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SYSTEMATIC REVIEW

Match Running Performance in Young Soccer Players: A Systematic Review

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Abstract

Background To date, athletic performance has been extensively assessed in youth soccer players through laboratory and field testing. Only recently has running performance via time–motion analysis been assessed during match play. Match running data are often useful in a practical context to aid game understanding and decision making regarding training content and prescriptions. A plethora of previous reviews have collated and appraised the literature on time–motion analysis in professional senior players, but none have solely examined youth players.

Objective The aim of the present systematic review was to provide a critical appraisal and summary of the original research articles that have evaluated match running performance in young male soccer players.

Methods Following the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement, literature searches were performed in four databases: PubMed, ISI Web of Science, SPORTDiscus and SciELO. We used the following descriptors: soccer, football, young, youth, junior, physical performance, running performance, match running performance, movement patterns, time–motion analysis, distances covered, activity profile, work rate, match analysis, and match performance. Articles were included only if they were original articles written in the English language, studied populations of male children and/or adolescents (aged ≤ 20 years), were published/ahead of print on or before 31 December 2017 and showed at least one outcome measure regarding match running performance, such as total distance covered, peak game speed or indicators of activities performed at established speed thresholds.

Results A total of 5801 records were found. After duplicates were removed and exclusion and inclusion criteria applied, 50 articles were included ($n = 2615$ participants). Their outcome measures were extracted and findings were synthesized. The majority of the reviewed papers covered the European continent (62%) and used global positioning systems (GPS) (64%). Measurement error of the tools used to obtain position data and running metrics was systematically overlooked among the studies. The main aims of studies were to examine differences across playing positions (20%), age groups (26%) and match halves (36%). Consistent findings pointed to the existence of positional role and age effects on match running output (using fixed running speed thresholds), but there was no clear consensus about reductions in activity over the course of match play. Congested schedules negatively affected players' running performance. While over 32% of all studies assessed the relationships between match running performance and physical capacity, biochemical markers and body composition, ~ 70% of these did not account for playing position.

Conclusions This review collated scientific evidence that can aid soccer conditioning professionals in understanding external match loads across youth categories. Coaches working with youth development programs should consider that data derived from a given population may not be relevant for other populations, since game rules, match format and configuration are essentially unstandardized among studies for age-matched players. Despite limited evidence, periodization training emphasizing technical-tactical content can improve match running performance. Occurrence of acute and residual impairments in the running performance of young soccer players is common. Prescription of postmatch recovery strategies, such as cold water immersion and spa treatment, can potentially help reduce these declines, although additional research is warranted. This review also highlighted areas requiring further investigation, such as the possible influence of environmental and contextual constraints and a more integrative approach combining tactical and technical data.

Extended author information available on the last page of the article

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Key Points

The number of studies on match running performance has exponentially increased over the current decade in youth soccer populations, providing information that could aid the development of physical conditioning programs and their prescription across different age categories.

While the current empirical evidence provides a general understanding of external match loads across different age groups, disparities in experimental approaches across studies in age-matched players exist, whilst measurement error and the potential impact of situational variables are also frequently overlooked.

Match running activity can decrease over the course of games and during fixture congestion (i.e., signs of acute and residual fatigue, respectively), yet information is limited on the effects of recovery interventions (e.g., cold water immersion and spa treatment) to temper performance declines during intensive schedules.

1 Introduction

Professional soccer clubs invest significant amounts of money to nurture elite players [1, 2]. The monitoring of match running performance using time–motion analysis (TMA) is now considered a fundamental part of contemporary youth development processes [3]. This is reflected by a notable shift in the body of knowledge over the current decade compared with 10 years ago, when a review showed a lack of information on match play running performance in youth soccer players [4]. While several further reviews have collated and appraised the TMA literature, none have solely examined younger populations (e.g., Mohr et al. [5], Sarmento and colleagues [6, 10], Lago-Peñas [7], Carling et al. [8], Reilly et al. [9], Taylor et al. [11]) despite a plethora of original investigations comparing performance across different age groups [12–20].

In general, running data are useful in a practical context to aid game understanding and decision making in relation to individual and collective physical training content and prescriptions [4, 21–24]. This information can also help distinguish player performances across different competitive standards [6] and improve understanding of the potential effects of contextual factors such as match location, quality of opponents, and match status [25]. Regarding youth players, TMA data can also help to clarify the demands necessary when moving up into older age brackets, especially when talented youth players (e.g., U18–U20) are promoted to the senior squad. The data can help determine at which age(s) young players demonstrate match running outputs that are sufficient to meet the demands of professional standards. Insights into athletic and game evolution can be gained that, in turn, enable the tailoring of age-specific training programs [3] and improvement of long-term training interventions [18] and help avoid replication of methods used in senior players, since very young soccer players should not be considered small adults [24, 26].

Yet, to our knowledge, critical appraisals of study design and the information derived from TMA of match running performance at the youth level are currently lacking [3]. For example, it is necessary to investigate the potential discrepancies among studies in the cutoffs used for age-band definitions (12 months [14, 15, 18] or 24 months [20, 27, 28]) and running speed thresholds (e.g., high-intensity running: 13.1–16 [18], 15.1–18 [29], 15–36 [30], and > 19.8 km/h [31]) for age-matched players. Furthermore, in contrast with senior players [3, 7, 20], the potential impact of contextual factors, also known as situational variables (e.g., influence of match location or result), has not been examined in younger players. Finally, investigations of the possible effects of match format (e.g., small-sided games [13, 32] or full-sized pitches [16, 18, 24]) and decrements in performance (e.g., half-times [3, 16, 17] and specific game periods [13, 15, 33]) would be beneficial to aid in the understanding of the characteristics specific to youth soccer match play. Therefore, the purpose of the present systematic review was to provide a critical appraisal and summary of original research articles that have investigated match running performance in young male soccer players.

2 Methods

2.1 Search Strategy

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [34]. Permission was granted by the Institutional Human Research Ethics Committee (School of Physical Education and Sport of Ribeirão Preto, University of São Paulo, Brazil; protocol number CAAE 61884716.9.0000.5659). The searches for relevant content related to the running performance of young soccer players during match play were performed on 31 December 2017, using four electronic databases: PubMed/NCBI (National Center for Biotechnology Information, US National Library of Medicine), Institute for Scientific Information (ISI) Web of Knowledge, SciELO (Scientific Electronic Library Online), and SPORTDiscus via EBSCOhost. In each database, the following descriptors were used: [soccer OR

football] AND [young OR youth OR junior] AND [physical performance OR running performance OR match running performance OR movement patterns OR time–motion analysis OR distances covered OR activity profile OR work rate OR match analysis OR match performance]. Additional searches were performed on Google Scholar when the full texts were not available in these databases and for articles found on ResearchGate™ [35]. Dedicated computer software (EndNote X7, Thomson Reuters©, New York, NY, USA) was used for reference management, facilitating deduplication and screening steps.

2.2 Selection Criteria

2.2.1 Inclusion Criteria

We opted to include papers if they filled all of the following criteria: (1) original article; (2) abstract available for screening; (3) samples of male children and/or adolescents; (4) published in the English language; (5) published/ahead of print up to and including 31 December 2017; (6) in a scientific indexed peer-reviewed scientific journal (thus, abstracts published in conference proceedings, books, theses, dissertations, reviews, systematic reviews, and meta-analyses were not considered); (7) included at least one outcome measure regarding the following dependent variables of match running performance: total distance covered, mean speed or distance covered per time, peak game speed, activities performed at established speed thresholds (e.g., expressed as distance covered, distance covered per minute, percentage of total distance covered) or movement category (e.g., subjective estimates of percentage of time in walking, jogging; low, medium, and high intensities). No restrictions regarding the date of publication were imposed, other than those described in item 5.

2.2.2 Exclusion Criteria

Exclusion criteria included (1) goalkeepers as participants; (2) female participants; (3) samples presenting a mean age > 20 years; (4) matches performed on pitches with reduced dimensions (i.e., small-sided games, except as defined by the local soccer governing body according to information presented in the text); (5) games played as training/practice sessions; (6) laboratory-based and/or field tests measuring running performance; (7) use of running protocols to simulate soccer match play demands; (8) studies investigating other football codes (American football, Australian Rules football, Gaelic football, rugby, indoor soccer) rather than soccer; (9) unrelated samples (e.g., referees); and (10) soccer players competing and/or originally described as senior professionals or semiprofessionals. We also excluded articles that did not contain one of the descriptors cited in the search strategy (see Sect. 2.1) in the title, abstract and/or keywords.

2.3 Methodological Quality Assessment

The methodological quality was assessed in line with two previous review articles related to sport physical performance [35] and soccer match running data collection [36]. All of the included studies were appraised using the answers to nine questions (Q1–9), designed with minor adaptations from the aforementioned systematic review papers (Table 1). For this purpose, a three-point scale was adopted (where "yes" = 2 points; "maybe" = 1 point; "no" = 0), except for Q4 [36]. Strict rules that were applied to Q2, Q3 and Q8 are also described in a footnote to Table 1. Next, a summation of the attributed points from all the questions was performed for each study; the possible quality rating varied from 0 to 18 points. Finally, the obtained values were converted into percentages (minimum 0% to maximum 100%). The studies were deemed to have an appropriate level of quality when they scored > 75% [35]. Methodological quality was not evaluated for the purpose of including/excluding studies.

2.4 Data Extraction

In each search in the aforementioned databases, two evaluators (LV, RA) independently examined the article title, abstract and keywords in the first stage of screening according to the established inclusion and exclusion criteria. Inter-rater agreement was evaluated by Cohen's kappa coefficient (k). If any disagreements occurred, a senior researcher (CC) examined the situation on a case-by-case and determined the inclusion or exclusion of a given article using his greater experience in the field. The agreement rate was $k = 0.97$. We examined the texts to identify the terminologies employed in reference to the method used and for running performance variable(s) definition. Demographic details of the included studies were then extracted, including sample size, age/age group of the participants and the geographical location where the study was conducted. Methodological descriptions included match type, format (pitch size, number of players a-side, whether a rolling substitute policy was adopted) and configuration (duration and number of periods), measurement techniques/equipment, acquisition frequency used to obtain running performance data and speed threshold limits. Finally, general results regarding match running performance were extracted and the main findings were organized and described in Sect. 3.4. When outcome measures were presented as figures (e.g., column graphics), a specific routine that was custom written in the MATLAB® environment (The MathWorks Inc., Natick, USA) using the "ginput.m" function was employed to perform a more accurate extraction of the data.

Table 1 Methodological quality assessment scoring system

	Question	Answer	Score
Q1	Study objective(s) is/are clearly set out	Yes = 2; Maybe = 1; No = 0	0–2
Q2	Demographic data are presented (including assignment of age/age group, maturity status measured)	Yes = 2; Maybe = 1; No = 0	0–2
Q3	Game rules (including five items: match duration, field size, players a-side, match type, whether rolling substitute policy was adopted) are described	Yes = 2; Maybe = 1; No = 0	0–2
Q4	The reliability/validity of the time–motion system/equipment is not stated, mentioned (i.e., a citation of previous studies) or measured under local conditions where data collections took place	Measured = 2; Mentioned = 1; Not stated = 0	0–2
Q5	Dependent variables defined	Yes = 2; Maybe = 1; No = 0	0–2
Q6	The duration of players recordings/inclusion criteria (an entire half time, a whole match, a certain percentage, etc.) is clearly indicated	Yes = 2; Maybe = 1; No = 0	0–2
Q7	Statistics are appropriate	Yes = 2; Maybe = 1; No = 0	0–2
Q8	Results are detailed (mean and standard deviation, percent change/difference, effect size/mechanistic magnitude-based inference)	Yes = 2; Maybe = 1; No = 0	0–2
Q9	Conclusions are insightful (clear, practical applications, and future directions)	Yes = 2; Maybe = 1; No = 0	0–2
Total			0–18

Adapted from Bishop et al. [35], Castellano et al. [36], with permission

Strict rules applied to Q2 (no information = 0 point; only age/age group was informed = 1 point; maturity offset also measured = 2 points); Q3 (0–1 item described = 0 point; 2–3 items described = 1 point; 4–5 items described = 2 points); and Q8 (description of mean, standard deviation and null hypothesis significance test [p-value] = 1 point; also included effect size/magnitude-based inferences = 2 points)

3 Results

3.1 Search Results

The search process obtained 5801 records. Figure 1 presents the number of articles found in each electronic database and a flow chart of the literature search, including all the steps performed. Following the removal of duplicates, 2102 titles remained in the reference manager. Following the examination of titles, abstracts and keywords of all these manuscripts, 73 academic studies were eligible and retained for additional (i.e., full-text) analysis; 34 articles were excluded at this stage. Upon further inspection of the full text of the eligible articles and their respective bibliographical references, a total of 50 articles [12–20, 23, 24, 26–33, 37–67] fulfilled all of the inclusion criteria and none of the exclusion criteria and were included in the current systematic review (i.e., qualitative analysis).

