A systematic review about established methods and thresholds to determine velocity and accelerations in soccer

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Abstract

Background

Velocity and accelerations have been highlighted as the most important variables in soccer. However, there is a consensus gap to define different levels of effort. The purpose of this systematic review is to identify those articles that purposed a threshold to establish (i) movement intensity at different velocities using tracking systems and (ii) accelerations using inertial measurement units, classifying the justification methods.

Methods

A systematic review of Cochrane Library, EBSCO, PubMed, Scielo, Scopus, SPORTDiscus, and Web of Science databases was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.

Results

From the 1983 studies initially identified, 40 were fully reviewed, and their outcome measures were extracted and analyzed.

Conclusions:

The 40 m maximal linear sprint test is the preferred method used in originating speed and acceleration thresholds in soccer despite recent research opted also to consider composite fitness measures such as anaerobic speed reserve. However, there is a substantial heterogeneity on locomotor testing procedures and workload zones established from these performance data while construct validity of several fitness indicators is not yet supported. Studies diverged on recommending, maybe consider or suggested avoid the use of individualized thresholds. Low sampling frequency (≤ 10 Hertz) in publications computing acceleration and deceleration demands should be also interpreted with caution. The present study collated evidence that may help conditioning professionals when processing and interpreting external load data in a soccer context.

1. Background

The soccer game is characterized by its intermittent regimen in periods of low-to-moderate intensity that are interspaced by high-intensity efforts [1]. Since the intermittent efforts, monitoring external load (or physical demands) of the players is not so simple as assessing the total distance covered [2]. In fact, as an intermittent running-based activity, the monitoring process of soccer is dependent on considering the intensity of running and the amount of time spent in different velocity thresholds [3]. This monitoring

process helps coaches and sports scientists to identify the physical demands imposed by the match and to adjust the training load to the individual or collective needs of the players [4]. In fact, a proper individualization of the training stimulus will consider the specific demands of each player (mainly considering playing position), and to do that, specific information about physical demands in different intensity zones is required [5].

Usually, external load demands imposed by the match are assessed by microelectromechanical instruments, in which, global navigation satellite system, local position system, and/or inertial sensor units are the most popular and used [6]. These instruments allow controlling the displacement of players in a specific timeframe, thus allowing to measure not only the distances covered but also the velocity in which these distances are covered or the intensity of accelerations and decelerations during the movements performed [7]. Since the great amount of data generated, the definition of intensity zones become important, since coaches should consider the amount of low, moderate, or high demands for each player aiming to control not only the prevalent intensities but also the determinant ones [8].

As an example, although low-intensity running being prevalent in match scenarios, the most determinant running activities are related to the most intensity zones, namely considering the associations with specific player's performance or also using this information for controlling the injury risk [9]. Information about peak velocity, high speed running, or sprinting running has been used for managing training stimulus, implementing preventive training programs, or identifying mediators or moderators of injury [9, 10]. Therefore, establishing thresholds for running or acceleration/deceleration intensities are determinant.

The process of definition of thresholds is not easy and far to be the ideal. In fact, velocity thresholds can have a basis on the energetic systems and points of the threshold [11, 12]. However, this fact would lead to individual velocity thresholds for each player based on his capacity [13]. Despite such an approach, this is not easy to implement, and for that reason, standard velocity thresholds (for all players) are the most common practice in external load monitoring [14]. Despite this standardization for all players, the velocity thresholds vary from company to company or from study to study. This also increases the complexity of understanding variations in these demands between-players and contexts.

Due to a wide range of running and acceleration/deceleration thresholds used in the literature, it is important to summarize the evidence and provide recommendations for standardization in the future. This will improve the capacity of comparing results across different scenarios and generalize evidence. Although the importance of such summarization, as far we know no systematic review was conducted so far. Therefore, the purpose of this systematic review is to identify those articles that purposed a threshold to establish (i) movement intensity at different velocities using tracking systems and (ii) accelerations using inertial measurement units, classifying the justification methods.

2. Method

The systematic review was reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) guidelines [15] and methodology to conduct a systematic review of systematic reviews [16]. This review was not registered previously.

2.1 Design

The protocol was not registered prior to initiation of the project and did not require Institutional Review Board approval. A systematic search of five databases (i.e. PubMed, Web of Sciences, Cochrane Plus, Proquest, and Scopus) was performed by the authors to identify articles published before 16:00 p.m. on 5 October 2020. In all databases the search was limited to reviews. The authors were not blinded to journal names or manuscript authors. The PICO [15] design was used to provide an explicit statement of the question. Three main groups were created: (1) *sport*: soccer, football; (2) technology related words: GPS, "global positioning system*", LPS, "Local Positioning Systems", video, camera; (3) variables-related words: "physical performance", "running performance", "match running performance", "movement patterns", "time–motion analysis", "distances covered", "activity profile", "physical profile", "work rate", "match analysis", "match performance", "high intensity", acceleration, deceleration, thresholds, "training load", "acceleration profile", "acceleration zones", "acceleration thresholds", "velocity profile", "velocity thresholds", "velocity zones", "speed zones", "speed thresholds", "speed profile". The keywords were connected with AND to combine the three groups and using OR to link the words of each group.

