Acceleration and deceleration demands during training sessions in football: a systematic review

Article *in* Science and Medicine in Football · June 2022

DOI: 10.1080/24733938.2022.2090600

CITATIONS
20

READS
2,058

4 authors:

Hugo Silva
University of Maia
6 PUBLICATIONS **26** CITATIONS
SEE PROFILE

Fabio Yuzo Nakamura
Universidade da Maia
578 PUBLICATIONS **11,679** CITATIONS
SEE PROFILE

Marco Beato
University of Suffolk
144 PUBLICATIONS **2,647** CITATIONS
SEE PROFILE

Rui Marcelino
Universidade da Maia (University of Maia)
104 PUBLICATIONS **2,659** CITATIONS
SEE PROFILE

Science and Medicine in Football

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rsmf20

Acceleration and deceleration demands during training sessions in football: a systematic review

Hugo Silva, Fábio Yuzo Nakamura, Marco Beato & Rui Marcelino

To cite this article: Hugo Silva, Fábio Yuzo Nakamura, Marco Beato & Rui Marcelino (2022): Acceleration and deceleration demands during training sessions in football: a systematic review, Science and Medicine in Football, DOI: 10.1080/24733938.2022.2090600

To link to this article: https://doi.org/10.1080/24733938.2022.2090600

SCIENCE AND MEDICINE IN FOOTBALL
https://doi.org/10.1080/24733938.2022.2090600

Routledge
Taylor & Francis Group

SYSTEMATIC REVIEW

Acceleration and deceleration demands during training sessions in football: a systematic review

Hugo Silva [a,b], Fábio Yuzo Nakamura [a,b], Marco Beato [c] and Rui Marcelino [a,b]

[a]Research Center in Sports Sciences, Health Sciences and Human Development, CIDESD, CreativeLab Research Community, Vila Real, Portugal; [b]Department of Sports Sciences and Physical Education, University of Maia, Maia, Portugal; [c]School of Health and Sports Sciences, University of Suffolk, Ipswich, UK

ABSTRACT

Purpose: The aim of this review is to summarize the current scientific knowledge about acceleration and deceleration demands during football training.

Methods: A systematic search of three electronic databases (PubMed, SPORTDiscus, Web of Science) was performed to identify peer-reviewed relevant English-language articles, following PRISMA guidelines.

Results: All acceleration and deceleration data were analyzed and organized into four categories: i) training drills variables (i.e. manipulated drills variables such as number of players in small-sided games), ii) training exercises (i.e. different drills such small games or circuit training), iii) players' positions (i.e. demands for each playing position) and iv) training schedule (i.e. training sessions presented as microcycles, season sections or full season). Full-text articles of 42 studies were included in the final analysis. Players' level included: amateur, youth, semi-professional, professional and elite players. All playing positions were considered, including goalkeepers. Six different global position systems brands were used, with the majority measuring data at 10 Hz. Different thresholds and intensities were used in several papers. Lower acceleration and deceleration intensities occurred more often than higher intensities in all four categories.

Conclusion: Different exercises elicit different demands and small-sided games presented higher acceleration and deceleration demands than circuit training and other running based drills. Furthermore, manipulating drills variables, as reducing or increasing number of players in small-sided games increase or decrease demands, respectively. Additionally, wide playing positions, such as fullbacks, are generally exposed to higher acceleration and deceleration demands. From a planning point of view, acceleration and deceleration demands decrease as match day approaches.

ARTICLE HISTORY
Accepted 11 June 2022

KEYWORDS
Small-sided game; training load; training drills; GPS; soccer; microcycle

Introduction

Football is an intermittent sport in which players repeatedly perform low and high-intensity activities, with concomitant sport-specific technical actions (Stølen et al. 2005; Bradley et al. 2010). Players need to perform many accelerations (ACC) and decelerations (DEC) during the match which impact the players' physical level and their performance during the final minutes of the game (Russell et al. 2016; Beato and Drust 2021). ACC and DEC are categorized as external training load and are usually monitored with Global Positioning System (GPS) technology (Aughey 2011; Cummins et al. 2013; Beato et al. 2018; Beato and de Keijzer 2019). The importance of ACC and DEC for competition has been highlighted due to the high mechanical and metabolic demand of these actions, which players have to perform repeatedly (Martín-García et al. 2018a; Riboli et al. 2020). The load from ACC and DEC constitutes a considerable portion of the total load for a player during match play (Dalen et al. 2016) and are associated with post-match muscle damage and fatigue indicated by changes in creatine kinase (increase) and countermovement jump performance (decrement) during recovery time (de Hoyo et al. 2016). This may be justified because ACC and DEC elicit higher metabolic and mechanical loads than constant speed running in football players (Osgnach et al. 2010; Hader et al. 2016; Jaspers et al. 2018).

To be physically prepared for the match, players must train to develop specific physical skills (e.g., lower limb muscle power, ability to change direction). The knowledge of such match demands can lead professionals to apply the approach 'train as you play' (Holt et al. 2006); however, it appears that football players frequently do not train with the same intensity as they compete, because higher physiological demands were found during competition than during training sessions (Castillo-Rodríguez et al. 2020; Oliva-Lozano et al. 2020). This is particularly true since many variables that are present in football training can affect ACC and DEC volume and intensity such as football drills used, players' positions and coaching philosophy (Dello Iacono et al. 2021). For instance, previous studies found that the distances performed during ACC and DEC could differentiate between positions during training, where higher distances were reported for central midfielders and lower distances for central defenders (Akenhead et al. 2016). Moreover, different ACC and DEC demands were found with variations in playing

CONTACT Hugo Silva hugorodriguessilva.35@gmail.com Research Center in Sports Sciences, Health Sciences and Human Development, CIDESD, CreativeLab Research Community, Avenida Carlos de Oliveira Campos Castêlo da Maia, Vila Real, Maia 4475-690, Portugal

Supplemental data for this article can be accessed online at https://doi.org/10.1080/24733938.2022.2090600

formations across different playing positions (Tierney et al. 2016). Since training specificity is important to improve performance and secure optimal adaptation (Reilly et al. 2009), a review on ACC and DEC demands during training may grant key information for coaches and practitioners, which could better plan and structure their training sessions.

Despite the great interest in ACC and DEC demands in football during the recent years, to the best of our knowledge, there is a lack of a practical and concise approach in scientific research that can summarize this important topic. Due to the importance of ACC and DEC in physical performance and training load, a systematic review on this topic can help practitioners and researchers in training design and in data analysis. Variations in ACC and DEC demands across a training week (with reference to the match day) and in different players' positions have not been systematically reviewed to date. These items, as well as different exercises and their variables adaptation to specific objectives, are the four main categories of both planning football training and conducting scientific research. Therefore, the aim of this review is to summarize the current scientific knowledge about ACC and DEC demands during football training.

Materials and methods

The current review was conducted in accordance with PRISMA (Preferred Reporting Items for Systematic Review and Meta-analysis) guidelines (Moher et al. 2010) and is described in Figure 1.

Search strategy

Systematic searches of three electronic databases (PubMed, SPORTDiscus, Web of Science) were conducted to identify peer-reviewed articles published in the English language between 1 January 2010 and 30 June 2020. Initial search was performed in different days for each electronic database (PubMed: 26 June 2020; SPORTDiscus: 30 June 2020; Web Of Science: 28 June 2020). Search terms were accelerat* and decelerat* with 'AND' and 'OR' with related terms as presented in Table 1.

The selection of the terms presented was based in two factors: from reviews and original articles keywords previously read; and from preliminary search of terms in databases.