3.2 Methodological Quality

The methodological quality scores attributed to the included studies can be found in Table 2. Scores for the articles ranged from a minimum of 44% [66] to the maximal possible score (100%) (two studies [20, 47]). We identified a mean ± standard deviation quality score for the 50 selected articles of 79 ± 13%. Several papers ($N = 20$), accounting for 40% of the total literature, were classified as 80–90% [13, 14, 16, 17, 19, 24, 26, 29, 30, 33, 38, 41, 42, 48, 49, 52–54, 57, 60]; in addition, six papers (12%) received very high ratings of between 90 and 100% [15, 18, 20, 46, 47, 51]. A total of 72% of the papers ($N = 36$ publications [12–20, 24, 26, 28–30, 32, 33, 38, 40–43, 46–49, 51–54, 56–58, 60–63]) reached an appropriate quality score, being classified as > 75% [34], and this was not the case for the remaining articles (28%; $N = 14$ publications [23, 27, 31, 37, 39, 44, 45, 50, 55, 59, 64–67]).

3.3 Research Paradigm

3.3.1 General Information

Table 3 describes in detail the demographic and methodological characteristics of the included papers. Running performance was investigated in match play in a total of 2615 young players. This represents a mean of ≈ 52 players per study. The sample sizes ranged from a minimum of six [37] to a maximum of 380 [48] participants. The earliest articles were published in 2001 [37, 59]. Figure 2 shows the yearly distribution frequency of publications since 2000. A gradually increasing trend has occurred over the current decade (2010–2017; approximately five articles published per year) compared with the previous decade (2001–2009; approximately one article published per year). The mean age for the youngest group identified was 7.9 years [20], and the oldest group included 20-year-old players [57]. The majority of evaluations were from the European continent (62% of the total): England (14%) [13, 15, 19, 26, 33, 44, 47], Italy (10%) [20, 24, 37, 57, 66], Denmark [38, 54, 67], Portugal [43, 62, 65], Poland [23, 55, 64], Spain [56, 61], San Marino [39, 40], Norway [31, 59], Turkey [29], Croatia [50] and Austria [49]. Other investigations were conducted in Asia, particularly in Qatar (18%) [12, 14, 17, 18, 41, 42,

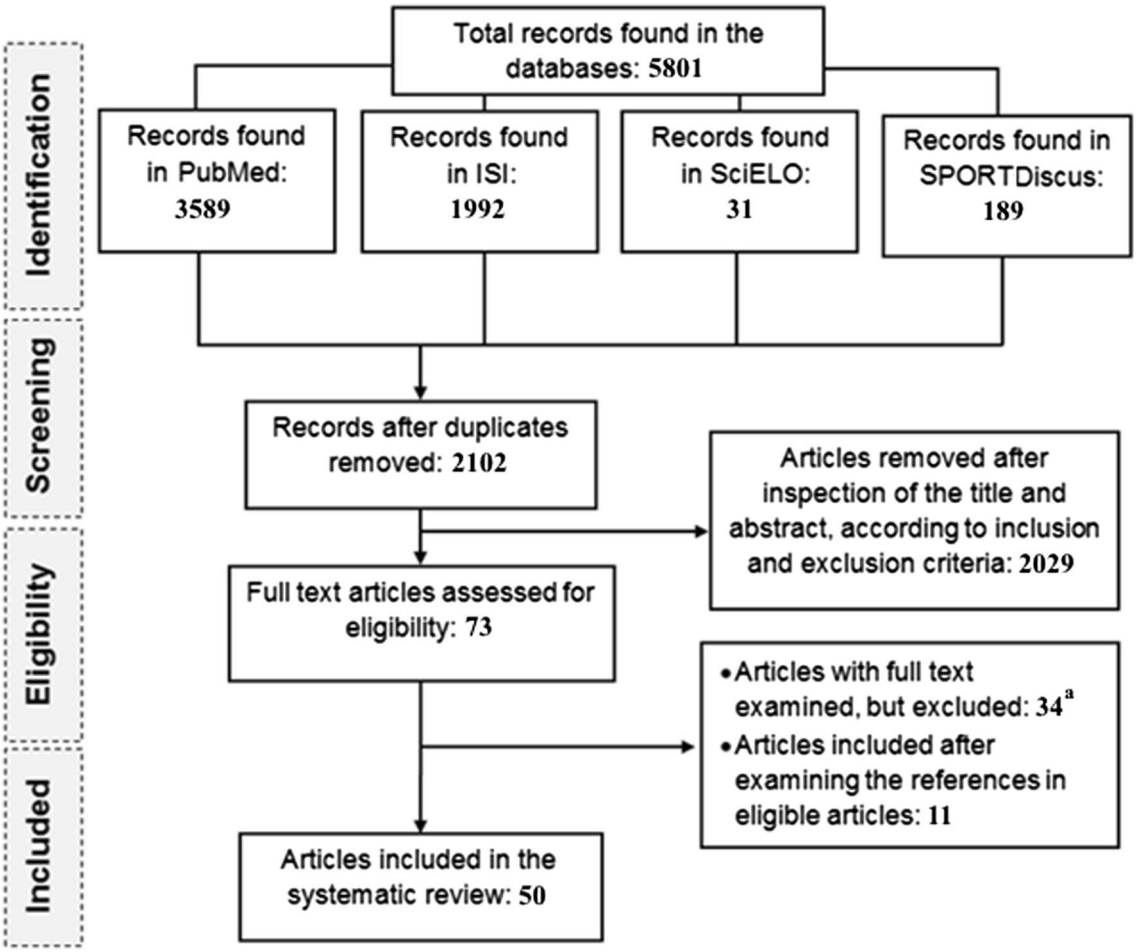

Fig. 1 Flow chart of literature search including all steps performed according to the PRISMA statement. [a]Failed to meet inclusion criterion 7 ($n=7$), and fulfillment of exclusion criteria 3 ($n=3$), 4 ($n=1$), 5 ($n=3$), 6 ($n=17$) and 7 ($n=3$)

48, 51, 60]. Studies from Oceania (10%), including New Zealand [15] and Australia [30, 52, 53, 58], were also identified. The remaining publications were from North America (USA [53]) and South America (14%), most frequently Brazil (10%) [27, 28, 32, 45, 46]; two records from Bolivia [30, 58] were also found (Table 3).

3.3.2 Study Objectives

The main study objectives identified were primarily to characterize general game demands (22%) [12, 14, 15, 23, 24, 26, 27, 29, 43, 48, 64] and to compare the running performance between playing positions (20%) [12, 14, 18, 19, 23, 27, 48, 62, 65, 66], age groups (26%) [12–18, 20, 26, 27, 60, 66, 67] and match halves/periods (36%) [12, 14, 16, 20, 23, 24, 29, 31, 32, 37–40, 45, 48, 56, 57, 64]. Further studies also examined the influence of biological maturity [38, 51, 60], playing standards [33, 38, 48, 54] and retained versus released players [15, 19, 26] and compared match running performances between game formats [37, 54, 61] and between specific training regimens [63]. Approximately one-third of all the studies evaluated relationships between the variables of match running performance and (1) anthropometric measures (e.g., height, body weight, and skinfolds) [50, 60], (2) physiological markers [45, 57] (e.g., creatine kinase [CK], lactate dehydrogenase [LDH], cortisol, interleukin [IL]-6, and testosterone levels) and, more frequently, (3) indicators of physical capacity provided through laboratory-based methods (e.g., maximal oxygen consumption [$\dot{V}O_{2max}$] and speed attained at $\dot{V}O_{2max}$ [$v\dot{V}O_{2max}$] obtained through an incremental treadmill protocol) and field testing (e.g., YoYo Intermittent Recovery Test Level 1 (YoYo IR1) [68], running-based anaerobic sprint test (RAST) [69], Hoff test [70] and Vam-Eval test [71]) [14, 17, 18, 20, 28, 29, 39, 40, 43, 46, 47, 65]. Researchers also investigated the effects of match congestion [49, 51, 52], moderate [53] and high

Table 2 Methodological quality outcomes attributed to studies on match running performance in youth soccer players

Study	Year	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Total (∑)	Quality score (%)
Al Haddad et al. [17]	2015	2	1	2	1	2	2	2	2	2	16	89
Andrzejewski et al. [55]	2011	1	1	0	0	2	2	2	1	1	10	56
Andrzejewski et al. [23]	2009	2	1	1	0	1	2	0	1	2	10	56
Aquino et al. [45]	2016	2	2	1	0	2	0	2	1	2	12	67
Aquino et al. [32]	2016	2	1	1	1	2	2	2	1	2	14	78
Aquino et al. [28]	2018	2	1	1	1	2	2	2	1	2	14	78
Arruda et al. [49]	2015	2	1	1	1	2	2	2	2	2	15	83
Aslan et al. [29]	2012	2	1	2	0	2	2	2	2	2	15	83
Atan et al. [16]	2016	2	1	2	1	2	1	2	2	2	15	83
Aughey et al. [30]	2013	2	2	2	0	2	1	2	2	2	15	83
Bravo-Sánchez et al. [61]	2017	2	2	2	0	2	0	2	2	2	14	78
Bellistri et al. [20]	2017	2	2	2	2	2	2	2	2	2	18	100
Brito et al. [62]	2017	2	1	2	0	2	1	2	2	2	14	78
Buchheit et al. [18]	2010	2	2	2	1	2	2	2	2	2	17	94
Buchheit et al. [12]	2010	2	1	2	1	2	2	1	1	2	14	78
Buchheit et al. [51]	2011	2	2	2	1	2	2	2	2	2	17	94
Buchheit et al. [42]	2013	2	2	2	1	2	1	2	2	2	16	89
Buchheit and Mendez-Villanueva [60]	2014	2	2	2	1	2	2	2	1	2	16	89
Buchheit et al. [58]	2015	2	1	2	0	2	2	2	2	1	14	78
Capranica et al. [37]	2001	2	1	1	2	2	0	1	1	1	11	61
Castagna et al. [24]	2003	2	1	2	2	2	1	2	1	2	15	83
Castagna et al. [39]	2009	2	1	1	1	2	0	2	1	2	12	67
Castagna et al. [40]	2010	2	1	1	2	2	0	2	2	2	14	78
Dello Iacono et al. [63]	2017	2	1	0	1	2	2	2	2	2	14	78
Doncaster et al. [47]	2016	2	2	2	2	2	2	2	2	2	18	100
Fernandes-da-Silva et al. [46]	2016	2	2	2	1	2	2	2	2	2	17	94
Garvican et al. [53]	2014	2	1	1	1	2	2	2	2	2	15	83
Goto et al. [26]	2015	2	2	2	1	2	2	2	2	1	16	89
Goto et al. [15]	2015	2	1	2	2	2	2	2	2	2	17	94
Harley et al. [13]	2010	2	1	2	1	2	2	2	2	2	16	89
Helgerud et al. [59]	2001	2	1	0	2	1	0	2	1	2	11	61
Hunter et al. [44]	2015	2	1	0	0	2	2	2	2	2	13	72
Kęsicki and Lewicki [64]	2017	1	1	1	0	2	2	0	0	2	9	50
Mendez-Villanueva et al. [41]	2011	2	1	2	1	2	2	2	2	2	16	89
Mendez-Villanueva et al. [14]	2013	2	1	2	1	2	2	2	2	2	16	89
Pereira Da Silva et al. [27]	2007	2	1	1	2	2	0	1	1	1	11	61

Table 2 (continued)

Study	Year	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Total (∑)	Quality score (%)
Pettersen et al. [31]	2014	2	1	1	0	2	1	2	2	2	13	72
Rago et al. [65]	2017	2	1	1	0	2	0	2	1	2	11	61
Randers et al. [56]	2010	2	1	1	2	2	2	1	1	2	14	78
Randers et al. [54]	2014	2	1	2	1	2	1	2	2	2	15	83
Rebelo et al. [43]	2014	2	1	1	1	2	2	2	1	2	14	78
Izzo and Varde'i [66]	2017	2	1	0	0	2	1	0	0	2	8	44
Romagnoli et al. [57]	2016	2	1	2	2	2	2	2	1	2	16	89
Rowsell et al. [52]	2011	2	1	1	1	2	2	2	2	2	15	83
Saward et al. [19]	2016	2	1	1	1	2	2	2	2	2	15	83
Sporis et al. [50]	2017	2	1	1	0	2	0	2	1	2	11	61
Stroyer et al. [38]	2004	2	2	1	2	2	2	1	1	2	15	83
Varley et al. [48]	2017	2	1	1	1	2	2	2	2	2	15	83
Vigh-Larsen et al. [67]	2018	2	1	0	1	2	2	2	1	2	13	72
Waldron and Murphy [33]	2013	2	1	2	1	2	2	2	1	2	15	83
Mean ± standard deviation		1.96 ± 0.20	1.24 ± 0.43	1.36 ± 0.69	0.94 ± 0.71	1.96 ± 0.20	1.48 ± 0.79	1.78 ± 0.55	1.52 ± 0.58	1.90 ± 0.30	14 ± 2	79 ± 13

altitude [30, 58], specific pitch surface [62] and opponent quality [48] on running performance. Seasonal changes in physical capacity (i.e., performance derived from fitness tests) associated with those in match running performance were examined [42]. Also examined were interventional pre- and postmatch strategies, including prematch supplementation with caffeine [31] and postmatch recovery using cold water immersion [52] or spa treatments (combined sauna, cold water immersion and jacuzzi) [51]. Five remaining articles (10% of the total) investigated the effects of training on running performance during match play using longitudinal experimental approaches [19, 32, 42, 55, 59]. Figure 3 presents the various research topics addressed in the studies on match running performance.