2.2. Screening strategy and study selection

When the referred authors had completed the search (FDS, MRG), they compared their results to ensure that the same number of articles were found. Then, one of the authors downloaded the main data from the articles (title, authors, date, and database) to an Excel spreadsheet (Microsoft Excel, Microsoft, Redmond, USA) and removed the duplicate records. Subsequently, the same authors screened the remaining records to verify the inclusion-exclusion criteria (Table 1).

Table 1
Inclusion/exclusion criteria

Nº Criteria	Inclusion Criteria	Exclusion Criteria
1	Studies developed in soccer	Studies conducted in other sports
2	Studies that identified external training load (velocity or accelerations).	Studies that extracted external TL (not velocity or accelerations) and internal TL. Also, studies not aimed to extract TL.
3	Studies that provide velocity and acceleration threshold using EPTS or IMU.	Studies that assess other technologies.
4	Only original and full-text studies written in English	Written in other language than English. Other article types than original (e.g., reviews, letters to editors, trial registrations, proposals for protocols, editorials, book chapters and conference abstracts).
5	Justification of the threshold by means of a test, competition data or other analysis techniques	Studies that did not justify the threshold used
EPTS = electronic performance and tracking systems; IMU = inertial measurement unit; TL = training load.		

2.3. Data analysis

All studies were summarised and then divided into groups depending on the classification type (i.e. velocity or acceleration). The values are presented in Table 2 and 3, extracting the following relevant information: EPTS used to data registration, manufacturer who belongs the used EPTS, branch, software in which efforts classification was made, sample, sex, level, task, and thresholds in speed categories. In additions, these studies were classified depending on the methods used to justify thresholds (e.g. test, maximum speed during training).

2.4. Methodological Assessment

Quality of studies was not assessed because aim of study was observational and therefore absolute values from articles were not considered. Therefore, as no quantitative results were included, no quality survey was utilised as scales of evaluation. All 39 articles outlined in Table 2 and 3 were assessed for suitability and evaluated by authors prior to inclusion. All studies had to meet all items on *criteria* list to be included in analysis.

3. Results

3.1. Identification and selection of studies

A total of 1982 (i.e. PubMed: 1228; WoK: 754) original articles were initially retrieved from the mentioned databases, of which 679 were duplicates. Thus, a total of 1303 original articles were found. The titles, abstracts and full texts of these works were checked, leading to the exclusion of 686, 99, 518, 127, 33, and 319 by exclusion criteria number 1, 2, 3, 4, and 5, respectively. Thus, a total of 39 articles met all the inclusion criteria and were finally included in the qualitative synthesis (Figure 1).

3.2. Study characteristics

The characteristics of the studies included in the systematic review can be found in Table 2 and 3 (Table 2 and 3).

4. Discussion

The main goal of the current work was to systematically review the scientific knowledge contained in peer-reviewed research articles that proposed threshold(s) used in establishing soccer players' movement intensity. A total of thirty-nine published papers addressing velocity and/or acceleration/deceleration bands respectively using tracking systems and inertial measurement were considered here. Based on these, our main collated findings were: (1) for either, velocity zones or acceleration demands, the preferred method to define intensity among studies was based on outcomes from 40 m sprint test, which was used in more than one-third of all literature covered in the searches; (2) the most frequent data collection systems employed to obtain external load measures were GPSs adjusted at a sampling frequency of 10 Hz (~72%); these were also often used in creating the thresholds (~41%); (3) nearly half of evidence is derived from youth male samples and during competitive matches; (4) there was a predominant choice toward depicting movements solely in the meter unit (~60%) and it is evident that the specific type of displacement recorded is unspecified in all excepting one work. Finally and of most importance to the current aim (5) it was not possible to identify a standardization in speed categories linked with distinct levels of movement given the wide discrepancies found across literature formulating individualized thresholds.