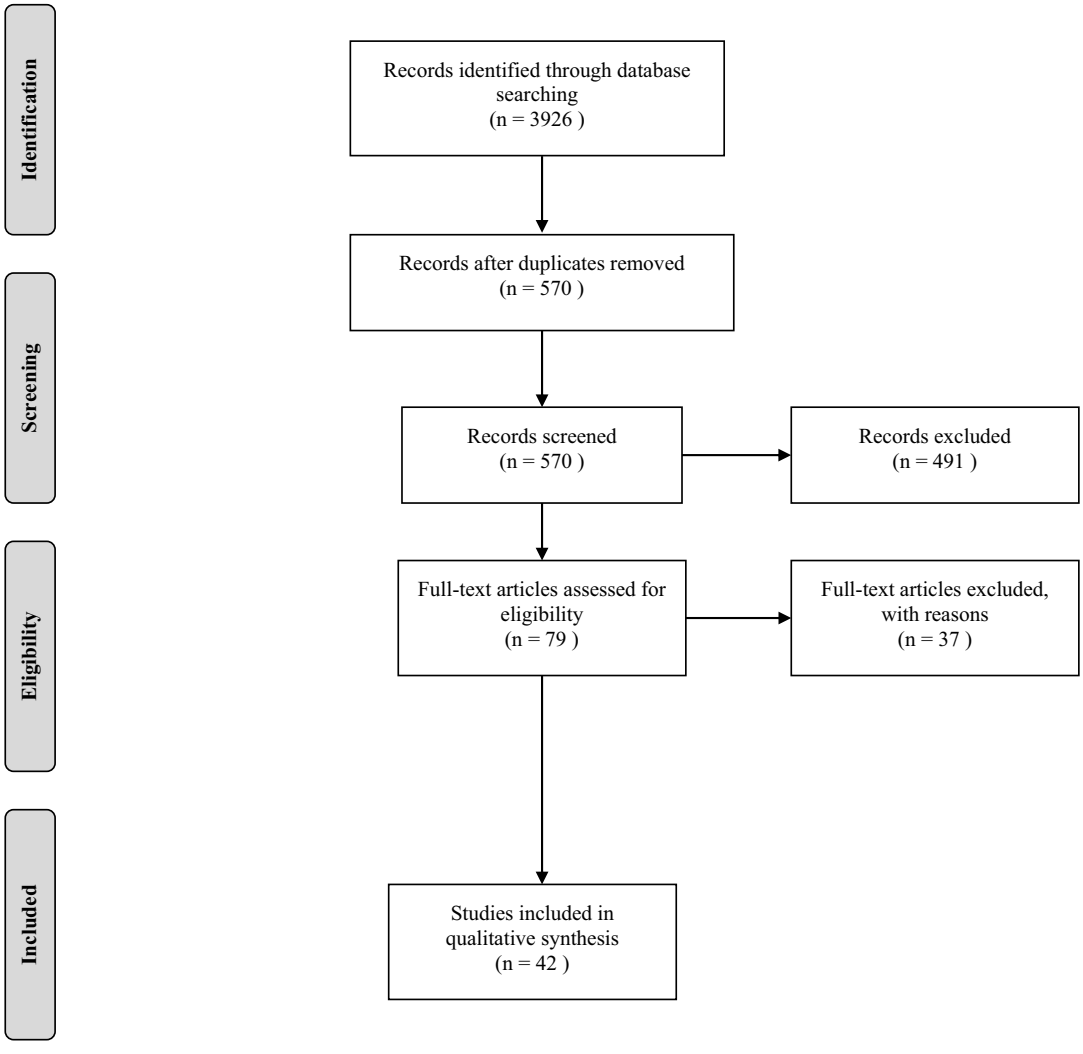

Figure 1. PRISMA flow diagram.

Table 1. Database search strategy.

Key search terms	Related search terms
1. Accelerat* OR Decelerat*	3. GPS OR external load OR tracking system OR time-motion OR movement profile OR training load OR microcycle OR small-sided games
2. Soccer OR Football	
Search: 1 AND 2 AND 3	

Studies screening

All search results were initially exported to Microsoft Excel (Microsoft, Redmond, WA, USA). Eligible studies were identified throughout different steps. First, duplicates were removed, after confirmation of title, year and author(s). Then, title and abstract were analyzed according to exclusion criteria reported in Table 2 and if any of these were clearly present the study was excluded. If an abstract was not clear for exclusion, the article remained selected for the next stage. In the final stage, studies were fully analyzed and excluded if exclusion criteria were met, or inclusion criteria were absent.

Risk of bias

The risk of bias assessment followed Cochrane recommendations and used the Risk Of Bias In Non-Randomized Studies of Interventions tool (ROBINS-I) (Sterne et al. 2016a). This tool uses different domains that results in a classification of low, moderate, serious, or crucial risk of bias for each domain and an overall assessment of each study. Domains of ROBINS-I are: 1) Bias due to confounding; 2) Bias due to selection of participants; 3) Bias in classification of interventions; 4) Bias due to deviations from intended interventions; 5) Bias due to missing data; 6) Bias in measurement of outcomes; 7) Bias in selection of the reported result. Finally, an overall risk of bias is provided. To perform this assessment, each study was analyzed by two authors, with a third author resolving disagreements, following the guidelines from the detailed guidance (Sterne et al. 2016b). Detailed assessment can be consulted in supplementary information (Table S1). Since this review includes a high number of studies, we chose to provide a summary plot (Figure 2), with each domain and the overall risk of bias assessment. To do so, we used Risk-of-bias VISualization (robvis) (McGuinness and Higgins 2021).

Table 2. Inclusion-Exclusion criteria.

	Inclusion criteria	Exclusion criteria
1	Original research articles	Reviews; books; letters to editors; conferences; magazines or journals; periodicals; unpublished; non-peer-reviewed.
2	Football training	Other sports; only match (official, friendly or simulation) data; single exercise trial used to define thresholds, validate equipment or tests.
3	Able soccer players with mean age ≥ 15 years old	Athletes of other sports; recreational players; referees; players <15 years old; athletes with physical or mental disability; data relative only to one player.
4	GPS systems (with or without accelerometers) identified	Acceleration data provided exclusively by accelerometer; any non-GPS system (e.g. video-based tracking); GPS Hz information not provided; players used additional equipment other than GPS, accelerometer or heart-rate bands/straps (e.g. sled).
5	Clear and identifiable acceleration data provided as external training load	Only player-load or acceleration load data; training data is merged with match data; acceleration presented only as percentage or effects sizes in relation to other variable; acceleration scale not clearly defined.

GPS, Global Positioning System

Statistical analysis

This systematic review does not have any meta-analysis or statistical analysis between studies because different GPS brands, different ACC and DEC metrics, different ACC and DEC thresholds were used. The authors decided that the risk of bias for a meta-analysis and related between analyses were too high and any analysis could have been biased.

Results

Search results

Figure 1 reports the selection of 42 studies for this review from a total of 3926 articles. Two of the selected studies were not sufficiently clear in their ACC data and the corresponding authors were contacted via e-mail for further information. Information was provided and both studies were included in this review. This review does not differentiate between GPS and Global Navigation Satellite System technology (Beato and de Keijzer 2019).

Studies characteristics

Descriptive characteristics of the selected 42 studies are presented in Table 3.

Regarding samples, the main level categories were professional level (36%, n = 15) and elite (17%, n = 7). Other labels were used and can be seen in supplementary information (Figure S1). From the 835 football players, 56 (7%) are female football players. Average ages from all studies ranged between 16 and 28 years old. Player positions were identified in different studies, including goalkeepers.

Different equipment was used by the selected studies, with the majority, 69% (n = 29), using GPS with a sampling frequency of 10 Hz, followed by 17% that used 15 Hz (n = 7), 7% (n = 3) using 18 Hz, 5% (n = 2) using 20 Hz and 2% (n = 1) using 5 Hz. One study adopted 15 Hz sampling frequency for other variables but used 5 Hz when collecting ACC data (Mara et al. 2016). Additional information regarding the equipment's used can be found in supplementary information Figures S2 and S3.

Acceleration and deceleration measurements and thresholds

21% (n = 9) of the 42 selected studies did not provide DEC data. The presented ACC/DEC data was analyzed through different variables (e.g. number, distance, frequency) that can be found

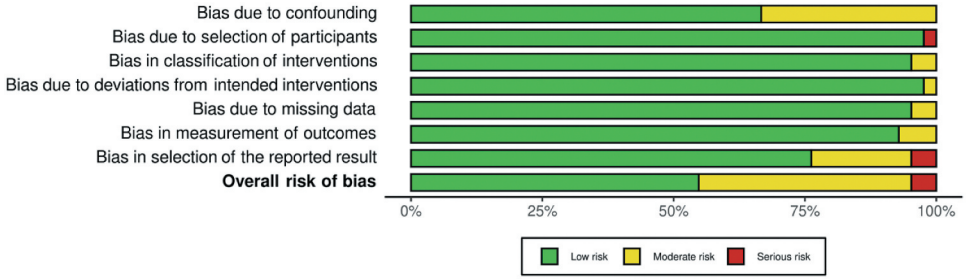

Figure 2. Summary plot of the risk of bias for each seven domains and the overall risk of bias ROBINS-I tool.

in supplementary information (Figure S4). Additionally, different intensity thresholds were used to measure ACC and DEC, which are detailed in Table 4. To fill this gap, we created four main categories to interpret the data: i) training drills variables (i.e. manipulated drills variables such as number of players in small-sided games), ii) training exercises (i.e. different drills such small games or circuit training), iii) players' positions (i.e. demands for each playing position) and iv) training schedule (i.e. training sessions presented as microcycles, season sections or full season).

Training drills variables

Typically, SSG formats increase ACC and DEC demands when a reduced number of players (Castellano et al. 2013; Gaudino et al. 2014; Mara et al. 2016; Casamichana Gómez et al. 2018; Giménez et al. 2018a, 2020b; Martin-Garcia et al. 2019; Martín-García et al. 2020; Sannicandro et al. 2020; Zurutuza et al. 2020) and smaller pitch sizes (Mara et al. 2016; Casamichana et al. 2018; Madison et al. 2019) are used. However, some exceptions were found for 5vs.5 that had less ACC > 2.5 $m{\cdot}s^{-2}$ than 7vs.7 format (Castellano et al. 2013), while more maximal ACC and DEC were found in 10vs.10 than in 7vs.7 and 5vs.5 (Gaudino et al. 2014); finally, short wide pitch size (25x66m) elicited more moderate intensity ACC and high-intensity DEC than short narrow size (25x40m) (Casamichana et al. 2018). Contrasting results such as higher demands in medium or larger pitches sizes, were also registered, but that can be due to the different measurement used to assess demands (ACC and DEC distance covered) (Hodgson et al. 2014; Castagna et al. 2019) or goalkeeper demands (Jara et al. 2019).