3.3.3 Match Type and Configuration

In total, 29 studies (58% of the total) analyzed performance in official competitions [13–20, 23, 24, 26–28, 33, 37–40, 43, 44, 48–51, 61, 63, 65–67], eight (16%) were friendly matches [12, 29, 30, 41, 42, 53, 58, 60] and 11 (20%) were simulated matches [31, 32, 45–47, 52, 54, 56, 57, 62, 64]. Two studies did not clearly specify the match type [55, 59]. Among the studies, 50% exclusively used a game format with 11 players a-side [12–17, 24, 27, 29, 30, 37, 39–43, 46, 47, 50, 51, 54, 57, 60, 62, 65]. Some of these compared age groups and used the 11-a-side format regardless of age (e.g., U11 to U16 [15], U12 to U16 [13] and U13 to U18 [12, 14, 42, 51]). In contrast, Goto et al. [26] employed 6 versus 6 in the U9–U10 age groups, and Bellistri et al. [20] used 5 versus 5 and 7 versus 7 for U8 and U10 players, respectively. Additionally, Saward et al. [19] examined U9 to U18 soccer players, adopting 11 versus 11 in U12 to U18s, whereas the authors adjusted the number of players per side for the younger players of U9–U10 (5 vs. 5 and 7 vs. 7) and U11s (7 vs. 7 and 11 vs. 11). The remaining articles (44%) did not provide sufficient information to fully characterize the number of players per side [23, 28, 31, 32, 38, 44, 45, 48, 49, 52, 53, 55, 56, 59, 63, 64, 66, 67]. Some studies (8%) (England [13, 33], Italy [20], New Zealand [16]) adopted a rolling substitute policy, in which players were allowed to return to the field after being replaced. One study [53] used both the official and the interchangeable substitution methods. Additional information regarding game configuration (field size, duration and number of playing periods) is presented in Table 3.

3.3.4 Speed Thresholds

Table 4 presents speed thresholds adopted (i.e., superior and inferior speed limits) across studies. A total of 34 studies employed arbitrary fixed speed thresholds (68% of the total) with unit measures in km/h or m/s [12, 15,

Table 3 Demographic characteristics and methodologies employed in studies measuring match running performance in young soccer players

Study	*N*	Age (years)[a]	Duration (min)	Field size (m)[b]	Match type	Rolling substitute policy	Players a-side	Location	Technology used and acquisition frequency
Bellistri et al. [20]	$n=27$	U8 U10	3×15	45×25 60×40	Official	Yes	5 vs. 5 7 vs. 7	Italy	GPS–K-GPS, K-Sport, Italy (10 Hz)
Goto et al. [26]	$n=34$	U9 U10	4×15 or (2×20+2×15)	44.8×26	Official	–	6 vs. 6	England	GPS–GPsports, Australia (1 Hz)
Bravo-Sánchez et al. [61]	$n=154$	10.7±0.8	2×25	40×60	Official	–	7 vs. 7 or 8 vs. 8	Spain	GPS–GPsports, Australia (5 Hz)
Capranica et al. [37]	$n=6$	11	–	100×65	Official	–	11 vs. 11	Italy	Observational analysis–video records
Castagna et al. [24]	$n=11$	11.8±0.6	2×30	100×65	Official	–	11 vs. 11	Italy	Triangular surveying method
Stroyer et al. [38]	$n=26$	12.1±0.7 12.6±0.6 14±0.2	2×30 2×30 2×35	–	Official	–	–	Denmark	Observational analysis–video records
Pereira Da Silva et al. [27]	$n=75$	U15 U17 U20	2×30 2×40 2×45	–	Official	–	11 vs. 11	Brazil	Observational analysis–video records
Randers et al. [54]	$n=41$	U13	20	105×68	Simulated	–	11 vs. 11	Denmark	GPS–MinimaxX, Catapult, Australia (10 Hz)
Andrzejewski et al. [55]	$n=19$	13.5±0.4	–	–	–	–	–	Poland	Visual tracking system–software BANAL
Andrzejewski et al. [23]	$n=10$	13.5±0.4	2×25	100×68	Official	–	–	Poland	Kinematic method–software BANAL
Fernandes-da-Silva et al. [46]	$n=33$	13.5–15.9	2×35	90×45	Simulated	–	11 vs. 11	Brazil	GPS–K-GPS, K-Sport, Italy (10 Hz)
Doncaster et al. [47]	$n=17$	12–14	2×20	90×50	Simulated	–	11 vs. 11	England	GPS–Catapult, Australia (10 Hz)
Buchheit et al. [18] Mendez-Villanueva et al. [14] Buchheit et al. [51] Al Haddad et al. [17] [except U18]	$n=99$ $n=103$ $n=33$ $n=180$	U13 U14 U15 U16 U17 U18	2×35 2×35 2×40 2×40 2×40 2×45	100×70	Official	–	11 vs. 11	Qatar	GPS–GPsports, Australia (1 Hz)
Buchheit et al. [12] Buchheit et al. [42]	$n=99$ $n=124$	U13 U14 U15 U16 U17 U18	2×35 2×35 2×40 2×40 2×40 2×45	100×70	Friendly	–	11 vs. 11	Qatar	GPS–GPsports, Australia (1 Hz)
Castagna et al. [39]	$n=21$	14.1±0.2	2×30	–	Official	–	11 vs. 11	San Marino	GPS–GPsports, Australia (1 Hz)

Table 3 (continued)

Study	*N*	Age (years)[a]	Duration (min)	Field size (m)[b]	Match type	Rolling substitute policy	Players a-side	Location	Technology used and acquisition frequency
Castagna et al. [40]	$n=18$	14.4 ± 0.1	2×30	–	Official	–	11 vs. 11	San Marino	GPS–GPsports, Australia (1 Hz)
Harley et al. [13]	$n=112$	U12 U13 U14 U15 U16	3×25 or $(2 \times 25 + 2 \times 12.5)$ 2×40	77×60 77×60 99×65 99×65 99×65	Official	Yes	11 vs. 11	England	NdGPS–MinimaxX, Catapult, Australia (5 Hz)
Rowsell et al. [52]	$n=13$	15.9 ± 0.6	90	–	Simulated	–	–	Australia	GPS–GPsports, Australia (1 Hz)
Mendez-Villanueva et al. [41]	$n=14$	16.7 ± 0.7	2×40–45	100×70	Friendly	–	11 vs. 11	Qatar	GPS–GPsports, Australia (1 Hz)
Brito et al. [62]	$n=66$	U14	30	100×64	Simulated	No	11 vs. 11	Portugal	GPS–Qstarz, Taiwan (10 Hz)
Waldron and Murphy [33]	$n=31$	U14	$2 \times 25 + 2 \times 12.5$	99×65	Official	Yes	–	England	GPS–GPsports, Australia (5 Hz)
Buchheit and Mendez-Villanueva [60]	$n=36$	U15	2×40	100×70	Friendly	–	11 vs. 11	Qatar	GPS–GPsports, Australia (1 Hz)
Rebelo et al. [43]	$n=30$	U17	80	–	Official	–	11 vs. 11	Portugal	Observational analysis–video records
Goto et al. [15]	$n=81$	U11 U12 U13 U14 U15 U16	$(2 \times 20 + 2 \times 15)$ or 3×25 3×25 3×25 2×40 2×40 2×40	78.7×54.1 78.7×54.1 88×64.2 100.8×68.2 100.8×68.2 100.8×68.2	Official	–	11 vs. 11	England	GPS–GPsports, Australia (1 Hz)
Saward et al. [19]	$n=263$	U9 U10 U11 U12 U13 U14 U15 U16 U17 U18	60–80 60–80 60–80 75–80 75–80 80–90 80–90 80–90 80–90 80–90	–	Official	–	5 vs. 5–7 vs. 7 5 vs. 5–7 vs. 7 7 vs. 7–11 vs. 11 11 vs. 11 11 vs. 11 11 vs. 11 11 vs. 11 11 vs. 11 11 vs. 11 11 vs. 11	England	GPS–GPsports, Australia (1 and 5 Hz)
Aquino et al. [45]	$n=18$	U16	2×30	70×50	Simulated	–	–	Brazil	Videogrammetry method
Aquino et al. [32]	$n=10$	15.4 ± 0.2							Automatic tracking–DVIDEOW, Brazil (30 Hz)

Table 3 (continued)

Study	*N*	Age (years)[a]	Duration (min)	Field size (m)[b]	Match type	Rolling substitute policy	Players a-side	Location	Technology used and acquisition frequency
Atan et al. [16]	$n=85$	U13 U14 U15	2×30 2×35 2×40	100×60	Official	Yes	11 vs. 11	New Zealand	GPS–GPsports, Australia (5 Hz)
Arruda et al. [49]	$n=10$	U15	2×25–30	–	Official	–	–	Austria	GPS–GPSports, Australia (15 Hz)
Aquino et al. [28]	$n=18$	U15 U17	2×30 2×40	105×68	Official	–	–	Brazil	Videogrammetry method Manual tracking–DVIDEOW, Brazil (30 Hz)
Varley et al. [48]	$n=380$	U17	2×45	–	Official	–	–	Qatar	Videogrammetry method–Prozone Sports Ltd
Aslan et al. [29]	$n=32$	17.6±0.6	2×45	105×68	Friendly	–	11 vs. 11	Turkey	Videogrammetry method Manual tracking–Mathball Match Analysis System, Algoritma Company, Turkey
Helgerud et al. [59]	$n=19$	18.1±0.8	–	–	–	–	–	Norway	Videogrammetry method Manual tracking–Wacom Digitizer SD-421-E digital board (Wacom Co., Ltd, Japan) and a marking pen (Arntzen Engineering, Norway)
Sporis et al. [50]	$n=37$	18.4±0.1	2×45	–	Official	–	11 vs. 11	Croatia	System 3D tille sport analyzer
Vigh-Larsen et al. [67]	$n=30$	U17 U19	–	–	Official	–	–	Denmark	Local positioning system ZXY Tracking System (20 Hz)–radio, Chyron-Hego Corp., USA
Aughey et al. [30] Buchheit et al. [58]	$n=20$ $n=13$	U17–U18	2×45	105×68	Friendly	–	11 vs. 11	Australia/Bolivia	GPS–MinimaxX, Catapult, Australia (10 Hz)
Pettersen et al. [31]	$n=22$	17.6±1.1	90	–	Simulated	–	–	Norway	ZXY Sport Tracking System (20 Hz)–radio, Norway
Hunter et al. [44]	$n=12$	U18	–	–	Official	–	–	England	GPS–Catapult Innovations, Australia (5 Hz)
Rago et al. [65]	$n=29$	U19	–	–	Official	–	11 vs. 11	Portugal	GPS–Qstarz, Taiwan (5 Hz)
Dello Iacono et al. [63]	$n=24$	U19	–	–	Official	–	–	NYL and UEFA	GPS–GPsports, Australia (15 Hz)

Table 3 (continued)

Study	*N*	Age (years)[a]	Duration (min)	Field size (m)[b]	Match type	Rolling substitute policy	Players a-side	Location	Technology used and acquisition frequency
Kęsicki and Lewicki [64]	$n=18$	18.1 ± 1.2	90	–	Simulated	–	–	Poland	GPS–OptimEye, Catapult, Australia (10 Hz)
Garvican et al. [53]	$n=20$	U20	2×45 3×25–30	–	Friendly	No Yes	–	Australia/USA	GPS–MinimaxX, Catapult, Australia (10 Hz)
Izzo and Varde'i [66]	–	U20	–	–	Official	–	–	Italy	GPS–K-GPS, K-Sport, Italy (20 Hz)
Randers et al. [56]	$n=20$	19.3 ± 1.2	2×47.5	105×68	Simulated	–	–	Spain	GPS (MinimaxX, Catapult/GPsports, Australia) (1 and 5 Hz); video-based time-motion and semi-automatic video tracking (Amisco Pro®, France)
Romagnoli et al. [57]	$n=22$	17–20	2×45	–	Simulated	No	11 vs. 11	Italy	Semi-automatic video tracking–Wisport, Italy