An important finding of this review study was that 40 m sprint test seemingly the most frequent procedure in establishing individualized speed thresholds in soccer. In fact, recommendations were formulated indicating that a 40 m path may be sufficient for players reaching their peak speed, being faster than in competitive matches and thereby possibly represent an adequate method of depicting players' external load [54]. Nevertheless, in none of the studies considering the 40 m sprint test either when evaluating players velocity [17–27] or accelerations/decelerations [11, 12, 52], there was a mention regarding its measurement properties (e.g. validity and reliability) for the specific population assessed while only three [11, 12, 23] provided references which commented or directly determined a given of these aspects ($r = 0.95–0.97$; $ICC = 0.94–0.99$; $TEE = 1.67–1.95\%$) [37, 55]. The transference of a locomotor testing outcome to match-play running performance is also critical when selecting appropriate testing

tools. The so-called construct–or ecological–validity of the 40 m sprint test lacks consensus [see for a review: [56]] as reports are confirming its associations with match running performance [57] whilst no meaningful [37] or only position-dependent results were elsewhere observed [58]. One existing potential solution is the adoption of the maximal sprinting speed (MSS) [59] or a cluster technique using players' velocity samples [60] both obtained in the own matches, as input parameters to obtain thresholds. Yet only a few studies included here considered in-game MSS [47–49], and the clustering method was challenged [61]. Thus, despite gaining popularity to help individualize soccer demands, doubts may persist on the practical value of 40 m on-field sprinting test.

It is important to note that the individualization of thresholds may arguably benefit soccer practitioners. Examples include an *a priori* more accurate representation of player's demands experience in practice or match-play when using individualized thresholds. Enhanced ability in the management of individuals' workload will theoretically allow for the design of more effective recovery schedules and periodization training [19, 30, 31, 59]. Also, the use of customized thresholds helps reduce high-speed running variability in either, within and between matches as well as from an individual or position-specific point of view [62]. On the other hand, some studies provided evidence that it can represent no additional value to the understanding of soccer external loads. The clearest example falls in the case of determining dose-response to daily training routines. MSS in 40 m test routine showed impaired correlations with heart rate, ratings of perceived exertion [26] and wellness [27]. Furthermore, MSS is not necessarily higher in 40 m testing as compared to match-play outputs [63]. Most important, training-induced adaptations in running performance encountered during actual match-play are not always matched with those changes verified in 40 m sprint performance [64] whilst the frequency to which fitness components needs re-assessment, aiming at adjust thresholds accounting for those time-related changes, seemingly also unknown [65]. Collectively, such results reinforce the lack of full confidence and consensus in applying a 40 m linear sprint test as a way to obtain “anchors” of speed/acceleration thresholds. Soccer demands generally involve also energetic cost in changing direction, unorthodox displacements and physical impacts [27] which might be difficult to capture in common outcome metrics derived from traditional linear sprint tests.

In an attempt to overcome possible limitations of a single bout maximal linear sprint as mentioned above, also considering the lowest weight it may have to a dataset of soccer external load measures collected in official matches [66] likely given the one-off nature of MSS in soccer [67], some authors employed test protocols more prolonged in nature. These included Yo-Yo Intermittent Recovery Test level 1, Vam-Eval maximal incremental running test, 30:15 Intermittent Fitness test (30–15_{IFT}) and Conconi test performed on a treadmill. Despite having large-to-very large associations with match-play running performance either relating to the total distance covered or high-intensity running [56], graded exhaustive treadmill tests represent serious limitations to most clubs given time requirements, costs and players motivation implying a need to consider other solutions with more prominent practical value such as field-based assessments [68]. Instead, a trend of a recent increase in the use of anaerobic speed reserve (ASR) as a threshold was noted here for approximately one-fourth of all studies included of which most were

published over the last three years [20, 27, 35, 36, 38, 39, 42]. The ASR is a compound of two markers, i.e. computed as the difference between player MSS and maximal aerobic speed thus combining in a single index the individual's fitness characteristics observed on a separate all-out sprint effort and those from $v\dot{V}O_{2max}$. Such metric seemingly of benefit in creating thresholds since players showing similar $v\dot{V}O_{2max}$ (not uncommon across outfield playing positions; [69]) may not have a matched MSS performance [57,70]. In this conditions, ability to cope with a given load, in particular at high-intensity domain, would depends on the proportion of ASR reached [71] rather than looking solely for a percentage of the former fitness indicator. Again, one of the issues which arguably preclude unrestricted recommendation of ASR to date is none empirical evidence supporting its construct validity (e.g. 30–15_{IFT} performance versus match-play running outputs; see also [72]).