SSG can also be manipulated by changing specific rules; for instance, numerical superiority decreases ACC and DEC demands (Praça et al. 2015, 2018), especially for the floaters (Praça et al. 2015; Casamichana Gómez et al. 2018; Rábano-Muñoz et al. 2019). Another common rule used during SSG is the number of ball touches allowed; however, this review reports conflicting results were found in this review (Casamichana et al. 2014; Gómez-Carmona et al. 2018; Giménez et al. 2018b). SSG are often proposed in two formats, first to maintain the possession of the ball, which reported high demands in one study (Halouani et al. 2019); second, to score goals, which reported more ACC and DEC than possession games in other two studies (Castellano et al. 2013; Gaudino et al. 2014). The presence or absence of fatigue was also analyzed and, the only paper reported in this review on this specific topic reported that mental fatigue can affect ACC and DEC demands (Coutinho et al. 2017). Finally, drills were also conditioned by the relation of work and rest times. While one study found more ACC in the regimen of 3 sets of 6 minutes than 6 sets of 3 minutes in a 5vs.5 SSG (both with 2 minutes of rest) (Clemente 2018), opposite results were found with the same regimens in another study (Manuel Clemente et al. 2019).

Regarding efforts, ACC had higher values in some studies (Hodgson et al. 2014; Gómez-Carmona et al. 2018; Giménez et al. 2018a, 2018b, 2020b; Castagna et al. 2019; Jara et al. 2019; Madison et al. 2019; Manuel Clemente et al. 2019; Zurutuza et al. 2020), while DEC had in others (Coutinho et al. 2017; Halouani et al. 2019; Martin-Garcia et al. 2019; Rábano-Muñoz et al. 2019; Owen et al. 2020; Sannicandro et al. 2020). Finally, low ACC and DEC intensities occur more frequently than higher intensities (Castellano et al. 2013; Hodgson et al. 2014; Praça et al. 2015; Gómez-Carmona et al. 2018; Giménez et al. 2018a, 2018b).

Training exercises

When comparing training drills and matches, higher ACC and DEC demands were found in SSG (Giménez et al. 2018a, 2020b; Giménez and Gomez 2019; Martin-Garcia et al. 2019), in friendly matches (Campos-Vazquez et al. 2019) and official matches (Castillo et al. 2019). Matches (official and friendly) imposed higher DEC demands in female players, except in central midfielders, while technical-tactical training elicited higher ACC demands (Passos Ramos et al. 2019). Contrasting with these findings, friendly matches elicited the lowest ACC and DEC demands in comparison with training sessions that included SSG, large-sided games (LSG) and mini-goals games (Giménez et al. 2020a). Between training protocols, the same study reported the lower DEC demands in the training session composed with SSG, circuit training and LSG, while the lower ACC demands were found in the training session with mini-goals, circuit training and LSG. Additionally, circuit training was also the least-demanding drill when compared with SSG, LSG, mini-goals games and friendly matches (or match simulations) (Giménez and Gomez 2019; Giménez et al. 2020b). Furthermore, higher ACC and DEC distances were covered during 1vs.1 and 2vs.2 SSG formats than in continuous and shuttle running drills (Ade et al. 2014; Castagna et al. 2017). In a study investigating female players, warm-up drills and

Table 3. Detailed description of selected studies.

Study	Year	Purpose	Sample	Variable	Acceleration Data	Acceleration Scale (thresholds)	Conclusion
(Giménez et al. 2020a)	2020	Investigate relationship among physical demands of Friendly Matches (Bradley et al. 2010) and 3 different training sessions	n = 14 male professional age = 23.2 ± 2.7	Friendly Matches; Training 1 (SSG + Mini-goals Large Sided Game), 2 (SSG + circuit training + long sided game), 3 (mini-goal + circuit training + long sided game)	No. ACC & DEC	ACC & DEC between 2 $m{\cdot}s^2$ intervals	Training routines did not replicate the main set of high intensity efforts experienced in competitive conditions
(Martín-García et al. 2020)	2020	Compare physical demands of different SSG according to player field position and the most demanding passages of matches	n = 25 male age = 20.4 ± 2.1	Match demanding passages (MDP) vs. 4 × 4 + 3 vs. 5vs5 + 3 vs. 7v7 + 3 vs. 8vs8 + 3 according to player position	Frequency (rep/min) ACC & DEC	ACC & DEC > 3 $m{\cdot}s^{-2}$	Distance, distance covered at high speed and distance covered when sprinting are the variables that have the lowest MDP percentage while performing the games studied
(Owen et al. 2020)	2020	Quantify association between 5 × 5 SSG and Yo-YoIR1	n = 23 elite age = 25.3 ± 3.1	5x5 and Yo-YoIR1	No. ACC & DEC	ACC & DEC (≥3.3 $m{\cdot}s^{-2}$)	5 vs. 5 SSG assessment protocol can be utilized more regularly by coaches as aerobic fitness testing to assess the intermittent aerobic capacity of elite football players
(Querido and Clemente 2020)	2020	Characterize microcycle (Internal/ External Load) and identify effects of SSG and strength training	n = 15 male elite age = 18.55 ± 0.39	Microcycle (each training session presented different SSG – identified with intervals)	Frequency (rep/min) ACC & DEC	ACC>2 $m{\cdot}s^{-2}$/min & >4 $m{\cdot}s^{-2}$/min & DEC>2 $m{\cdot}s^{-2}$/ min & >4 $m{\cdot}s^{-2}$/ min	External load monitoring revealed that MD-4 had the highest values of ACC and DEC > 2 $m{\cdot}s^2$ /min
(Sannicandro et al. 2020)	2020	Compare the external training load of different SSG formats	n = 22 male professional age = 24.7 ± 3.9	SSG (5x5, 6x6, 7x7, all with GK) +wildcard players	Max ACC & DEC; No. ACC & DEC	ACC>2.5 $m{\cdot}s^{-2}$ DEC<2.5 $m{\cdot}s^{-2}$	Significantly more ACC events were detected in the 5vs5 format whereas the number of DEC was significantly greater in the 6vs6 compared with the 7vs7 format
(Zurutuza et al. 2020)	2020	Investigate the structure of interrelationships among external/internal training intensity metrics and how these vary depending on game format	n = 23 male semi-professional age = 25.1 ± 3.7	SSG vs. MSG vs. LSG vs. Simulated Game	Distance ACC & DEC	ACC & DEC (>2 $m{\cdot}s^{-2}$)	ACC and DEC component was the most stimulated in SSG, the cardiovascular demands were highest in MSG, and peak and average velocity were most demanded in LSG and SG
(Campos-Vazquez et al. 2019)	2019	Compare demands of Friendly Matches & Training Sessions during Pre-Season	n = 22 male professional age = 28.1 ± 4.7	Friendly Matches; Different Training Sessions (Tactical; Fitness, Pre-match activation; Fitness reserves)	Distance ACC & DEC per hour	Moderate: 2–3 $m{\cdot}s^{-2}$; and High: >3 $m{\cdot}s^{-2}$ ACC & DEC	Friendly matches produce the highest loaded training stimulus across the preseason period
(Castagna et al. 2019)	2019	Examine the internal/external load imposed by Long Sprint Ability oriented SSG using different players-to-pitch area ratio (densities)	n = 19 male professional academy-level age = 17.1 ± 0.3	SSG300m vs. 200 m vs. 100 m	Distance ACC & DEC	ACC & DEC (≥2 $m{\cdot}s^{-2}$)	During the SSG300m the players attained external and internal load values that were practically higher than those achieved during the other formats
(Castillo et al. 2019)	2019	Analyze external load of 3 different training sessions with competitive match	n = 16 male professional age = 21.0 ± 0.6	Training 1 (neuromuscular); Training 2 (endurance); Training 3 (speed); Match	No. High ACC per minute	ACC > 3 $m{\cdot}s^{-2}$	External loads were higher during matches when compared with acquisition training sessions
(Manuel Clemente et al. 2019)	2019	Analyze the variations of internal/ external load between and within intermittent regimens (6x3′ and 3x6′) during a SSG	n = 10 male amateur age = 23.7 ± 1.1	6x3′ vs. 3x6′ and each set separately	Frequency (rep/min) ACC & DEC	ACC & DEC (>2 $m{\cdot}s^{-2}$)	Shorter sets (6x3′) almost certainly largely increased total and running distances and very likely moderately and largely increased total ACC and DEC; increases in RPE were found in longer sets
(Curtis et al. 2021)	2019	Quantify and compare season total workload by starter vs. reserve	n = 22 male collegiate age = 20 ± 2	Total, Match and training workloads	No. ACC in four zones	AZ1, 0–0.99 $m{\cdot}s^{-2}$; AZ2, 1–1.99 $m{\cdot}s^{-2}$; AZ3, 2–2.99 $m{\cdot}s^{-2}$; and AZ4, .3 $m{\cdot}s^{-2}$	Starters accumulated substantially more total physical and physiological workloads over the season

(*Continued*)

Table 3. (Continued).