GPS global positioning system, *NYL* National Youth League, *UEFA* Union of European Football Associations

[a]Mean, range or age category

[b]Field size = length × width

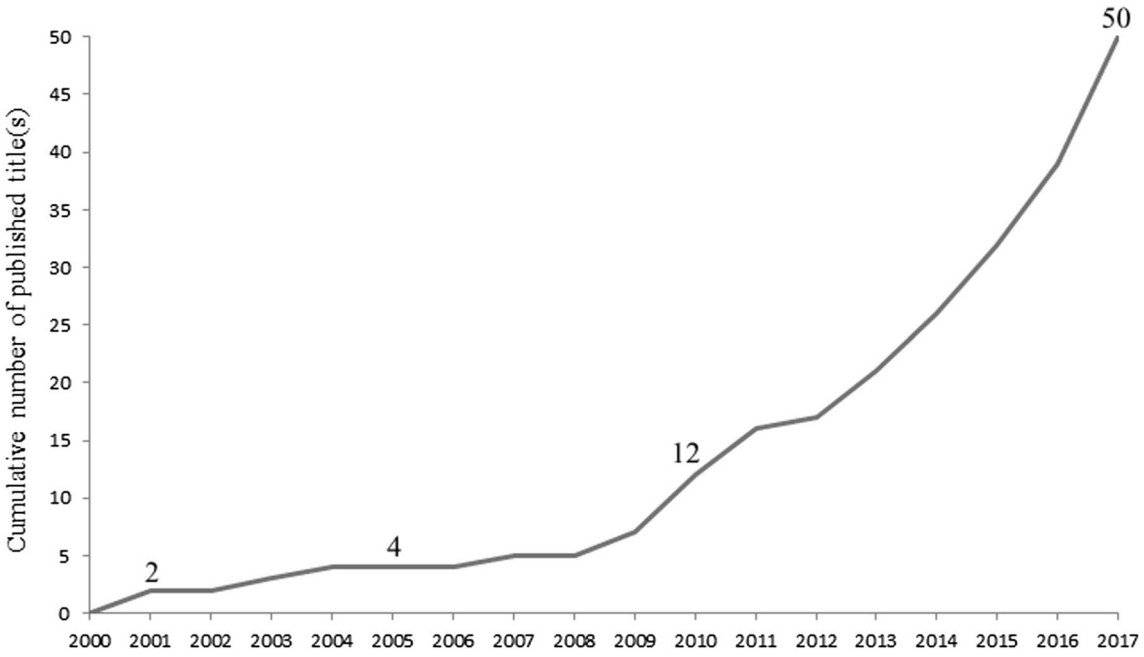

Fig. 2 Yearly distribution frequency and cumulative sum of the number of publications included in the current systematic review addressing match running performance in young soccer players

18, 23, 24, 28–33, 39, 40, 42–46, 48–57, 60–62, 65–67], whereas 14 (28%) used individualized speed thresholds [12–17, 19, 20, 26, 29, 41, 42, 44, 47]. Nine studies (18%) employed both methods [12, 15, 17, 29, 41, 42, 44, 58, 63]. Three types of individualization techniques were reported: (1) speed thresholds derived according to individual physical capacity using data from fitness testing protocols (20%)—these were generally based on maximal linear sprint speed, lactate concentrations, and $v\dot{V}O_{2max}$ tests [12, 14, 15, 17, 29, 41, 42, 44, 47, 58]; (2) thresholds proposed according to mean values for physical capacity (e.g., maximal linear sprint speed test) for each age group (12%) [13, 15, 16, 19, 20, 26]; and (3) individual sprinting threshold using a percentage of individual peak game speed relative to an arbitrary fixed threshold (25.2 km/h) [63]. Four remaining studies [27, 37, 38, 43] were conducted using operator judgment of the intensities reached during running displacements (i.e., video-based time-motion [VTM]) performed by players in a given movement category. The number of speed thresholds used ranged from a minimum of one to a maximum of eight (ST1–ST8). There were 31 distinct arbitrary fixed speed thresholds, 26 distinct individualized speed thresholds by mean age-band physical capacity, and 11 distinct individualized speed thresholds by individual physical capacity employed to characterize the youth players' running performance (see Table 4).

3.3.5 Technology

In reference to the technologies utilized to quantify match running performance, 25 studies employed global positioning systems (GPS) exclusively (64%), with sampling frequencies preset at 1 Hz (28%) [12, 14, 15, 17–19, 26, 39–42, 51, 52, 60], 5 Hz (14%) [13, 16, 19, 33, 44, 61, 65], 10 Hz (16%) [20, 30, 46, 47, 53, 54, 62, 64], 15 Hz [49, 63] and 20 Hz [66]. Among the remaining studies, four employed VTM [27, 37, 38, 43], and eight used video tracking (i.e., videogrammetry) approaches (16%), which were performed either manually [28, 29, 59], semi-automatically [48, 57] or automatically (30 Hz) [32, 45], or the method was not stated [55]. One investigation compared 1 Hz GPS, 5 Hz GPS, VTM techniques and semiautomatic video-tracking methods [56]. Two studies did not provide sufficient information about their methodologies [23, 50]. Castagna et al. [24] adopted a triangular surveying method (for more information see Carling et al. [4] and Ohashi et al. [72]), and two studies utilized a three-dimensional local radio processing system (20 Hz) [31, 67].

3.3.6 Terminology

Nine distinct nomenclatures were used to the report the methodology used to obtain the running performance variables, ordered from the most to least frequent, as follows: (1) match analysis (36%) [12, 15, 16, 19, 24, 26, 27, 29, 31,

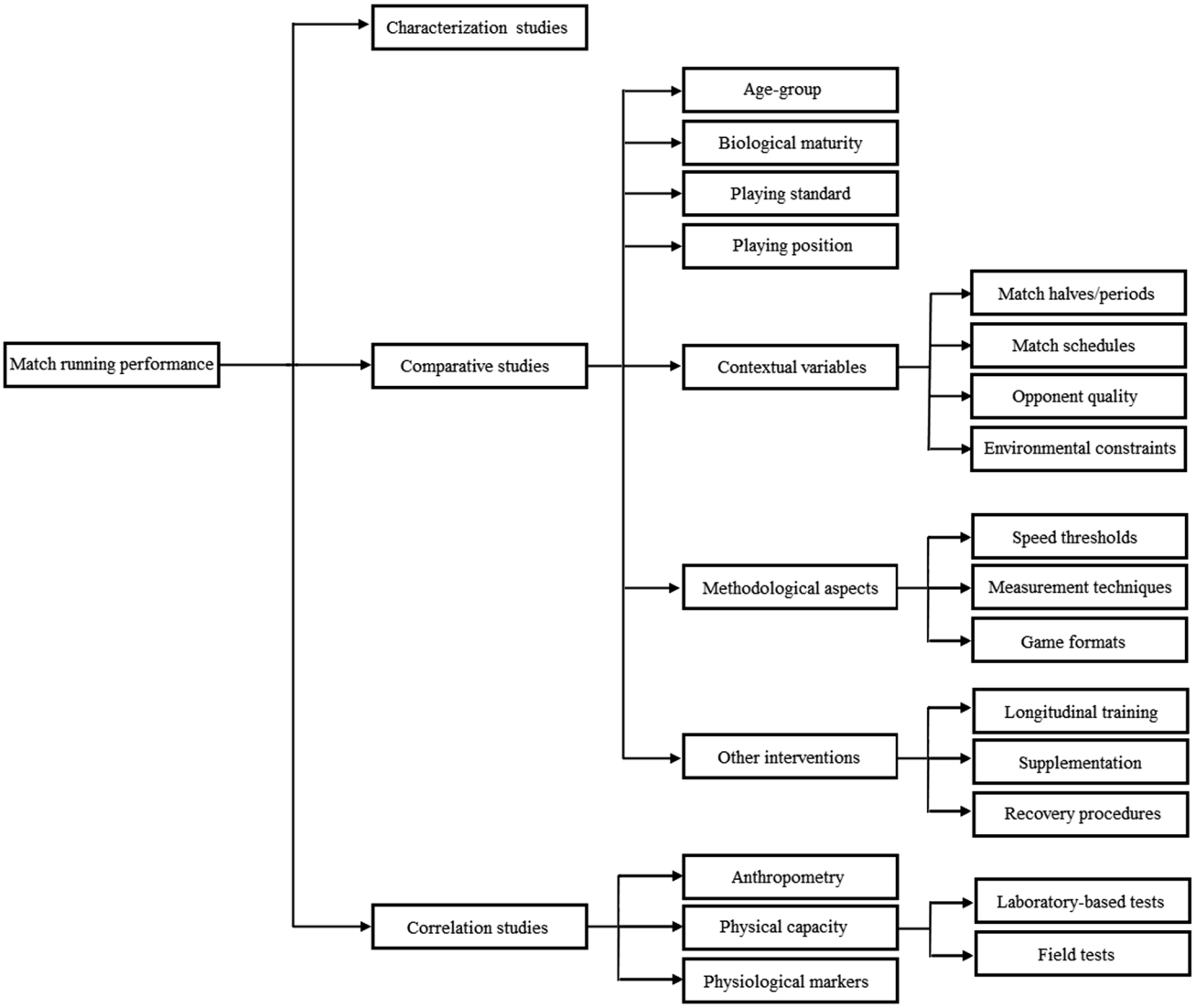

Fig. 3 Research topics of studies on match running performance in young soccer players

37, 41, 43, 44, 46, 51, 57, 60, 61]; (2) TMA (22%) [12, 14, 17, 18, 41, 42, 44, 51, 56, 62, 65]; (3) performance analysis [28, 32, 39, 52]; (4) motion analysis [13, 15, 16]; (5) kinematic analysis [23, 55]; (6) physical analysis [45]; (7) video analysis [59]; (8) movement analysis [33]; and (9) external load data collection [63]. To define and group dependent variables related to running performance, we verified 20 different descriptions, ordered from the most to least frequent, as follows: (1) match running performance (26%) [14, 16–20, 28, 41, 42, 51, 52, 58, 60]; (2) match activities (24%) [15, 16, 24, 26, 31, 33, 38–40, 43, 47, 50]; (3) activity profile (22%) [24, 30, 31, 39, 40, 46, 53, 54, 56, 58, 67]; (4) distances covered (10%) [13, 27, 57, 59, 64]; (5) physical performance [32, 40, 47, 48]; (6) movement patterns [27, 29, 32, 65]; (7) activity pattern [38, 41, 54]; (8) player's movements [37, 44, 48]; (9) physical loads [23, 40]; (10) physical match performance [43, 46]; (11) running performance [53]; (12) running activity [62]; (13) motor performances [23]; (14) displacement patterns [45]; (15) running measures [49]; (16) match intensity [58]; (17) match play intensity [14]; (18) running activity [41]; (19) physical variables [61]; (20) time–motion variables [63]; and unknown [55].

