. Physiological profiles of Hong Kong elite soccer players. Br J Sports Med. 1992;26:262–6.
201. Rhodes EC, Mosher RE, McKenzie DC, Franks IM, Potts JE, Wenger HA. Physiological profiles of the Canadian Olympic Soccer Team. Can J Appl Sport Sci. 1986;11:31–6.

Authors and Affiliations

Nikolaos D. Asimakidis[1,2] · Chris Bishop[1] · Marco Beato[3] · Anthony N. Turner[1]

✉ Nikolaos D. Asimakidis
n.asimakidis@gmail.com

[1] Faculty of Science and Technology, London Sport Institute, Middlesex University, London, UK

[2] Performance Department, Ipswich Town Football Club, Ipswich, UK

[3] School of Health and Sports Sciences, University of Suffolk, Ipswich, UK