Study	Year	Purpose	Sample	Variable	Acceleration Data	Acceleration Scale (thresholds)	Conclusion
Giménez et al. (103)	2019	Predict the cut-off point values that best differentiate the physical demands of different training drills (SSG, LSG, MG, and CT) and match	n = 14 professional male age = 23.2 ± 2.7	SSG vs. MG vs. CT vs. LSG vs. Friendly Match	No. ACC & DEC	ACC & DEC (>2 $m \cdot s^{-2}$)	Training and match tasks place different demands on football players in terms of running, deceleration, acceleration and maximal velocity reached
(Halouani et al. 2019)	2019	Investigate the effects of the SSG-Stop Ball compared to SSG-Small Goals on physical responses	n = 16 young male age = 18.3 ± 0.7	4x4 SSG Stop-Ball vs. 4 × 4 SSG Small Goals	No. ACC & DEC	ACC & DEC 2–3 $m \cdot s^{-2}$ & > 3 $m \cdot s^{-2}$	SSG-Stop Ball induced higher physical and HR values than the SSG-Small Goals
(Jara et al. 2019)	2019	Analyze how modification of SSG pitch size affects the physical demands of GK	n = 3 professional male age = 24.5 ± 7.2	Small Pitch vs. Medium vs. Large	No. ACC & DEC	ACC & DEC > 3 $m \cdot s^{-2}$	Intensities were lower when the pitch size was larger and pitch exploration variables increased along with the increment of the pitch size
(Madison et al. 2019)	2019	Determine the effects of small sided game (SSG) variations on hamstring torque	n = 10 male semi-professional age = 23 ± 5	SSG (3x3; 300 m^2) vs. LSG (4x4; 1000 m^2)	Total No. ACC & DEC	ACC >1 $m \cdot s^{-2}$ & DEC >-1 $m \cdot s^{-2}$	Larger relative area SSG elicited the greatest internal and external loads, resulting in decrements in hamstring force
(Martin-Garcia et al. 2019)	2019	Determine the differences between four training games and competitive matches according to position and compared to the most demanding passages of match	n = 21 age = 20.4 ± 1.2	5x5 vs. 6 × 6 vs. 9 × 9 vs. 10 × 10 (all with GK) vs. match	Frequency (rep/min) ACC & DEC (all and by position)	ACC & DEC > 3 $m \cdot s^{-2}$	As the SSG format increases, all the rest of the variables increase and the number of cases with significant interposition differences also increases
(Moreno-Pérez et al. 2020)	2019	External Load GK	n = 20 male professional age = 27.6 ± 2.0	Training Load during 2 Microcycles	No. High & Low ACC & DEC	ACC > 3 $m \cdot s^{-2}$ DEC < 3 $m \cdot s^{-2}$	External load was progressively decreased in the days before match and habitual GK training has an excess of ACC/DEC
(Rábano-Muñoz et al. 2019)	2019	Compare demands of a SSG in different ages groups	n = 30 male age = 24.09 ± 3.51 (senior); 17.83 ± 0.85 (U-19) age = 15.97 ± 0.58 (U-17)	SSG (4x4 + 2 floaters) in U17, U19 and senior	Distance ACC & DEC	ACC > 2.5 $m \cdot s^{-2}$ DEC < 2.5 $m \cdot s^{-2}$	Demands of the SSG are determined by the age of the players and regular players have greater demands than floater players in the SSG utilized
(Passos Ramos et al. 2019)	2019	Compare activities profile of different training activities with competitive match	n = 21 female national players age = 26 ± 3.6	Match vs. Warm-up vs. SSG vs. technical/tactical vs. friendly match	Frequency (rep/min) ACC & DEC	All between </> 2.5 $m \cdot s^{-2}$	There were different ACC and DEC demands amongst different activities and only friendly match activity was replicated or exceeded matches
(Casamichana et al. 2018)	2018	Investigate the effect of pitch shape on heart rate and time-motion during SSG	n = 20 male amateur age = 21 ± 5	5x5 (short narrow pitch vs. short wide vs. long narrow vs. long wide)	No. ACC & DEC	ACC & DEC Moderate (> 3 $m \cdot s^{-2}$) and High (> 4 $m \cdot s^{-2}$)	Modifying length places greater physiological demands on players than modifying width
(Clemente 2018)	2018	Test associations between wellness and Internal/External Load during 2 SSG	n = 10 male amateur age = 19.8 ± 1.6	SSG 5 × 5 in two different regimens (3x6′ vs. 6x3′)	Total No. ACC	ACC > 2 $m \cdot s^{-2}$	Wellness status may influence workload in SSG; in particular, DOMS may be moderately-to-largely detrimental to both internal and external load variables. Moreover, it was confirmed that RPE is moderately-to-largely correlated to objectively measured external load variables.

(*Continued*)

Table 3. (Continued).

Study	Year	Purpose	Sample	Variable	Acceleration Data	Acceleration Scale (thresholds)	Conclusion
(Giménez et al. 2018b)	2018	Investigate the influence of n. ° of touches on SSG physical responses	n = 14 male professional age = 23.2 ± 2.7	4x4 (1 touch vs. 2 touches vs. free touches)	Distance ACC	ACC 1 (< −4 $m \cdot s^{-2}$), ACC 2 (−4 to −2 $m \cdot s^{-2}$), ACC 3 (−2 to 0 $m \cdot s^{-2}$), ACC 4 (0–2 $m \cdot s^{-2}$), ACC 5 (2 to 4 $m \cdot s^{-2}$), and ACC 6 (> 4 $m \cdot s^{-2}$).	The use of one touch during SSGs increases the time walking and high-intensity ACC
(Giménez and Gomez 2019)	2018	Investigate and compare different physical variables and load indicators of 2 SSG and ball circuit training	n = 14 male professional age = 23.2 ± 2.7	SSG, Mini-Goal Game, Circuit, Match simulation	No. ACC & DEC	ACC & DEC ±2 $m \cdot s^{-2}$	Although SSGs, MGs, CT, and MS activities do simulate certain match patterns, it seems that players in SSs engage in more high-intensity activity
(Casamichana Gómez et al. 2018)	2018	Study and compare the demands imposed on wildcard and regular players in different positional games (4v4 + 3, 5v5 + 3, 7v7 + 3 and 8v8 + 3)	n = 25 age = 20.5 ± 1.8	4v4 + 3, 5v5 + 3, 7v7 + 3 and 8v8 + 3 (regular vs. wildcard)	Frequency (rep/min) ACC & DEC	ACC & DEC > 3 $m \cdot s^{-2}$	Load imposed on wildcard players is lower than the one imposed on regular players
(Gómez-Carmona et al. 2018)	2018	Characterize External/Internal Load of matches and SSG related to their objective; compare SSG; and analyze SSG requirements to matches	n = 20 national level age = 17.32 ± 0.87	Match & 4 different SSG (6x6 with different objectives)	Frequency (no./min) Low, Medium and High ACC & DEC	ACC & DEC/min; Low (1–2.5 $m \cdot s^{-2}$); Medium (2.5–4 $m \cdot s^{-2}$); High (> 4 $m \cdot s^{-2}$)	The objective of the SSGs directly influenced the demands on the players in training sessions
(Martín-García et al. 2018b)	2018	Determine External Load across player position and relative to competition and a microcycle; examine variation in soccer players in MD+1	n = 24 professional age = 20 ± 2	Microcycle (MD+1 divided in players who competed >60′ and others)	No. ACC & DEC	ACC & DEC > 3 $m \cdot s^{-2}$	MD + 1C was more intense than the MD + 1 R; loads were greatest in MD-4 with selected metrics approaching competition loads; (c) the external load of the microcycle varied substantially based on the players tactical role in the team, and (d) the coefficient of variation (CV) for weekly training sessions was generally large across all elements of the microcycle.
(Praça et al. 2018)	2018	Analyze the influence of SSG variables in physical demands of SSG	n = 18 male young age = 16.4 ± 0.4	3x3 vs. 4 × 3 (+ floater) with GK. Players divided by tactical knowledge test results (G1vsG2)	No. ACC and Percentage of total distance	ACC > 2 $m \cdot s^{-2}$	Cognition factors (tactical knowledge) and SSG settings influence athletes' physical and physiological demands during SSG.
(Castagna et al. 2017)	2017	Examine the effects of Running Drills & SSG as Long Sprint Ability on internal/external load	n = 14 male academy level age = 17.6 ± 0.61	Difference between Running Drills and SSG (1x1) in Maintenance (work:rest 1:2) and Production (1:5)	ACC & DEC distance	ACC & DEC (≥ 2 $m \cdot s^{-2}$)	Generic drills showed superiority over specific drills in inducing Long Sprint Abilities related physiological responses.
(Coutinho et al. 2017)	2017	Examine the effects of mental fatigue and additional corridor and pitch sector lines on players' physical and tactical performances during SSG		With mental fatigue vs. non-fatigued opponents in normal pitch and with vs. without mental fatigue with reference lines	No. ACC & DEC	ACC & DEC: Low (1–2 $m \cdot s^{-2}$); Medium (2–3 $m \cdot s^{-2}$); High (> 3 $m \cdot s^{-2}$)	Mental fatigue affects the ability to use environmental information and players' positioning, while the additional reference lines may have enhanced the use of less relevant information to guide their actions during the mental fatigue and normal pitch and with condition.
(Giménez et al. 2018a)	2017	Compare the movement patterns during SSG, LSG and FM	n = 14 male professional age = 23.2 ± 2.7	Friendly Match vs. SSG (4x4) vs. LSG (8x8)	No. ACC & DEC	ACC & DEC: 0.0–2.0 $m \cdot s^{-2}$; 2.1–4.0 $m \cdot s^{-2}$; > 4.0 $m \cdot s^{-2}$	SSG do not replicate exactly the movement patterns of a competitive match, but can increase the execution of short-term and high-intensity movements for specialized training.