3.4 Match Running Performance

3.4.1 Playing Standard

For age-matched players (U13 and U14 categories), match running performance was greater in elite players (e.g., total distance covered, distance covered per minute, high-intensity running, peak game speed) [33, 54]. Conversely, these players performed fewer standing or low-intensity

Table 4 Speed thresholds used in studies to assess match running performance in youth soccer players

References	ST							
	Measure	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8
Fixed									
Castagna et al. [24]	km/h	< 8.0	8.1–13	13.1–18	> 18	> 13	–	–	–
Castagna et al. [39]	km/h	0–0.4	0.4–3	3–8	8–13	13–18	> 18	ST5 + ST6	
Buchheit et al. [18] Brito et al. [62]	km/h	< 13	13.1–16	16.1–19	> 19.1	ST3 + ST4	–	–	–
Castagna et al. [40]	km/h	0–0.4	0.4–3	3–8	8–13	13–18	> 18	–	–
Aslan et al. [29]	km/h	0–6	6.1–8	8.1–12	12.1–15	15.1–18	> 18.1	–	–
Waldron and Murphy [33]	km/h	< 6	6.1–13	13.1–19	> 19.1	–	–	–	–
Rebelo et al. [43]	km/h	0–0.4	0.4–3	3–8	8–13	13–18	> 18	RB	–
Goto et al. [15]	m/s	0–1.5	1.6–3.0	3.1–4.5	4.6–6.0	> 6.0	–	–	–
Hunter et al. [44]	km/h	< 14.99	15–17.99	18–24.99	25–35	–	–	–	–
Buchheit et al. [58]	km/h	> 14.4	–	–	–	–	–	–	–
Aquino et al. [45] Aquino et al. [32]	km/h	≤ 0.4	0.4–3	3.1–8	8.1–13	13.1–18	> 18	ST5 + ST6	–
Fernandes-da-Silva et al. [46]	km/h	13–18	> 18	ST1 + ST2	–	–	–	–	–
Varley et al. [48]	m/s	< 4	> 4	≥ 5.5	≥ 7	–	–	–	–
Arruda et al. [49]	km/h	> 18	–	–	–	–	–	–	–
Sporis et al. [50]	km/h	0.4–3	3–8	8–13	13–18	> 18			
Andrzejewski et al. [23]	m/s	< 3.5	≥ 3.5	–	–	–	–	–	–
Andrzejewski et al. [55]	m/s	≥ 5	–	–	–	–	–	–	–
Buchheit et al. [51]	km/h	< 13	13.1–16	16.1–19	> 19.1	ST3 + ST4	–	–	–
Rowsell et al. [52]	km/h	> 15	–	–	–	–	–	–	–
Aughey et al. [30] Garvican et al. [53]	m/s	0.01–4.16	4.17–10	–	–	–	–	–	–
Pettersen et al. [31]	km/h	> 19.8	> 25.2	–	–	–	–	–	–
Randers et al. [54]	km/h	0–0.2	0.2–4	4–8	8–12	12–16	16–20	> 20	–
Aquino et al. [28]	km/h	0–0.4	0.41–3	3.01–8	8–13	13.01–16	16.01–19	> 19.01	ST6 + ST7
Randers et al. [56]	km/h	> 7	9–13	16–22	> 22	–	–	–	–
Izzo and Varde'i [66]	km/h	0–10	10–14	14–16	16–21	21–24	> 24	–	–
Romagnoli et al. [57]	km/h	< 15	> 15	> 20	–	–	–	–	–
Vigh-Larsen et al. [67]	km/h	19.8–25.2	≥ 25.2	–	–	–	–	–	–
Buchheit et al. [12] Buchheit et al. [42] Dello Iacono et al. [63]	km/h	> 19	–	–	–	–	–	–	–
Bravo-Sánchez et al. [61]	km/h	≥ 13	≥ 15.7	≥ 20	–	–	–	–	–

Table 4 (continued)

References	ST									
	Measure		ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8
Buchheit and Mendez-Villanueva [60]	km/h		> 16	> 19	–	–	-	–	–	–
Rago et al. [65]	km/h		16–19	19–22	> 22	≥ 16	–	–	–	–
Individualized										
Age-band										
Bellistri et al. [20]	km/h	U8	< 6.3	6.4–8.4	8.5–11.5	11.6–17.3	> 18.2	ST3 + ST4 + ST5	–	–
		U10	< 6.7	6.8–9.6	9.7–13.2	13.3–18.2	> 17.3			
Goto et al. [26]	m/s	U9	0–1.0	1.1–2.0	2.1–3.1	3.2–4.1	> 4.1	–	–	–
		U10	0–1.0	1.1–2.1	2.2–3.1	3.2–4.2	> 4.2			
Saward et al. [19]	m/s	U9	< 2.74	≥ 2.74	≥ 4.56	–	–	–	–	–
		U10	< 2.84	≥ 2.84	≥ 4.73	–	–	–	–	–
		U11	< 2.91	≥ 2.91	≥ 4.85	–	–	–	–	–
		U12	< 3.05	≥ 3.05	≥ 5.08	–	–	–	–	–
		U13	< 3.19	≥ 3.19	≥ 5.31	–	–	–	–	–
		U14	< 3.34	≥ 3.34	≥ 5.6	–	–	–	–	–
		U15 U16	< 3.49	≥ 3.49	≥ 5.81	–	–	–	–	–
		U17, U18	< 3.51	≥ 3.51	≥ 5.85	–	–	–	–	–
			< 3.59	≥ 3.59	≥ 5.98	–	–	–	–	–
Goto et al. [15]	m/s	U11	0–1.1	1.2–2.1	2.2–3.2	3.3–4.2	> 4.2	–	–	–
		U12	0–1.1	1.2–2.2	2.3–3.2	3.3–4.3	> 4.3	–	–	–
		U13 U14	0–1.1	1.2–2.2	2.3–3.3	3.4–4.4	> 4.4	–	–	–
		U15, U16	0–1.2	1.3–2.3	2.4–3.5	3.6–4.6	> 4.6	–	–	–
			0–1.2	1.3–2.4	2.5–3.7	3.8–4.9	> 4.9	–	–	–
Atan et al. [16]	km/h	U13	0–0.4	0.4–4	4–8	8–13	13–18	> 18	–	–
		U14	0–0.4	0.4–4.5	4.5–8.5	8.5–13.5	13.5–18.5	> 18.5	–	–
		U15	0–0.4	0.4–5	5–9	9–14	14–19	> 19	–	–
Harley et al. [13]	m/s	U12	> 3.04	> 4.18	≥ 5.32	–	–	–	–	–
		U13 U14	> 3.16	> 4.34	≥ 5.53	–	–	–	–	–
		U15	> 3.18	> 4.37	≥ 5.56	–	–	–	–	–
		U16	> 3.56	> 4.89	≥ 6.22	–	–	–	–	–
			> 3.66	> 5.04	≥ 6.41	–	–	–	–	–
Individual physical capacity										
Buchheit et al. [58]	–		> 80% vs. YoYoIR1	–	–	–	–	–	–	–
Dello Iacono et al. [63]	–		(25.2/Vpeak) × 100							
Doncaster et al. [47]	–		> 50% MLV	> 70% MLV	> 90% MLV	–	–	–	–	–
Goto et al. [15]	m/s		0–20%MS_{5m}	21–40%MS_{5m}	41–60%MS_{5m}	61–80%MS_{5m}	80–MS_{5m}			
Mendez-Villanueva et al. [14]	km/h		< 60%MAS	61–80% MAS	81–100% MAS	101%MAS–30%ASR	> 31% ASR	–	–	–

Table 4 (continued)

References	ST								
	Measure	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8
Hunter et al. [44]	km/h	< RCT	RCT–$v\dot{V}O2_{max}$	$v\dot{V}O2_{max}$ –29%ASR	30%ASR–MSS	–	–	–	–
		< 79% MAS	80–99% MAS	100–139%MAS	10%MAS–35	–	–	–	–
		< 49% MSS	50–59% MSS	60–79% MSS	80–100%MSS	–	–	–	–
		< 79%MAS	80–99% MAS	100%MAS–29%ASR	30%ASR–MSS	–	–	–	–
Aslan et al. [29]	m/s	< FBL_2	$FBL_{2–4}$	> FBL_4	–	–	–	–	–
Buchheit et al. [42] Buchheit et al. [12]	km/h	> 61%MSS	–	–	–	–	–	–	–
VTM									
Capranica et al. [37]	–	Running	Walking	Inactivity	Jumping	–	–	–	–
Stroyer et al. [38]	–	Standing	Walking	LIR	HIR	–	–	–	–
Pereira Da Silva et al. [27]	–	Jogging	Walking	Sprint	LM	WB	RB	JB	SPR-b
Rebelo et al. [43]	–	Standing	Walking	Jogging	MIR	HIR	SPR	RB	–

ASR anaerobic speed reserve, obtained from the difference between MSS and MAS value, *FBL* running velocity correspondent to fixed blood lactate (FBL) < 2 (FBL_2), 2–4 ($FBL_{2–4}$) and > 4 $mmol{\cdot}L^{-1}$ ($FBL_{2–4}$) obtained from an incremental field test [29], *HIR* high-intensity running, *JB* jogging with the ball, *LIR* low-intensity running, *LM* lateral movement, *MAS* maximal aerobic speed, provided from the Vam-Eval incremental field test [71] or an incremental treadmill test [44], *MIR* medium-intensity running, *MLV* maximal linear velocity in a 20-m sprint test, MS_{5m} "flying" 5-m sprint speed reached during the 10-m sprint test, *MSS* maximal sprinting speed in a 40-m sprint test, *RB* running backward, *RCT* speed corresponding to respiratory compensation threshold, *SPR* sprinting, *SPR-b* sprint with the ball, *ST* speed threshold, $v\dot{V}O_{2max}$ velocity corresponding to 95% of the maximal oxygen consumption, *Vpeak* peak game speed, *VTM* video-based time-motion, *vYoYoIR1* final velocity reached in the YoYo Intermittent recovery test level 1 [68], *WB* walking backward

displacements [33, 38] than did nonelite or recreational peers. Studies also highlighted differences in match running performance, favoring academy players who were retained (e.g., greater distance covered per minute and low- to moderate-intensity running) compared with those released in some age groups [15, 19, 26]. In addition, a greater sprint distance was covered by top- and middle-ranked teams than by bottom-ranked U17 peers [48]. Table 5 summarizes the general match running performance results extracted from the reviewed papers. Indicators of running load included total distance covered, distance covered per minute, peak game speed reached and the distribution of distances covered according to speed thresholds.

3.4.2 Match Halves

Contrasting results regarding comparisons between halves were observed. Several studies (~47%) reported reductions in second-half measures of running performance (e.g., total distance covered, high-intensity running, repeated sprint sequences) [12, 14, 16, 29, 39, 40, 57]. In contrast, numerous articles (40%) reported no changes (e.g., total distance covered, time spent in high-intensity running, high-intensity running distance) [16, 20, 23, 24, 37, 43], and two (~13%) identified an increase (e.g., average speed, high-intensity running, peak game speed and number of sprints) [32, 45] in match running performance during the second half.

3.4.3 Age Group Comparisons

Concerning age-related performance, the values for some parameters (e.g., peak game speed, total distance covered, repeated sprint sequences, high-intensity running, high-intensity activities) were greater in the older than in the younger groups in cross-sectional studies [13–15, 17, 18, 20, 67] that used fixed speed thresholds. In addition, older players performed more high-intensity actions than younger peers in the same U15 age group [60]. Age-related differences varied from slight [18] to large [15]. On the other hand, when individualized speed thresholds were applied or distances covered were adjusted by effective playing time, the differences were less evident [12, 13, 15, 16, 18]. While studies rarely identified greater running outputs in younger than in older players in absolute terms (e.g., distance covered per minute [27]), this finding was more frequent when individualized speed bands were employed (e.g., repeated sprint sequences and peak game speed relative to maximal sprinting speed in field tests, distance covered above maximal aerobic speed) [12, 14, 16, 17]. In addition, players commencing puberty spent more time in standing/walking and lower jogging movements than did mature players [38]. There was evidence that more mature players achieved greater peak speeds and performed more high-intensity actions and repeated high-intensity actions in match-play than did less mature peers in the U15 category [60].

3.4.4 Between-Position Differences

Studies were in accordance that match running performance measures (e.g., total distance covered, peak game speed, frequency of sprints, sprinting distance) were position dependent [12, 14, 17–19, 23, 27, 29, 41, 42, 48, 62, 65, 66]. Centre backs reported the lowest values for total distance covered [14] and high-intensity activities [18, 23, 48, 62]; midfielders and second forwards covered the highest total distance covered; wide midfielders and forwards demonstrated the highest peak game speeds and frequency of high-intensity activities [17, 18, 66].