Regardless of whether there is currently an unsolved debate, since studies recommend using [54, 62, 73], maybe [19, 65, 74] or others suggest avoid [26, 56, 59] fitness testing when defining speed thresholds, a lack of standardization was observed here in both, determinations of individualized speed/acceleration categories representing distinct workload demands and the parameters used to extract a given anchor. To be explicit and using the 40 m sprint test as an example, timing gates at the start, 10 and 40 m [22]; 30 and 40 m [21]; 10-m intervals [17–20, 26, 27]; or MSS attained independent of location [23, 24, 52] were among methods used. Furthermore, following these procedures, the levels for “higher” intensity recorded were defined considering 50–60% [52], 80–100% [19, 20], >61% [17, 18, 21], >65% [26], >75% [22], >80% [23, 24, 27] or >90% [52] of MSS. It makes it difficult to directly compare results across literature and provide systematic concluding remarks on the most appropriate one. To assist move beyond on this question, intervention designs assessing the practical effect of individualized thresholds in various aspects (e.g. fitness, injury and match performance) are recommended as opposed to common application/comparison of methods [73].

Finally, particular attention should be also paid to the technology employed in obtaining performance indices often used in originating the movement intensity thresholds. Ten-hertz GPS were identified as the most common devices used in both, determination of velocity/acceleration thresholds during testing routines and collection of task external loads. It is recognized that these generally provide valid measures to assess distance and velocity in linear movements and during simulations of running characteristics pertaining to team sports while no additional benefits of a nearby higher acquisition frequency can exist [6, 75]. However, during acceleration occurrences above 4 m/s² limits, accuracy using 10 Hz GPS is not always ensured [76]. One can argue that there is not a true ‘gold standard’ available in computing external load such as running performance [17, 77, 78] while others recognize high-speed three-dimensional motion capture systems [6]. Context, logistics and the need for a qualified team that has the how-to for data treatment of image sequences are among potential constraints on the use of the latter. Examples include respectively the costs involved, set-up configuration and time-consuming nature which collectively make difficult application of video-based tracking systems in practice. This is also observed in the present analysis owing that only one study using the latter method was found (see Table 2). Regardless of which EPTS or IMU are used, one further point requiring more caution is the fact that

measurement error should be ideally evaluated considering the specific location they were collected [see for a review: [59]], and only 2 studies included in our analysis did it such way [47, 48]; most cited data from previous investigations or reported just the horizontal dilution of precision calculated by the proprietary software. In sum, interpreting current evidence on speed but not acceleration thresholds using 10 Hz GPS may be reliable, and quality-control experiments are still needed within original investigations.

5. Limitations

A number of potential limitations should be recognized to the methods used in the present review as well as the derived implications: (1) inclusion of studies only in English, which may have resulted in a loss of evidence on the topic when published in other language; (2) consideration of all works regardless of whether it varies concerning the quality of evidence; (3) lack of a quantitative synthesis of extracted information, which is partly attributed to a substantial heterogeneity of methods used across included articles; (4) only 8 studies [17, 27, 30–32, 37, 45, 46, 48] were conducted with a minimum of 80 players as per previous recommendations to ensure sufficient statistical power [79]; (5) evidence may apply to a greater extent to youth male players rather than senior male and women's soccer and finally (6) despite the probed importance of curvilinear movements [80], these were not specifically determined in any of the reviewed studies.

6. Conclusion

In short, 40 m sprint test performed on-field was identified here as the preferred method to create individualized speed or acceleration thresholds in depicting players' external load in soccer. While the benefits of drawing thresholds from a single fitness indicator such as maximal sprinting performance are evidently accompanied by a number of limitations (e.g. may lack superior sensitivity to profile dose-response to training-induced changes), a rapid increase was identified in recent years suggesting the use of compound measures such as anaerobic speed reserve. However, in either case, the construct validity of fitness data to predict match-play running performance is not supported up to date. Also, the lack of standardization on test procedures and threshold zones established as well as the low sampling frequency in studies computing acceleration and deceleration demands defy practical applications. Finally, extending previous research using match data to obtain thresholds is still required aiming at overcome potential issues incurring from testing outside game context, otherwise intervention works are needed to confirm the value of individualisations based on fitness status.

Abbreviations

ASR = Anaerobic speed reserve

EPTS: Electronic performance and tracking systems

GPS = Global positioning system

LPS = Local Positioning Systems

MSS = Maximal sprinting speed

PRISMA = Preferred reporting items for systematic reviews and meta analyses

Declarations

Ethics Approval and Consent to Participate

Not applicable.

Consent for Publication

Not applicable.

Availability of Data and Materials

Not applicable.

Competing Interests

The authors declare that they have no competing interests relevant to the content of this article.

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FDS, MRG, and JPO made substantial contributions to the conception of the manuscript. FDS, MRG, LPV, FMC, HN, and JPO, drafted, revised and approved the final version.

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Tables

Due to technical limitations, Table 2 and 3 is only available as a download in the Supplemental Files section.

Figures

Figure 1

Flow diagram of the selection of studies.

Supplementary Files

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