(*Continued*)

Table 3. (Continued).

Study	Year	Purpose	Sample	Variable	Acceleration Data	Acceleration Scale (thresholds)	Conclusion
(Malone et al. 2018)	2017	Impact pre-training performance and CK status on subsequent training performance	n = 30 male elite age = 25.3 ± 3.1	ACC presented as season average and session intensity (relatively)	Total No. ACC & DEC and ACC & DEC per minute	ACC & DEC > 3 $m \cdot s^{-2}$	Training output can be influenced by reduced neuromuscular performance and increased creatine kinase levels
(Akenhead et al. 2016)	2016	Describe external load during 1 season 1-game weeks	n = 33 male professional age = 24 ± 4	Data per training day and per player position	Total No. ACC & DEC	ACC > 1 $m \cdot s^{-2}$ & DEC > −1 $m \cdot s^{-2}$	Only total distance, ACC and DEC distance were able to differentiate between playing positions and expressing ACC and DEC variables relative to training time and total distance reduced the effect size of inter-day differences and altered the rank-order of training sessions within the microcycle.
(Mara et al. 2016)	2016	Investigate the physical and physiological response to different formats of SSG	n = 18 female elite age = 24.3 ± 4.2	SSG (4x4 & 5 × 5), MSG (6x6 & 7 × 7), LSG (8x8 & 9 × 9)	Mean ACC interval and distance; maximum ACC distance; peak speed, peak ACC and recovery duration; commencement and final velocities	ACC (≥ 2 $m \cdot s^{-2}$)	Coaches can manipulate sprinting, HSR, ACC profiles, heart rate and metabolic demands by concurrently modifying the number of players and field dimensions in elite female soccer training games
Gaudino et al. (104)	2015	Identify most influential external load markers on session RPE	n = 22 male elite age = 26 ± 6	Average of complete season	No. ACC & DEC No. ACC & DEC per minute	ACC & DEC > 3 $m \cdot s^{-2}$	The external-load measures that were found to be moderately predictive of RPE-TL in soccer training were HSR distance and the number of impacts and ACC
(Mara et al. 2015)	2015	Investigate the variation in training demands, physical performance and player wellbeing across a female soccer season	n = 17 female elite age = 16.4 ± 0.7	Preseason vs. early season vs. late season	No. ACC & DEC	ACC & DEC (≥ 2 $m \cdot s^{-2}$)	Training demands fluctuated between preseason and early season, with observed declines in all training variables following preseason
(Praça et al. 2015)	2015	Compare physical demands of 3x3, 4 × 3 and 3 × 3 + 2	n = 18 young male age = -	SSG 3 × 3 vs. 3 × 3 + 2 vs 4 × 3 (GK included in all)	No. ACC and Percentage of total distance	ACC 1: > 2 $m \cdot s^{-2}$; > 2.5 $m \cdot s^{-2}$	A reduction in physical demands was observed for small-sided games performed in unbalanced situations (4vs.3)
(Ade et al. 2014)	2014	Quantify physiological responses, time-motion characteristics of Speed-Endurance-Production and Speed-Endurance-Maintenance drills	n = 16 elite male youth age = 17 ± 1	Running Production (30:60″) and Maintenance (120:60″) vs. SSG Production (1vs1 30:60″) and Maintenance (2x2 120:60″)	Distance ACC & DEC	High ACC & DEC: 2–3 $m \cdot s^{-2}$ Maximum ACC & DEC: > 3 $m \cdot s^{-2}$	The physiological responses were greater in the running drills than in the respective SSG except in ACC and DEC
(Casamichana et al. 2014)	2014	Examine the effect of exercise duration and n. ° of touches during SSG	n = 12 male semi-professional age = 22.7 ± 4.3	6x6 free vs. 6 × 6 with 2 touches max; 12′ divided (6′+6′)	No. ACC in four zones	ACC zones (1.0–1.4, 1.5–1.9, 2.0–2.4, and ≥2.5 $m \cdot s^{-2}$)	SSG with free play touches decrease the intensity of physical parameters during the second 6-min period. During the second period (6–12 min) of SSG with 2 touches there was an increase in HRmean and in the time spent in high exercise intensity zones, but these differences were not observed in SSG free play.
(Vargas Fuentes et al. 2014)	2014	Observe the evolution of the external load of a player return to training after injury	n = 13 male age = 20.9 ± 1.7	Difference between team and injury player for each day	No. ACC & DEC in three zones	ACC & DEC 1: 0–2 $m \cdot s^{-2}$; 2: 2–3 $m \cdot s^{-2}$; 3: 3–5 $m \cdot s^{-2}$	Intensity of the training of the injured player was probably too high after a fairly long recovery period of one month
(Gaudino et al. 2014)	2014	Influence of SSG variables in physical demands of SSG	n = 26 male age = 26 ± 5	5x5 vs. 7 × 7 vs. 10 × 10 (possession only vs. regular play with GK)	No. & Max ACC & DEC	Moderate (2–3 $m \cdot s^{-2}$) & High (>3 $m \cdot s^{-2}$) ACC & DEC	SSG represent an appropriate and efficient training mode to stimulate all the specific physical aspects of playing football

(*Continued*)

Table 3. (Continued).

Study	Year	Purpose	Sample	Variable	Acceleration Data	Acceleration Scale (thresholds)	Conclusion
(Hodgson et al. 2014)	2014	Quantify characteristics and technical demands of (SSG) played on small, medium and large pitches	n = 8 university level age = 20 ± 1	Small (30x20) vs. Medium (40x30) vs. Large (50vs40)	Distance ACC & DEC	ACC & DEC: Low (1–2 $m \cdot s^{-2}$); Medium (2–3 $m \cdot s^{-2}$); High (> 3 $m \cdot s^{-2}$) Total ACC & DEC (≥ 1 $m \cdot s^{-2}$)	Small pitch sizes are characterized by a reduced physical demand and an increased technical demand in comparison to large pitches. Medium pitch sizes seem to be optimal; providing both a high frequency of technical actions, and a high physical demand that is unchanged as pitch size increases
(Castellano et al. 2013)	2013	Influence of SSG variables in physical demands of SSG	n = 14 male semi-professional age = 21.3 ± 2.3	3x3 vs. 5 × 5 vs. 7vs7 (with GK vs. with small goals vs. possession)	No. ACC in four zones	ACC zones (1.0–1.5, 1.5–2.0, 2.0–2.5, and >2.5 $m \cdot s^{-2}$)	Changes both in game format and the number of players affect the players' physiological and physical demands

ACC, Acceleration

CK, Creatine Kinase; CT, Circuit Training; CV, Coefficient of Variance; DEC, Deceleration; GK, Goalkeeper; HSR, High speed running; HR, Heart rate; HRmean, Heart rate mean; LSG, Large-sided games; MD+1C, Match day plus one day compensatory session; MD+1 R, Match day plus one day recovery session; MDP, Match demanding passages; MG, Mini Goal; MS, Match simulation; MSG, Medium-sided games; RPE, Rate of Perceived Exertion; RPE, Rate of Perceived Exertion Training Load; SG, Simulated game; SSG, Small-sided games; U-17, Under 17; U-19, Under 19.

Table 4. Acceleration and deceleration intensities and thresholds from the selected studies.