3.4.5 Association with Physical and Physiological Factors

Match running performance was moderately to strongly correlated with postmatch physiological markers (CK, LDH, cortisol, IL-6) in two studies [45, 57]. Positive relationships were also revealed on several occasions between match running performance (e.g., total distance covered, sprinting, high-intensity running, high-intensity activities) and physical capacity, as determined by the following tests: YoYo IR-1, YoYo IR-2, multistage fitness, Carminatti, 20-m shuttle run, Zig Zag, Hoff, RAST and 40-m sprint [17, 20, 28, 29, 39, 40, 43, 46, 47]. On the other hand, analysis across positional roles showed significant relationships between match running performance and physical capacity only in strikers and second strikers (e.g., very high-intensity match activities vs. Vam-Eval test [71]). Otherwise, nonsignificant trivial correlations were identified for fullbacks, center backs, midfielders and wide midfielders [18] (see an example of contrasting results in Rago et al. [65]). Similarly, low explanation power was revealed for several of the aforementioned tests (i.e., Zig-Zag Test, RAST, YoYo IR-1) used to predict match running performance (peak game speed, total distance covered, and percentage at velocity 8–13 km/h) ($R^2 = 17$–22%) [28]. Additionally, $\dot{V}O_{2max}$, whether estimated or directly determined, was not associated with match running performance in some papers [29, 43], whereas in other papers, VO_2 kinetics were significantly related to total distance covered and high-intensity running [47]. Mendez-Villanueva et al. [14] reported no significant relationships between match running performance (i.e., differences between first and second half) and physical capacity (i.e., maximal aerobic speed) determined using the Vam-Eval test, irrespective of playing position. There were also contrasting examples of correlation outcomes between match running performance and anthropometric measures. Nonsignificant (vs. body mass, height, body fat percentage) and weak to moderate correlations (vs. subscapular and abdominal

Table 5 Results for measures of match running performance extracted from a literature research of studies on youth soccer players[a]

Reference	Ag (years)[b]	TD (m)	TD (m/min)	Vpeak (km/h)	ST1 (m)	ST2 (m)	ST3 (m)	ST4 (m)	ST5 (m)	ST6 (m)	ST7 (m)	ST8 (m)
Bellistri et al. [20]	U8	2229	50	–	1073 (49%)	318 (14%)	440 (20%)	365 (16%)	25 (1%)	836 (39%)	–	–
	U10	3541	78	–	1249 (36%)	800 (22%)	855 (24%)	556 (16%)	86 (2%)	1503 (42%)	–	–
Goto et al. [26]	U9	4356	77.92	–	966 (22%)	1560 (36%)	1189 (27%)	462 (11%)	166 (4%)	–	–	–
	U10	4056	79.63	–	865 (21%)	1594 (39%)	927 (23%)	485 (12%)	186 (5%)	–	–	–
Bravo-Sánchez et al. [61]	10.7	–	85.39	–	11 m/min	5 m/min	0.4 m/min	–	–	–	–	–
Capranica et al. [37]	11	–	–	–	55%	38%	4%	3%	–	–	–	–
Castagna et al. [24]	11.8	6175	103	–	1112 (18%)	32 (1%)	217 (4%)	3200 (52%)	986 (16%)	468 (8%)	114 (2%)	9.4%
Stroyer et al. [38]	12.1	–	–	–	9.6%	63.9%	19.6%	6.8%	–	–	–	–
	12.6	–	–	–	3.6%	57.1%	31.3%	7.9%	–	–	–	–
	14	–	–	–	3.1%	53.8%	34.0%	9.0%	–	–	–	–
Doncaster et al. [47]	12–14	–	110–116	–	1207 (26%)	184 (7.9%)	–	–	–	–	–	–
Buchheit et al. [51]	12.8	5966	–	24–25	4866 (82%)	607 (10%)	299 (5%)	196 (3%)	1101 (18%)	–	–	–
	15.9	7130	–	27–28	5536 (78%)	788 (11%)	420 (6%)	386 (5%)	1593 (22%)	–	–	–
Andrzejewski et al. [23]	13.5	4252	83	23–25	3596 (85%)	656 (15%)	–	–	–	–	–	–
Andrzejewski et al. [55]	13.5	–	–	–	135–196	–	–	–	–	–	–	–
Atan et al. [16]	U13	4516	96.6	23.5	2205 (5%)	747 (17%)	491 (33%)	1413 (31%)	612 (14%)	4.7 (0.1%)	–	–
	U14	5385	95.8	25.4	324 (6%)	746 (14%)	1847 (34%)	1628 (30%)	835 (16%)	4.3 (0.08%)	–	–
	U15	6600	94.3	26.5	306 (5%)	536 (8%)	2152 (32%)	2000 (30%)	1599 (24%)	5.5 (0.08%)	–	–
Randers et al. [54]	U13	2038	102	22.5	18 (1%)	311 (15%)	694 (34%)	527 (26%)	297 (15%)	134 (7%)	54 (3%)	–
Brito et al. [62]	U14	2964	–	–	2353 (79%)	318 (11%)	161 (5%)	95 (3%)	271 (9%)	–	–	–
Castagna et al. [39]	14.1	6204	103	–	508 (8%)	2981 (48%)	1694 (27%)	741(12%)	234 (4%)	975.6 (16%)	–	–
Pereira Da Silva et al. [27]	U15	7077	118	–	48%	33%	4%	5%	4%	2%	3%	0.4%
	U17	8639	105	–	44%	35%	6%	5%	4%	2%	3%	1%
	U20	9810	109	–	46%	32%	6%	6%	4%	3%	3%	1%
Buchheit et al. [18]	U13	6549	94	22.3	5370 (82%)	671 (10%)	323 (5%)	186 (3%)	509 (8%)	–	–	–
	U14	7383	105	24.4	5799 (79%)	821 (11%)	446 (6%)	318 (4%)	763 (10%)	–	–	–
	U15	8129	102	26	6288 (77%)	954 (12%)	477 (6%)	410 (5%)	887 (11%)	–	–	–
	U16	8312	104	26.3	6480 (78%)	968 (12%)	479 (6%)	384 (5%)	864 (10%)	–	–	–
	U17	8707	109	26.6	6749 (78%)	991 (11%)	519 (6%)	449 (5%)	967 (11%)	–	–	–
	U18	8867	99	28.3	6650 (75%)	976 (11%)	574 (6%)	666 (8%)	1239 (14%)	–	–	–
Castagna et al. [40]	14.4	6087	101	–	486 (8%)	3029 (50%)	1630 (27%)	713 (12%)	217 (4%)	930 (15%)	–	–
Fernandes-da-Silva et al. [46]	14.5	7159	102.3	–	1397 (18%)	569 (7%)	1967 (25%)	–	–	–	–	–
Waldron and Murphy [33]	U14	–	105–116	26–27	40%	44%	13%	3%	0.3%	–	–	–
Goto et al. [15]	U11	5800	95	–	2011 m/h	2166 m/h	1334 m/h	349 m/h	29 m/h	–	–	–
	U12	–	–	–	2119 m/h	2277 m/h	1257 m/h	363 m/h	52 m/h	–	–	–
	U13	–	–	–	2004 m/h	2319 m/h	1427 m/h	420 m/h	72 m/h	–	–	–
	U14	–	–	–	1908 m/h	2242 m/h	1595 m/h	515 m/h	118 m/h	–	–	–
	U15	7700	112	–	1830 m/h	2282 m/h	1709 m/h	629 m/h	148 m/h	–	–	–
	U16	–	–	–	1927 m/h	2343 m/h	1675 m/h	578 m/h	64 m/h	–	–	–

Table 5 (continued)

Reference	Ag (years)[b]	TD (m)	TD (m/min)	Vpeak (km/h)	ST1 (m)	ST2 (m)	ST3 (m)	ST4 (m)	ST5 (m)	ST6 (m)	ST7 (m)	ST8 (m)
Harley et al. [13]	U12	5967	103.7	–	1713 (29%)	662 (11%)	174 (3%)	–	–	–	–	–
	U13	5813	98.8	–	1756 (30%)	644 (11%)	167 (3%)	–	–	–	–	–
	U14	5715	106.5	–	1841 (32%)	748 (13%)	248 (4%)	–	–	–	–	–
	U15	6016	118.7	–	1755 (29%)	669 (11%)	194 (3%)	–	–	–	–	–
	U16	7872	115.2	–	2481 (32%)	951 (12%)	302 (4%)	–	–	–	–	–
Arruda et al. [49]	15.1	5485	97–114	27–28	382 (7%)	–	–	–	–	–	–	–
Aquino et al. [28]	15.2	–	119	31	0.1%	4.6%	32.6%	28.9%	13.8%	9.4%	10.7%	20.1%
Aquino et al. [32]	15.4	6430	107.33	30–34	0.07–0.10%	6.03–6.71%	39.3–42.7%	27.3–30.2%	14.4–16.8%	7.7–10%	22–27%	–
Aquino et al. [45]	15.6	6249	104.17	–	0.08%	6.17%	41.64%	27.98%	15.67%	9.06%	24.73%	–
Rebelo et al. [43]	15.6	6331	79.14	–	0 (14%)	2116 (33%)	2025 (32%)	1102 (17%)	529 (8%)	230 (4%)	309 (5%)	–
Rowsell et al. [52]	15.9	9950	111	–	1170 (12%)	–	–	–	–	–	–	–
Mendez-Villanueva et al. [41]	16.7	–	–	26–31	–	–	–	–	–	–	–	
Varley et al. [48][c]	U17	5509	–	–	4135 (75%)	1375 (25%)	458 (8%)	113 (2%)	–	–	–	–
		5252	–	–	4012 (76%)	1243 (24%)	429 (8%)	109 (2%)	–	–	–	–
Aughey et al. [30]	U17/18	–	97.26	–	78%	13%	–	–	–	–	–	–
Vigh-Larsen et al. [67]	U17	–	114.97	–	8.2 m/min	1.6 m/min	–	–	–	–	–	–
	U19	–	117.31	–	7.9 m/min	2 m/min	–	–	–	–	–	–
Aslan et al. [29][c]	17.6	5146	114	–	1443 (28%)	671 (13%)	1263 (25%)	724 (14%)	454 (9%)	591 (11%)	–	–
		4754	106	–	1528 (32%)	596 (13%)	1076 (23%)	630 (13%)	395 (8%)	529 (11%)	–	–
Pettersen et al. [31]	17.6	9958	111	28	600 (6%)	111 (1%)	–	–	–	–	–	–
Mendez-Villanueva et al. [14][c]	U13	4024	–	–	2015 (50%)	792 (20%)	613 (15%)	349 (9%)	255 (6%)	–	–	–
	U14	3449	–	–	1741 (50%)	632 (18%)	547 (16%)	349 (10%)	180 (5%)	–	–	–
	U15	4099	–	–	2175 (53%)	849 (21%)	557 (14%)	330 (8%)	188 (5%)	–	–	–
	U16	3845	–	–	2090 (54%)	717 (19%)	519 (13%)	321 (8%)	198 (5%)	–	–	–
	U17	4118	–	–	2194 (53%)	877 (21%)	557 (14%)	292 (7%)	198 (5%)	–	–	–
	U18	3883	–	–	2156 (56%)	811 (21%)	491 (13%)	264 (7%)	161 (4%)	–	–	–
		4420	–	–	2420 (55%)	963 (22%)	575 (13%)	311 (7%)	151 (3%)	–	–	–
		4099	–	–	2250 (55%)	859 (21%)	538 (13%)	311 (8%)	141 (3%)	–	–	–
		4316	–	–	2467 (57%)	897 (21%)	519 (12%)	311 (7%)	122 (3%)	–	–	–
		4137	–	–	2411 (58%)	830 (20%)	472 (11%)	283 (7%) 292 (7%)	141 (3%)	–	–	–
		4256	–	–	2505 (59%)	840 (20%)	462 (11%)	274 (7%)	161 (4%)	–	–	–
		4052	–	–	2477 (61%)	726 (18%)	396 (10%)		179 (4%)	–	–	–

Table 5 (continued)

Reference	Ag (years)[b]	TD (m)	TD (m/min)	Vpeak (km/h)	ST1 (m)	ST2 (m)	ST3 (m)	ST4 (m)	ST5 (m)	ST6 (m)	ST7 (m)	ST8 (m)
Saward et al. [19]	U9	4586	76.43	–	3620 (79%)	979 (21%)	–	–	–	–	–	–
	U10	5326	88.77	–	3968 (75%)	1326 (25%)	–	–	–	–	–	–
	U11	5492	91.53	–	4013 (73%)	1492 (27%)	323.48 (6%)	–	–	–	–	–
	U12	5869	97.82	–	4118 (70%)	1703 (29%)	240.46 (4%)	–	–	–	–	–
	U13	6549	109.15	–	4390 (67%)	2126 (32%)	297.07 (5%)	–	–	–	–	–
	U14	6549	109.15	–	4586 (70%)	1945 (30%)	334.80 (5%)	–	–	–	–	–
	U15	7001	116.68	–	4888 (70%)	2096 (30%)	300.84 (4%)	–	–	–	–	–
	U16	6609	110.15	–	4798 (73%)	1809 (27%)	312.16 (5%)	–	–	–	–	–
	U17	7001	116.68	–	4949 (71%)	2066 (30%)	305.56 (4%)	–	–	–	–	–
	U18	6247	104.12	–	4330 (69%)	1900 (30%)	338.58 (5%)	–	–	–	–	–
Al Haddad et al. [17]	U13	–	–	23.4	–	–	–	–	–	–	–	–
	U14	–	–	25.1	–	–	–	–	–	–	–	–
	U15	–	–	25.6	–	–	–	–	–	–	–	–
	U16	–	–	26.2	–	–	–	–	–	–	–	–
	U17	–	–	26.8	–	–	–	–	–	–	–	–
Hunter et al. [44]	U18	10296	114.4	–	83%	9%	7%	1%	–	–	–	–
Kęsicki and Lewicki [64]	18.1	9213	–	27.2	–	–	–	–	–	–	–	–
Helgerud et al. [59]	18.1	9292	–	–	–	–	–	–	–	–	–	–
Sporis et al. [50]	18.4	9951	111	–	5535 (56%)	1603 (16%)	1726 (17%)	684 (7%)	403 (4%)	–	–	–
Garvican et al. [53]	18.8	–	113.6	–	86%	16%	–	–	–	–	–	–
Buchheit et al. [58]	U17/18	–	–	–	737	–	–	–	–	–	–	–
Rago et al. [65]	U19	8712	–	–	495 (6%)	235 (3%)	146 (2%)	876 (10%)	–	–	–	–
Dello Iacono et al. [63]	U19	–	111.8	–	4 m/min	–	–	–	–	–	–	–
Izzo and Varde'i [66]	U20	8464	100	–	2699 (32%)	2466 (29%)	2079 (25%)	755 (9%)	350 (4%)	115 (1%)	–	–
Romagnoli et al. [57]	17–20	11,734	130	–	9068 (77%)	2665 (23%)	905 (8%)	–	–	–	–	–
Randers et al. [56][d]	19.3	10,830	114	27–36	6230 (58%)	3600 (33%)	2650 (24%)	380 (4%)	–	–	–	–

ST speed threshold, *TD* total distance covered, *Vpeak* peak game speed

[a]See Table 4 to identify the corresponding (fixed) speed threshold reported. In studies where data were presented for different conditions and playing positions, the approximated mean value was calculated for all conditions/positions. Estimates were also performed regarding the percentage of distance covered at given speed thresholds relative to the total distance covered

[b]Mean, range or age category

[c]Results are presented for first (first line) and second (second line) halves

[d]Results from semi-automatic tracking method

skinfolds) were found in all player positions when the data were pooled [50]. In contrast, wingers showed moderate to large relationships for high-intensity running variables combined with body mass and height [60].

3.4.6 Environmental Constraints

Four studies assessed the possible effects of environment factors on match running performance in young soccer players. Locations with moderate (Denver, USA; 1600 m) [53] or high altitude (La Paz, Bolivia; 3600 m) [30, 58] had detrimental effects on match running performance (e.g., distance covered per minute, high-intensity activities) compared with sea level, regardless of where players were born/living. A single study assessing the effects of pitch surface identified slightly to moderately greater demands (total distance covered and very high-intensity running) when competing on artificial versus natural turf [62].

3.4.7 Congested Match Schedules

Three studies investigated congested match schedules. First, Buchheit et al. [51] showed that, in post peak height velocity (PHV) players (15.9 ± 1 year), two successive matches played within 48 h resulted in impaired running performance in the second fixture, whereas this was not the case in pre-PHV players (12.8 ± 0.6 years). Similarly, Rowsell et al. [52] observed decrements in match running performance over the course of four matches played in a 4-day period in players with a mean age of 15.9 years. In contrast, Arruda et al. [49] did not observe differences regarding total distance covered, distance covered per minute, high-intensity running efforts and distance, and body-load impacts (which had higher values in the final than in other matches) in U15 players (mean age 15.1 years) across five matches played over a 3-day competitive period. In contrast, the absolute frequency of accelerations (> 1.8 m/s^2) and accelerations per minute decreased over the course of the competition.

3.4.8 Recovery Methods

Two studies assessed the impact of postmatch recovery strategies on match running performance. Spa treatment (2 min hot shower at 33–43 °C + three times [sequence of 2 min sauna at 85–90 °C, 2-min jacuzzi/hydromassage at 36 ± 1.5 °C and cold water immersion at ~ 12 ± 1 °C]) in post-PHVs with a mean age of 15.4 years [51] or only cold water immersion (5 × 1 min at 10 °C) (players with a mean age of 15.9 years) [52] were associated with beneficial effects on subsequent match running performance output such as total distance covered, sprinting distance, repeated-sprint sequences and peak game speed. Additionally, a single publication evaluated the effects of supplementation on match running performance in youth soccer. In this sense, caffeine supplementation (6 $mg \cdot kg^{-1}$) did not enhance running output in players with a mean age of 17.6 years [31].

3.4.9 Comparisons Between Formal Games and Other Game Types

Two studies compared 11 versus 11 (i.e., formal match-play) with other game formats (i.e., small-sided games). Capranica et al. [37] observed no differences on TMA variables, including running (forward, backwards and with the ball), walking (forwards, backwards and sideways) and inactivity (no locomotion) between 11 versus 11 (field size 100 × 65 m) and 7 versus 7 (60 × 40 m) in 11-year-old players. In contrast, Randers et al. [54] reported that 11 versus 11 (105 × 68 m) resulted in a greater total distance covered, peak game speed and distances in several speed bands (e.g., > 4 km/h) than 8 versus 8 (52.5 × 68 m) in a sample of U13 players. Official U12 7-a-side matches were more demanding (i.e., greater total, high-intensity, very high-intensity and sprint distances) than 8-a-side, size-matched (40 × 60 m) games. An additional study comparing official U19 matches and game profile-based training sessions (3 × 8-min bouts including 30 s of physical and technical exercises at 50–75–105% vYoYoIR1, followed by 30 s of active recovery) revealed lower total and high-speed distances covered per minute and fewer high-intensity efforts in the former than in training [63].

3.4.10 Longitudinal Interventions

Four articles were longitudinal intervention studies. After periodization training (22 weeks), emphasizing technical-tactical ability, U16 players showed an increase in running performance, mainly in peak game speed and high-intensity activities during simulated matches (players from all positions grouped together) [32]. Buchheit et al. [42] demonstrated that seasonal changes (~ 7 months) in running performance during friendly matches (i.e., repeated sprint sequences and repeated high-speed running sequences) were position dependent in U13–U16s. Andrzejewski et al. [55] divided players (mean age 13.5 years) into two groups (endurance group ≤ average sprint test performance < speed group) in which "speed-type" players participated in training sessions of bouts of 9–17 m, whereas "endurance-type" players ran 4–9 m (with 40–60 and 25–50 s for recovery, respectively). After a 6-month macrocycle, the former group performed more sprints and distance ≥ 5 m/s during match play but covered a lower total distance than their endurance-type peers [55]. Finally, Helgerud et al. [59] reported an increase in the total distance covered and number of sprints in players with a mean age of 18.1 years after an 8-week training regimen consisting of regular (match play, technical, tactical, strength and sprint training) plus aerobic interval

training. The control group, for whom training involved only regular and additional technical training, did not experience similar improvements.

4 Discussion

The purpose of the present analysis was to systematically review the body of knowledge available on match running performance measures in young male soccer players. A total of 50 studies provided reference data from 17 different geographical locations. Most studies examined official match play, a broad range of chronological ages and, occasionally, positional roles. Hence, a reasonable amount of knowledge exists, although a lack of interventions that directly impacted training and preparation was evident. This discrepancy may be due to most of the research conducted being relatively recent (Fig. 2). Nevertheless, the available information contributes to the understanding of game requirements and can inform training content for physical conditioning sessions [73]. Here, the strengths and limitations of the current literature are discussed, and recommendations are made for further investigation.

4.1 Methodological Quality

Overall, the identified research articles generally presented high methodological quality ratings (79 ± 13%; Table 2). The questions with the highest mean rating, taking into account all included studies, were Q1 and Q5, suggesting that the literature aims and the dependent variables that were analyzed were generally clearly set out. In contrast, Q4 exhibited the lowest mean quality score. This highlights that essential characteristics of the time–motion system/equipment used were either unaccounted for and/or lacking in the text. This issue is explored in Sect. 4.2.5, where measurement techniques are discussed.

4.2 Research Paradigm

4.2.1 Location of Player Populations

An analysis of the geographical location of populations showed that almost all continents were represented. The greater portion of studies concerned European countries—particularly England—and also Qatar, with a recent trend for an increase in the number of publications in South America. No scientific studies were identified from African countries, clearly indicating a need for research in youth populations in these countries.

4.2.2 Player Categorization

An issue requiring further debate is the definition of criteria for categorizing youth players in soccer competitions for research purposes. As such, the majority of the scientific evidence observed used comparisons based on chronological age cutoff points. Studies in England [13, 15, 19, 26] and New Zealand [16] used 12-month age bands, according to the Premier League [74] and Auckland Football Federation regulations [75], respectively. Studies in the São Paulo State Championship (i.e., the leading state-level tournament in Brazil [32]) adopted age banding with 24-month cutoff points [3, 27, 28], similar to that employed in Italian youth competitions [20], according to Federazione Italiana Giuoco Calcio standards [76].

It is important to highlight that, in chronologically age-matched individuals, those demonstrating advanced biological maturity status can have an advantage in anthropometric (weight and height) and physical ability (aerobic resistance, sprint and jump performance) indicators over their less mature peers [77]. The same point is valid for match running performance. Indeed, Buchheit and Mendez-Villanueva [60] reported slightly to moderately greater peak game speed, high-intensity actions (> 19 km/h) and repeated high-intensity actions (two > 19-km/h runs interspersed by a maximum of 60 s) in more mature than in less mature players, both belonging to the same U15 group. Goto et al. [78] reported similar results in U13/U14 players. Recently, Cumming et al. [79] analyzed the effects of a BioBanded soccer tournament (i.e., games played by youth [U12–U15] players having 85–90% of predicted adult stature) and reported that players had a positive perception toward such practice compared with usual age group competitions. Early and late maturing players deemed the matches as more and less physically challenging, respectively. Future studies are necessary to assess match running performance using TMA in BioBanded players.

4.2.3 Match Type and Configurations

Simulated soccer matches can generate physiological responses that differ from those in official competition. However, no studies have directly compared match running measures among different soccer match play modalities (e.g., simulated, friendly, preseason tournament vs. official). Freitas et al. [80] reported that psychophysiological stress was greater during official competition than during a simulated game, and a lower reduced internal workload (e.g., session rating of perceived exertion) was also observed in the latter. Hence, caution is necessary when using running data from simulated and friendly matches to determine competition demands and inform physical preparation regimens.

In general, standardization was lacking across study designs in age-matched players, particularly with respect to game configurations. For example, pitch sizes, game durations, division of playing periods, the number of players per side, and rolling substitute policy application varied considerably (see Table 3) [3]. Variations in the aforementioned parameters have been shown to influence on-field running performance in soccer match play [54, 81, 82]. As such, conditioning practitioners working in youth soccer should consider that data published for a given population may not be pertinent for another.

4.2.4 Speed Thresholds

The absence of standardization in speed thresholds (see Table 4) across the literature makes it difficult to compare findings on running output [44]. Nevertheless, the use of fixed speed thresholds does provide useful information regarding player development (e.g., comparisons between age groups) and the effects of training on match running performance [15, 32, 42]. In addition, fixed speed thresholds allow direct outcome comparisons between studies [18]. However, several authors suggest that individualizing speed thresholds provides a more accurate representation of match running loads in young soccer players [13, 16, 44]. This practice can also aid individualized assessments and comparisons between players of differing maturational levels [16] and management of external workloads through the design of appropriate recovery and periodization schedules [44].

The majority of studies employed field testing procedures, such as linear sprint speed [13–17, 19, 20, 26, 47], as a means to determine age-specific or individualized speed thresholds. Yet, recent evidence suggests that maximal sprinting speed has limitations for establishing game speed thresholds for several reasons: (1) peak game speed values might exceed those derived from tests of maximal sprinting speed [83]; (2) individualized game speed thresholds do not enhance the dose-response determination to soccer training [44, 84]; and (3) seasonal changes in match running performance do not necessarily match those observed in sprinting test performance; players with decreased maximal sprinting speed demonstrated concomitantly increased match running performance (e.g., number of repeated sprint sequences and repeated-high speed sequences) [42]. Although two of the above-cited studies were not specifically performed in youth [83] and males [84], further investigations are required to assess the relevance of creating speed thresholds from game parameters per se to depict match running performance. A comparison of speed thresholds as a percentage of peak game speed and distances covered in fixed speed thresholds relative to total distance covered [3, 63], rather than using fitness testing performance to determine speed thresholds, would be useful.

4.2.5 Measurement Techniques

A key study by Randers et al. [56] compared data derived from GPS-based technologies, VTM and computational videogrammetry tracking techniques. Large between-system differences were present in the determination of the absolute distances covered, meaning that results between match analysis systems should be compared with caution [56]. Indeed, a wide variety of data acquisition methods was employed across studies (see Table 3). GPS is considered the most time-efficient method to collect and report match data in contemporary soccer [85]. Yet, most studies (42%) used low sampling frequency GPS devices (i.e., 1–5 Hz), which exhibit consequential error rates in determining high-speed activity [86]. Computer-based tracking adopted in investigations in youth players (e.g., Prozone® [48, 87], Mathball Match Analysis System [29] and DVIDEOW™ [28, 32, 45]) show low absolute error [3, 21, 29, 88]. Indeed, when compared with GPS and local position measurement, videogrammetry tracking methods are shown to have the most constant magnitude of error in computing distances when running occurs at low- and high-intensity speed thresholds [85]. However, logistical constraints can favor the use of GPS, especially when youth matches take place in training ground facilities [3, 13, 48].