Intensity classification	Threshold (ACC exclusively or both ACC and DEC)	Studies
No classification	> 1 $m \cdot s^{-2}$	(Akenhead et al. 2016,Madison et al. 2019)
	≥ 2 $m \cdot s^{-2}$	(Mara et al. 2016)
	> 2 $m \cdot s^{-2}$	(Giménez et al. 2018a,Zurutuza et al. 2020,Praça et al. 2018,Clemente 2018,Manuel Clemente et al. 2019,Giménez and Gomez 2019,Giménez et al. 2020a)
	> 2 $m \cdot s^{-2}$ and > $m \cdot s^{-2}$	(Querido and Clemente 2020)
	> 2.5 $m \cdot s^{-2}$	(Rábano-Muñoz et al. 2019)
	> 3 $m \cdot s^{-2}$	(Akenhead et al. 2016,Jara et al. 2019,Halouani et al. 2019,Malone et al. 2018, p. 103)
	≥ 3.3 $m \cdot s^{-2}$	(Owen et al. 2020)
	≥ 4 $m \cdot s^{-2}$	(Castellano et al. 2013)
Maximum Intensity	> 3 $m \cdot s^{-2}$	(Ade et al. 2014)
High Intensity/ High ACC/ Intense	> 4 $m \cdot s^{-2}$	(Casamichana et al. 2018,Gómez-Carmona et al. 2018)
	> 3 $m \cdot s^{-2}$	(Akenhead et al. 2016,Martin-Garcia et al. 2019,Martín-García et al. 2020,Casamichana Gómez et al. 2018,Gaudino et al. 2014,Hodgson et al. 2014,Giménez et al. 2018b,Coutinho et al. 2017,Campos-Vazquez et al. 2019,Castillo et al. 2019,Moreno-Pérez et al. 2020, Martín-García et al. 2018b)
	≥ 2.5 $m \cdot s^{-2}$	(Sannicandro et al. 2020)
	2 to 3 $m \cdot s^{-2}$	(Ade et al. 2014)
	> 2 $m \cdot s^{-2}$	(Mara et al. 2015, p. 104)
	≥ 2 $m \cdot s^{-2}$	(Castagna et al. 2019,Castagna et al. 2017)
Medium/ Moderate Intensity	> 3 $m \cdot s^{-2}$	(Casamichana et al. 2018)
	2.5 to 4 $m \cdot s^{-2}$	(Gómez-Carmona et al. 2018)
	2 to 3 $m \cdot s^{-2}$	(Akenhead et al. 2016,Gaudino et al. 2014,Hodgson et al. 2014,Giménez et al. 2018b, Coutinho et al. 2017,Campos-Vazquez et al. 2019)
Low Intensity	1–2.5 $m \cdot s^{-2}$	(Gómez-Carmona et al. 2018)
	1 to 2 $m \cdot s^{-2}$	(Akenhead et al. 2016,Hodgson et al. 2014,Coutinho et al. 2017)
Zones/Intervals/ Levels	< −2.5 $m \cdot s^{-2}$, −2.5 to −1 $m \cdot s^{-2}$, −1 to 1 $m \cdot s^{-2}$, 1 to 2.5 $m \cdot s^{-2}$ and > 2.5 $m \cdot s^{-2}$	(Passos Ramos et al. 2019)
	1.0 to 1.4 $m \cdot s^{-2}$, 1.5 to 1.9 $m \cdot s^{-2}$, 2.0 to 2.4 $m \cdot s^{-2}$ and ≥ 2.5 $m \cdot s^{-2}$	(Casamichana et al. 2014)
	0 to 2 $m \cdot s^{-2}$, 2 to 3 $m \cdot s^{-2}$, 3 to 5 $m \cdot s^{-2}$ and 0 to −2 $m \cdot s^{-2}$, −2 to −3 $m \cdot s^{-2}$, −3 to −5 $m \cdot s^{-2}$	(Vargas Fuentes et al. 2014)
	> 2 $m \cdot s^{-2}$ and > 2.5 $m \cdot s^{-2}$	(Praça et al. 2015)
	0 to 0.99 $m \cdot s^{-2}$, 1 to 1.99 $m \cdot s^{-2}$, 2 to 2.99 $m \cdot s^{-2}$ and ≥ 3 $m \cdot s^{-2}$	(Curtis et al. 2021)

ACC, Acceleration; DEC, Deceleration

When DEC data was reported, different approaches were used to present information, such as negative values or positive values with specific reference to DEC. For a more proficient analysis, only positive values were presented.

SSG elicited the lowest DEC and ACC demands, respectively, compared with matches and technical-tactical training (Passos Ramos et al. 2019). Moreover, two studies compared different training sessions with matches and both registered higher demands in matches (Campos-Vazquez et al. 2019; Castillo et al. 2019). Endurance sessions (with positional games, LSG and match simulation) had higher relative ACC than strength-based (with positional games, SSG and medium sided game) and speed sessions (positional games, LSG, tactical drills and free kicks) (Castillo et al. 2019). Additionally, a further study found lower ACC and DEC demands in tactical sessions and reserves fitness sessions, respectively (Campos-Vazquez et al. 2019).

More ACC were registered than DEC (Ade et al. 2014; Castagna et al. 2017; Giménez et al. 2018a, 2020a, 2020b; Campos-Vazquez et al. 2019; Giménez and Gomez 2019; Martin-Garcia et al. 2019), except for tactical training, where high DEC distance per hour (<-3 $m \cdot s^{-2}$) was higher than high accelerations distance per hour (>3 $m \cdot s^{-2}$) (Campos-Vazquez et al. 2019). Lower intensities were more frequent (Ade et al. 2014; Giménez et al. 2018a; Campos-Vazquez et al. 2019), except for higher distance covered in maximal DEC (≤-3 $m \cdot s^{-2}$) than high DEC (–2 to –3 $m \cdot s^{-2}$) during 1vs.1 SSG (Ade et al. 2014).

Players' position

Goalkeeper's demands were analyzed in two studies, reporting higher ACC and DEC demands in the training sessions in the middle of the week (in comparison with matches and other sessions) (Moreno-Pérez et al. 2020) and in small SSG formats (32x23 m > 50x35m) (Jara et al. 2019).

Players in central positions (central defenders, midfielders and attackers) performed fewer ACC and DEC efforts than in wide positions (fullbacks and wide midfielders) (Akenhead et al. 2016; Martín-García et al. 2018b, 2020; Martin-Garcia et al. 2019; Passos Ramos et al. 2019). Some exceptions were found in attackers with more DEC in 5vs.5 SSG (Martin-Garcia et al. 2019); central midfielders in compensatory session (MD+1C), MD-4 and MD-1 (Martín-García et al. 2018b); and offensive midfielders in LSG (Martin-Garcia et al. 2019).

Finally, starters performed more ACC and DEC efforts than non-starters (Moreno-Pérez et al. 2020).

Training schedule

For studies analyzing the training schedule, this review found that the MD-4 (Akenhead et al. 2016; Moreno-Pérez et al. 2020; Querido and Clemente 2020), MD-3 (Querido and Clemente 2020) and MD+1C (Martín-García et al. 2018b) were the most demanding sessions of the week; while MD-1 (Akenhead et al. 2016; Martín-García et al. 2018b; Querido and Clemente 2020) was the least demanding, with the exception for goalkeepers which reported the lowest demands during matches (Moreno-Pérez et al. 2020). One study, that compared training demands of the team with a player during his recovery from an injury, found that team and recovery player had different ACC and DEC demands during the week session (Vargas Fuentes et al. 2014).

In female players, no microcycle data was available. However, one study divided the season into preseason, the most demanding period of the season, early season, and late season – the least demanding (Mara et al. 2015).

Overall, this review found that more ACC were reported than DEC (Mara et al. 2015; Akenhead et al. 2016; Malone et al. 2018; Martín-García et al. 2018b; Moreno-Pérez et al. 2020; Querido and Clemente 2020), with one exception (Malone et al. 2018). Lower ACC and DEC intensities occurred more often than higher intensities (Vargas Fuentes et al. 2014; Curtis et al. 2021; Querido and Clemente 2020).

Discussion

The main purpose of this review was to provide a comprehensive summary of ACC and DEC demands during football training, which may help practitioners in their daily practice and to establish new lines of research. This review included male and female football players at different levels such as professional, semi-professionals, amateurs and youth players. Different players' positions were also analyzed, including goalkeeper, which is not common in this type of review. This review analyzed four main categories to promote a more comprehensive interpretation of different factors and conditions that may influence ACC and DEC: training drills variables, that consider the manipulation of drills variables that might influence ACC and DEC; training exercises, which addresses different exercises choices to implement in training sessions; players' positions, describing ACC and DEC demands according to tactical positions; and finally, training schedule category, which analyzed the training sessions distribution across a microcycle, organized according to the distance to the competition and the organization of that weeks during the season (Figure 3). This systematic review shows that ACC and DEC efforts are influenced by different variables within each of the categories previously presented. Regarding action frequency, ACC actions were more frequent than DEC, independent of the category analyzed. Lower intensities of ACC and DEC efforts tend to occur more often than higher intensities efforts during training sessions. More ACC were found in competition than in training sessions (Akenhead et al. 2013; Dalen et al. 2016; Russell et al. 2016). Regarding the four categories, SSG present higher ACC and DEC demands than other drills such as circuit training, especially when played in smaller formats (by manipulating number of players or pitch size) in comparison with larger formats of SSG; wide playing positions, as fullbacks, may be exposed to more ACC and DEC demands; and finally, middle of the week training sessions are the most demanding sessions of the week regarding ACC and DEC demands and these demands decrease as match day approaches.

Acceleration and deceleration measurements and thresholds

This review reports that the intensity thresholds were not the same across the studies analyzed (Table 4). Without a standardized classification of ACC and DEC thresholds, it is very difficult to perform a comparison among studies or to provide definitive statistical analyses and draw relevant conclusions for practice. Additionally, intensity classification can also be a problem when establishing conclusions. As previously stated, it is important to clarify thresholds and intensities and avoid arbitrary thresholds to classify intensities (McBurnie et al. 2022). A solution for this issue was suggested by Abbott et al. (Abbott et al. 2018b), who proposed the use of player-based ACC intensity thresholds, as it appears to represent individual intensity more accurately than generic thresholds. Briefly, these authors divided the players in three groups (low, medium and high accelerative capacity, obtained as <1, ±1 and >1 standard deviation from the mean, respectively), according to their maximum ACC testing scores. Abbott et al. categorized ACC intensities as low (25–50%), moderate (50–75%) and high-intensity (>75%) ACC as proposed previously by Sonderegger et al. (Sonderegger et al. 2016). In the latter, authors have presented the quantification of ACC percentage which takes in account both maximum voluntary ACC and initial running speeds, however, DEC would still be disregarded in this proposal, as stated by the authors. This approach could offer some benefits such as players' individualization based on their maximal effort, but it could also limit the comparison among players and studies since different thresholds would be used for each player (McBurnie et al. 2022).