Specific issues affect TMA data collection: (1) for GPS: the environment (e.g., topography), number of satellites connected and software/unit updates; and (2) for computer-based tracking: lighting, background objects, camera position and calibration quality. All these issues can interfere with data signal [85, 86, 89–91], and measurement error should ideally be calculated in the locations where matches are specifically played, a factor that was systematically overlooked in the current literature (see Table 2).

4.2.6 Terminology Issues

A total of 20 descriptors were adopted among studies included in the current systematic review to define and group dependent variables (e.g., total distance covered, mean speed or distance covered per time, peak game speed, indicators of activities performed at established speed thresholds or movement categories). Thus, there is a need to standardize terminology in this research area. To make it easier for readers to identify evidence related to this research area topic in the future, we suggest the authors simply use "match running performance", as this was the most cited term—used approximately 26% of the time—in the published articles.

4.3 Match Running Performance

4.3.1 Playing Standards

Match running performance metrics were used to discriminate youth players across different competitive standards (elite, nonelite and recreational) and status (retained and released from an academy). It is necessary to appraise these results in relation to talent identification and development. Conclusions drawn in some studies have received criticism mainly because of methodological flaws (e.g., accounting for the effect of biological maturity and/or relative age) [73]. Choices on whether or not youth players should be retained in a soccer academy cannot be based solely on match running performance data. Indeed, a holistic approach to evaluating young players is necessary to prevent one-dimensional insights into competitive performance [92]. This includes the integration of running performance analyses in a model including technical, tactical, decision making and anticipation measures [3, 73, 93]. Yet, obtaining information on technical measures and quantifying the tactical aspects of the game can be challenging [94]. Of all the publications examined in the current systematic review (i.e., $N = 50$), only nine (18%) performed an analysis of running performance concomitantly with other match-related performance variables, i.e., technical [33, 48, 54, 59, 61, 62] or tactical [24, 32, 45].

4.3.2 Playing Positions

The present literature showed that match running performance is position dependent in young soccer players. In general, studies analyzed match running performance (e.g., sprinting distance) across playing positions, adjusting the data for age and playing time (e.g., Mendez-Villanueva et al. [14], Buchheit et al. [18], Varley et al. [48]). However, a major concern is the extent to which the differences presented in the literature [12, 14, 18, 41] are meaningful and can be used to inform subsequent position-specific training regimens [93]. For example, one of the few studies that expressed sprinting distance relative to total distance covered revealed differences of $< 2\%$ across outfield playing positions in young soccer players aged U15–U20 [27]. A fundamental question left unanswered in the literature is: Are there meaningful differences between playing positions across all youth categories? Since match running performance is age dependent (see Sect. 4.3.3), addressing this gap could help practitioners determine the age(s) at which additional training to develop running ability is necessary for the most demanding positional roles.

4.3.3 Age-Related Performance

Match running performance determined using fixed speed thresholds increased concomitantly with age. In theory, therefore, designing conditioning sessions on the basis of actual match load means that the training of running capability should be progressively adjusted according to age across all categories. However, when using age-specific or individualized speed thresholds, discrepancies in results compared with fixed speed thresholds were identified. A trend for greater relative match running performance (e.g., peak game speed, distance covered in high-intensity running) was observed in younger than in older players [14, 16, 17]. The authors suggested this was due to a lower technical-tactical game understanding in younger players [3, 14, 16, 17]. In addition, it is necessary to avoid generalizations regarding changes in match running performance [3], since differences between age groups were accompanied by effect sizes ranging from small to large across the studies.

4.3.4 Between-Halves Comparisons

To date, there is an evident lack of agreement across studies on the occurrence of reductions in match running performance in age-matched youth players over the course of play. For example, it has been suggested that age groups that are pre-PHV will have unchanged or only slightly decreased running performance over the match because of lower running outputs at high intensities, whereas age groups that are post-PHV will exhibit reductions in running performance [3]. However, contrasting evidence exists, as some studies report that running outputs in pre-PHV age groups remained similar throughout match play [3, 16, 20, 24], whereas declines were observed in others [12, 14]. Similarly, no decrements were reported in post-PHV age groups [32, 43, 45]. Thus, the occurrence of reductions in running performance over the course of play does not appear to depend upon the PHV of the age group. Analysis of the literature needs to consider whether changes in between-half performance depends upon the duration of the halves [3] and/or the effective playing time [95]. Additional investigations of the effects of contextual factors, such as game rules, match type, format and configuration, situational and environmental factors (e.g., see Aquino et al. [45]) are also warranted.

4.3.5 Association with Physical and Physiological Factors

Significant relationships were observed between the total distance covered, high-intensity and sprinting distances and physiological markers of muscle damage prematch, immediately after (CK, LDH and IL-6) and 48 h (cortisol) post-match. Biochemical measures are potentially useful when monitoring the effects of running output on recovery status

[45, 57]. Body size appeared to be associated with match running performance output according to positional role but not when all positions were pooled, although only limited evidence was found [50, 60]. In contrast, over one-fourth of the entire literature was dedicated to understanding the physical capacity–match running performance relationship. In general, studies assessed the construct validity of a given test. To date, findings on this research issue are inconsistent (see Sect. 3.4.5). Yet, of 12 articles that investigated the association between physical capacity and match running performance, only four [14, 17, 18, 65] accounted for playing position. Moreover, the extent to which fitness tests can aid training prescription and predict match running performance in youth soccer is debatable (for more information see Mendez-Villanueva and Buchheit [96]).

4.3.6 Environmental Constraints

To date, the effects of altitude [30, 53, 58] and pitch surface [62] on match running performance are the only environmental factors that have been investigated in youth soccer players. However, when this information was reported, environmental conditions varied substantially among studies (e.g., the temperatures ranged from 9.4 °C [33] to 36 °C [52]), and ambient temperature was reported in less than half of the studies (36%) [14, 16–18, 20, 28, 29, 31, 33, 39, 40, 42, 45, 47, 48, 50, 52, 56]. In professional senior players, for example, a negative relationship between distances run at speed > 14 km/h and environmental wet-bulb globe temperature has been reported [97]. Extreme conditions causing heat and cold stress can predispose children and youth to harmful effects more than in adults (e.g., greater water loss, increased heat production and lower locomotive economy) [98]. Future research should consider the potential effects of environmental conditions on youth soccer match play, and information on these should be systematically reported.

4.3.7 Congested Match Schedules

In professional senior soccer, most of the literature has reported no deleterious effects of congested match schedules on match running performance [8, 99–101]. However, recent evidence has shown that participation in congested fixture schedules (e.g., two matches in the same week vs. only one match) negatively influenced match running performance in U23 players (from individualized analysis) [87]. Similar findings were also reported for youth players (mean age ~ 15–16 years) when playing two matches in 48 h, during a 4-day tournament with one match per day, and in five matches played over 3 successive days [49, 51, 52]. While performance in post-PHV players (mean age ~ 16 years) was negatively affected when playing successive matches, this was not the case for players with a mean age of ~ 13 years (i.e., pre-PHV players) [51]. Two studies that also observed reductions from congested schedules (mean player ages: 15.1 ± 0.2 and 15.9 ± 0.6 years [49, 52]) did not account for maturity. It can be speculated that these populations were composed of circum- (and mainly) post-PHV individuals, with very few pre-PHV individuals (for example, see Buchheit and Mendez-Villanueva [102]).

Limited evidence exists on strategies and postmatch recovery interventions to reduce decrements in match running performance during periods of match congestion. Squad rotation and systematic monitoring of performance have been recommended [87, 91]. Postmatch cold water immersion and spa treatment demonstrated beneficial effects on subsequent match running output, particularly in young players near or after the growth spurt [51, 52].

4.3.8 Longitudinal Training Interventions

Little research was found regarding the effects of different training interventions on match running performance in youth soccer. Only approximately 10% (five publications) in the current literature addressed longitudinal experimental approaches to the problem. Of these, two did not clearly state the match type [55, 59] or describe in detail the intervention results (e.g., pre and post outcomes) [55]. Another paper examined age-related changes in match running performance [19]. In applied settings, obtaining repeated measures of match performance in youth players is challenging. Nevertheless, the current results from longitudinal intervention studies demonstrate that young soccer players positively respond to a deliberate training stimulus, which improves their running performance during simulated/friendly matches. Interventions included periodization training (~ 14 h per week in addition to competitive play) with technical-tactical emphasis (38–50% of total training time; six to eight soccer training sessions per week) plus strength (15–23% of total training time; one session per week) and conditioning sessions (35–41% coordination-flexibility/speed/aerobic power; one to two sessions per week) [32, 42]. Additional investigations are necessary to compare the results of interventions on performance during official competition.

4.4 Limitations and Recommendations for Future Research

Over the course of this review, several limitations of the current literature were identified. These include (1) 28% of included studies did not demonstrate an appropriate level of quality, (2) some of the research topics (e.g., in reference to Sects. 3.4.8 and 3.4.9) and derived systematic conclusions were drawn from a limited number of studies, (3) a lack of conformity as a wide range of different measurement

systems were used, and (4) information on measurement error in obtaining running metrics was systematically overlooked.

Another key limitation across the studies that warrants discussion is the general lack of information concerning contextual variables (e.g., match location, quality of opponents, match status, result, fixture congestion), especially in comparison with the literature in professional senior players [6]. Indeed, congested match schedules have been shown to negatively affect match running performance in youth soccer, but at professional standards this is also dependent upon the specific team formation, match status and location [91]. While Varley et al. [48] showed that opposition quality can influence match running performance, additional research is merited to investigate other factors, including tactical elements (e.g., team and opponent formation), match context (location (home, away, neutral), match status (win, draw, loss, goal differential [20, 103]) and logistics (air/ground travel) on running performance indicators in youth soccer match play. The concomitant collection and analysis of verbalized coaching staff approach (e.g., adjustments in team tactical style), possible referee bias and crowd size would also be useful [104]. Other underexplored areas with potential practical applications include analysis of the possible effectiveness on performance of specific warm-up methods (e.g., postactivation potentiation via strength exercises [105]), nutritional strategies (e.g., supplementation with β-alanine [106], the effects of fasting during Ramadan), postmatch recovery techniques (e.g., active recovery, stretching, massage, sleep [107]) and the short- to long-term responsiveness to different training stimuli (e.g., high-intensity interval training) or even detraining.

Regarding data analysis, the inclusion of acceleration metrics would provide additional pertinent information to that of conventional measures (e.g., total distance covered, high-intensity and sprint distances), since hard accelerations and decelerations can occur even at low-intensity speed thresholds [67]. However, these were reported in only 20% of publications [30, 31, 49, 53, 54, 61, 63, 64, 66, 67]. Importantly, there is a general lack of information using an integrated approach that focuses on sensitive metrics such as high-intensity running, but contextualizes these in relation to key tactical activities for each position and collectively for the team [94], in order to develop a holistic approach to understanding match running performance of young soccer players. Furthermore, while still under debate [108], contemporary probabilistic statistics (e.g., magnitude-based inferences [MBI]) [109] were reported by only approximately 26% of the articles that were reviewed in the present analysis [14, 17, 18, 30, 41, 42, 44, 47, 48, 51, 53, 58, 60]. MBI (i.e., qualitative probabilistic mechanistic inference about the true change [58]) is suited to athletic performance and small sample sizes, and bias may be less than when traditional null hypothesis significance tests are used [109–111]. Nevertheless, normative values of the smallest worthwhile changes regarding match running performance still need to be determined [112].

5 Conclusions

The present study compiled current empirical evidence on match running performance in young male soccer players. Physical conditioning professionals should be aware of reference data of match running performance—when available—to inform conditioning programs for young soccer players on the basis of actual match demands. It is necessary to plan and adjust training according to players' development stage and age category as match running performance depends on maturity and age [13–15, 17, 18, 20, 38, 51, 60, 67]. Game rules (e.g., criteria for grouping players, rolling substitute policy), match format and configuration (e.g., number of players per side, pitch size, match duration, number of periods) are almost completely unstandardized in studies of age-matched players. Thus, coaches working with youth development programs should consider that normative data for a given population may not be relevant to all other populations. Despite limited evidence, it appears that periodization training emphasizing technical-tactical content can improve match running performance [32, 42]. Information from laboratory and field fitness tests should be used with caution to predict running performance, especially as evidence supporting the construct validity of such tools does not account for playing position. Evidence for residual (during fixture congestion) [49, 51, 52] and acute (over the course of a match) [12, 14, 16, 29, 39, 40, 57] decrements in running performance is common. The existence of residual decrements was more consistent across studies than were acute declines and is more likely to be dependent upon the maturity stage of the player. While additional research is necessary, the prescription of postmatch recovery strategies, including cold water immersion and spa treatments, have demonstrated positive findings [51, 52] in tempering the reductions in match running performance.

Compliance with Ethical Standards

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