It would be beneficial for coaches and researchers to have a common approach and to use specific thresholds to better quantify ACC and DEC in football. Sweeting et al. (Sweeting et al. 2017), reported in their review that there is no justification to the chosen thresholds used in the literature, which is a very important limitation. Since no consensus on how to define ACC and DEC thresholds exist, some findings interpretation could be biased. The same authors recommended thresholds of equal bandwidth to solve this issue. For example, for velocity thresholds, specific bandwidths of 0–5, 5–10, 10–15, 15–20 and >25 $km{\cdot}h^{-1}$ were proposed; however, no ACC and DEC bandwidths were suggested so far.

Another issue may arise with ACC zones and intensities classification, for example, ACC intensities > 3 $m{\cdot}s^{-2}$, which could be classified as high or moderate. Considering an example from velocity analysis, it is possible to see that sprints have been previously classified as events > 20 $km{\cdot}h^{-1}$ and > 25 $km{\cdot}h^{-1}$ for female and male football players, respectively (Bradley and Vescovi 2015), and this could be an issue because researchers

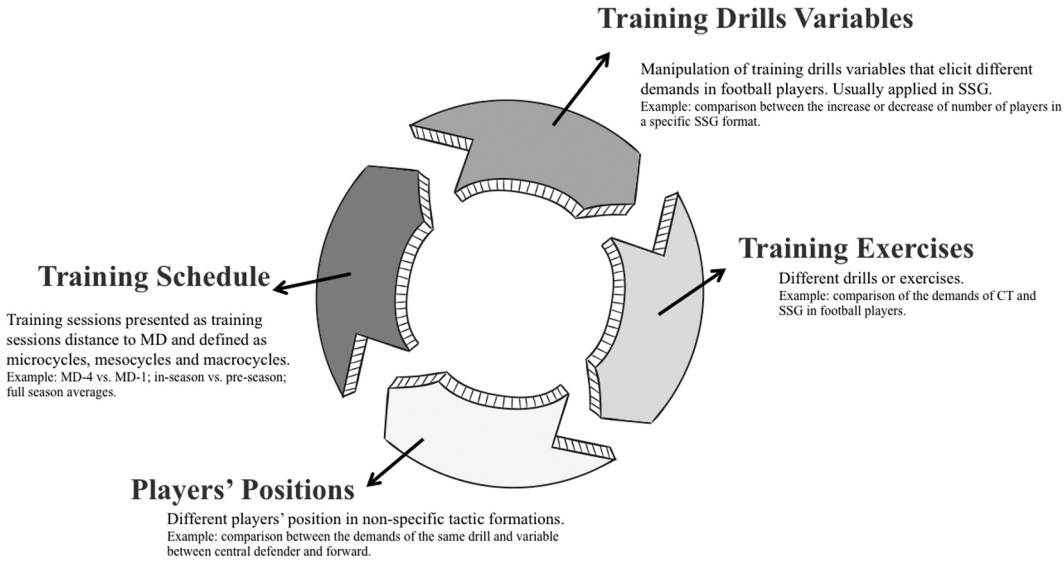

Figure 3. Categories for data analysis. SSG, Small-sided games; CT, Circuit training; MD, Match day; MD-4, Match day minus 4 days; MD-1, Match day minus 1 day

and practitioners could interpret external loads events using different terminologies (e.g., moderate or high for the same intensity). A second issue could relate to the use of open-ended thresholds, such as >2 $m{\cdot}s^{-2}$, >3 $m{\cdot}s^{-2}$, >4 $m{\cdot}s^{-2}$; considering again velocity analysis, it is possible to find papers reporting open-ended thresholds such as high-speed running > 15 $km{\cdot}h^{-1}$ and sprint > 25 $km{\cdot}h^{-1}$, which may lead to biased interpretation of high-intensity demands (Varley et al. 2017). Considering both these issues, this review suggests using specific thresholds bandwidth such as 0–0.99, 1–1·99 $m{\cdot}s^{-2}$ and so on avoiding using open-ended thresholds; in this way, ACC and DEC quantification could be more accurate and specific. Finally, this review suggests avoiding interpreting ACC and DEC intensities as low, moderate or high, but simply quantifying using specific thresholds.

Training drills variables

SSG drills are very common in football training and can be adapted according to coaches' objectives. For instance, an increase in the number of players may lead to fewer technical actions per player (Owen et al. 2004). Similarly, other variables such as pitch size, rules and work to rest ratio can also be modified to manipulate SSG and aim different training objectives (Hill-Haas et al. 2011). For example, the presence of goalkeepers and floaters elicited more DEC than ACC efforts (Sannicandro et al. 2020), while the opposite was found without goalkeeper but with floaters (Rábano-Muñoz et al. 2019) (more research is needed on this topic). Practitioners should be aware that the mere inclusion or exclusion of goalkeeper in SSG may increase or decrease the drill intensity (Hulka et al. 2016). In this review, ACC and DEC demands seem to increase as the SSG format decreases in number of players or area per player (Gaudino et al. 2014; Praça et al. 2015, 2018; Casamichana et al. 2018; Casamichana Gómez et al. 2018; Giménez et al. 2018a; Madison et al. 2019; Martin-Garcia et al. 2019; Martín-García et al. 2020; Sannicandro et al. 2020; Zurutuza et al. 2020). Similar results were found when comparing 4vs.4 + goalkeeper SSG and 8vs.8+ goalkeeper SSG format (Rebelo et al. 2016). However, the implementation of SSG during training present also some limitations: first, they require a high technical and tactical levels to achieve the desired physical intensities (Hill-Haas et al. 2011), second, this can negatively affect the long-term physical development of the players by limiting the intensity during training. Last, floaters (when used during SSG) may need physiological compensation due to their lower ACC and DEC demands reported in previous studies (Praça et al. 2015; Casamichana Gómez et al. 2018; Rábano-Muñoz et al. 2019).

Training exercises

Although SSG are very common in football, there are several other training exercises used by practitioners. Different training protocols, such as sprint training and speed endurance training, have been shown to improve players' conditioning (Sporis et al. 2008; Fransson et al. 2018; Beato et al. 2021). In our review, SSG presented higher ACC and DEC demands than other drills such as continuous and shuttle running (Ade et al. 2014; Castagna et al. 2017) and circuit training (Giménez and Gomez 2019). Moreover, when circuit training was present in a training session, ACC and DEC demands were lower than in sessions comprising only SSG (Giménez et al. 2020a). Additionally, more DEC but less ACC were recorded in SSG in comparison with warm-ups and tactical-technical training (Passos Ramos et al. 2019). Warm-up also had the lowest training load, monitored with different methods (i.e. rate of perceived exertion and heart rate) but not ACC and DEC, in comparison with technical-tactical training and physical training (programmed session that was devised to enable players to cope with the physical demands of match-play) (Jeong et al. 2011).

Finally, friendly matches or match simulations were also analyzed in this review. This type of training session can be used to simulate competition and regarding ACC and DEC demands that appears to happen (Campos-Vazquez et al. 2019; Castillo et al. 2019; Passos Ramos et al. 2019). However, in some other studies, friendly matches reported lower ACC

and DEC demands than other drills (Giménez et al. 2018a, 2020a). These conflicting results may result from how the friendly matches were conducted, for instance the level of the opponents could play a key role for the demands of the match. As previously said, competition tends to be the most demanding session of the week and it could be expected that friendly matches replicate these intensities, however, many factors could play an important role (such as team's motivation, opponent's level, etc.).

Player's positions

Previous research has highlighted central defender as the position with lowest ACC and DEC demands during matches (Dalen et al. 2016, 2019; Tierney et al. 2016; Vigh-Larsen et al. 2018) but contrasting results were also found (Ingebrigtsen et al. 2015; Baptista et al. 2020). In this review, central defenders reported a lower number of ACC and DEC but not consistently (Akenhead et al. 2016; Martín-García et al. 2018b, 2020; Martin-Garcia et al. 2019; Passos Ramos et al. 2019). Generally, central defender and forwards were predominately less exposed to higher ACC and DEC demands in comparison to fullbacks and midfielders (Akenhead et al. 2016; Martín-García et al. 2018b, 2020; Martin-Garcia et al. 2019; Passos Ramos et al. 2019). Two studies analyzed ACC and DEC during football matches and reported more ACC and DEC occurrences for wide players than central players (Dalen et al. 2016; Vigh-Larsen et al. 2018). Similar results were found in other studies (Ingebrigtsen et al. 2015; de Hoyo et al. 2018; Dalen et al. 2019), with wide midfielders and fullbacks performing more ACC than central defenders and midfielders. Instead, in the de Hoyo study (de Hoyo et al. 2018), strikers (or forwards) were the players with more ACC which could be due to specific tactical demands (e.g., due to counterattack situations created by the team). Since competition demands elicit different demands across player's positions (Abbott et al. 2018a), training drills should aim to prepare players to meet these specific requests. For instance, according to the results of this review, external positions such as fullbacks and wide midfielders may require higher physiological preparedness to match the ACC and DEC demands of competition.

Little is known about goalkeeper's ACC and DEC demands in football training and this may be because goalkeepers training sessions are mainly based on technical work (Otte et al. 2020) or actions such as jumping and diving and these demands come with no surprise because of the characteristics of the role (Taylor et al. 2004; Owen et al. 2017). According to our findings, goalkeepers performed more ACC and DEC in training sessions than in matches.

Training schedule

Considering the training week, ACC and DEC demands decrease as match day approaches and this strategy is frequently used in team sports to avoid pre-match fatigue and increase match preparedness (Issurin 2010; Mendes et al. 2018; Cross et al. 2019). The middle of the week, MD-4 and MD-3, and the compensation session (MD+1C) were the most demanding sessions and MD-1 the least demanding. Martín-García et al. (2018b) investigated compensatory and recovery sessions and presented the compensatory session as the most demanding session of the week. These results are aligned with the evidence that defines matches as the most demanding session of the week and the main cause of the training load difference between starters and non-starters (Los Arcos et al. 2017; Azcárate et al. 2018; Gualtieri et al. 2020). Furthermore, these differences could lead to non-starter players being undertrained (Stevens et al. 2017). In this sense, when conducting a compensatory session for non-starters, high ACC and DEC demands should be planned (to compensate for the load missed during the match). Recovery also plays an important role, as ACC and DEC actions during matches were associated to fatigue that lasted up to 72 h after the match (Nedelec et al. 2014). As so, in sessions immediately close to the match, training exercises should be carefully chosen, to avoid excessive ACC and DEC demands. For example, small (area and number of players) SSG should be avoided in these days. In this review, ACC actions were predominant in comparison with DEC during training, the opposite of what a recent review revealed when analyzing ACC and DEC demands in matches (Harper et al. 2019). Finally, football players reported a predominance of low intensities in ACC and DEC efforts compared to higher intensity efforts during training sessions, similarly to what happen in competition matches (Osgnach et al. 2010; Di Prampero et al. 2015) – this comes also as no surprise as low-intensity activities are more common than high-intensity activities.

Limitations and future directions

This review is not without limitations, first, the lack of consensus when establishing ACC and DEC thresholds limits the quality and depth of the analysis. Hence, future research should prioritize the standardization of ACC and DEC intensity thresholds. As previously stated, applying bandwidth zones instead of intensity or zones classification could help improve research data comparison and analysis. As an example, instead of presenting ACC and DEC data as high, moderate and low intensity, one can present the number of ACC and DEC efforts within each bandwidth (0–1 $m \cdot s^{-2}$; 1–2 $m \cdot s^{-2}$; 2–3 $m \cdot s^{-2}$; etc.). With this strategy, comparisons between measurements would be more precise and teams could classify intensities of their own players. However, it is important to notice that this would not be a definitive solution because the assessment of ACC and DEC with GPS is not absent of concerns. As stated by Buchheit et al. (2014), ACC and DEC measures can differ between models and between units. Second, not much information about ACC and DEC demands in female football training was reported in the literature, therefore a major part of the studies reported in this review included male participants. Future research should investigate female football players' training demands. Third, future studies should investigate the ACC and DEC demands during training of specific roles, like floaters, because the knowledge regarding roles is currently very limited. Finally, as scarce evidence exists on goalkeepers ACC and DEC demands representing an important limitation, future studies should investigate their demands to offer a better understanding of goalkeepers training needs.

In conclusion, this review summarizes the current knowledge about ACC and DEC demands in football training. Since football drills can be adjusted according to different tactical and technical goals, different ACC and DEC demands can be expected. SSG is a training drill widely used in football training and elicits higher ACC and DEC demands than other training methods such as circuit training and running-based drills and its format can be modified to match specific objectives. SSG formats with few players and/or small pitch size tend to increase ACC and DEC demands and these demands can also differ for each playing position, for instance, central positions appear to be subject to fewer demands than players that play in wide positions. Considering the training week, ACC and DEC demands decrease as match day approaches and this strategy is frequently used in team sports to avoid pre-match fatigue and increase match preparedness. Moreover, ACC and DEC demands were greater during MD-4, MD-3 and MD+1C, while MD-1 was the least demanding. Lastly, this review found that the match represents the most demanding session of the week, therefore a compensatory session could be used to avoid under-loading non-starter players.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The author(s) reported there is no funding associated with the work featured in this article.

ORCID

Hugo Silva http://orcid.org/0000-0002-6797-1616
Fábio Yuzo Nakamura http://orcid.org/0000-0002-5336-3652
Marco Beato http://orcid.org/0000-0001-5373-2211
Rui Marcelino http://orcid.org/0000-0001-8717-3243

References

Abbott W, Brickley G, Smeeton NJ. 2018a. Physical demands of playing position within English Premier League academy soccer. J Hum Sport Exerc. 13(2):285–295. doi:10.14198/jhse.2018.132.04.

Abbott W, Brickley G, Smeeton NJ, Mills S. 2018b. Individualizing acceleration in English Premier League academy soccer players. J Strength Cond Res. 32(12):3503–3510. doi:10.1519/JSC.0000000000002875.

Ade JD, Harley JA, Bradley PS. 2014. Physiological response, time-motion characteristics, and reproducibility of various speed-endurance drills in elite youth soccer players: small-sided games versus generic running. Int J Sports Physiol Perform. 9(3):471–479. doi:10.1123/ijspp.2013-0390.

Akenhead R, Hayes PR, Thompson KG, French D. 2013. Diminutions of acceleration and deceleration output during professional football match play. J Sci Med Sport. 16(6):556–561. doi:10.1016/j.jsams.2012.12.005.

Akenhead R, Harley JA, Tweddle SP. 2016. Examining the external training load of an English premier league football team with special reference to acceleration. J Strength Cond Res. 30(9):2424–2432. doi:10.1519/JSC.0000000000001343.

Aughey RJ. 2011. Applications of GPS technologies to field sports. Int J Sports Physiol Perform. 6(3):295–310. doi:10.1123/ijspp.6.3.295.

Azcárate U, Yanci J, Los Arcos A. 2018. Influence of match playing time and the length of the between-match microcycle in Spanish professional soccer players' perceived training load. Sci Med Footb. 2(1):23–28. doi:10.1080/24733938.2017.1386322.

Baptista I, Johansen D, Figueiredo P, Rebelo A, Pettersen SA. 2020. Positional differences in peak-and accumulated-training load relative to match load in elite football. Sports. 8(1):1–10. doi:10.3390/sports8010001.

Beato M, Devereux G, Stiff A. 2018. Validity and reliability of global positioning system units (STATSports Viper) for measuring distance and peak speed in sports. J Strength Cond Res. 32(10):2831–2837. doi:10.1519/JSC.0000000000002778.

Beato M, de Keijzer KL. 2019. The inter-unit and inter-model reliability of GNSS STATSports Apex and Viper units in measuring peak speed over 5, 10, 15, 20 and 30 meters. Biol Sport. 36(4):317–321. doi:10.5114/biolsport.2019.88754.

Beato M, Drust B. 2021. Acceleration intensity is an important contributor to the external and internal training load demands of repeated sprint exercises in soccer players. Res Sports Med [Internet]. 29(1):67–76. doi:10.1080/15438627.2020.1743993.

Beato M, Drust B, Iacono AD. 2021. Implementing high-speed running and sprinting training in professional soccer. Int J Sports Med. 42(4):295–299. doi:10.1055/a-1302-7968.

Bradley PS, Di Mascio M, Peart D, Olsen P, Sheldon B. 2010. High-intensity activity profiles of elite soccer players at different performance levels. J Strength Cond Res. 24(9):2343–2351. doi:10.1519/JSC.0b013e3181aeb1b3.

Bradley PS, Vescovi JD. 2015. Velocity thresholds for women's soccer matches: sex specificity dictates high-speed-running and sprinting thresholds-female athletes in motion (FAiM). Int J Sports Physiol Perform. 10(1):112–116. doi:10.1123/ijspp.2014-0212.

Buchheit M, Al Haddad H, Simpson BM, Palazzi D, Bourdon PC, DiSalvo V . 2014. Monitoring accelerations with GPS in football: time to slow down. Int J Sports Physiol Perform. 9(3):442–445. doi:10.1123/ijspp.2013-0187.

Campos-Vazquez MA, Castellano J, Toscano-Bendala FJ, Owen A. 2019. Comparison of the physical and physiological demands of friendly matches and different types of preseason training sessions in professional soccer players. Ricyde. 15(58):339–352.

Casamichana D, Suarez-Arrones L, Castellano J, Román-Quintana JS. 2014. Effect of number of touches and exercise duration on the kinematic profile and heart rate response during small-sided games in soccer. J Hum Kinet. 41(1):113–123. doi:10.2478/hukin-2014-0039.

Casamichana D, Bradley PS, Castellano J. 2018. Influence of the varied pitch shape on soccer players physiological responses and time-motion characteristics during small-sided games. J Hum Kinet. 64(1):171–180. doi:10.1515/hukin-2017-0192.

Casamichana Gómez D, Gómez Díaz AJ, Cos Morera F, Martín García A. 2018. Wildcard players during positional games. Apunt Educ Fis y Deportes . (133):85–97.

Castagna C, Francini L, Póvoas SCA, D'Ottavio S. 2017. Long sprint abilities in soccer: ball versus running drills. Int J Sports Physiol Perform. 12(9):1256–1263. doi:10.1123/ijspp.2016-0565.

Castagna C, D'Ottavio S, Cappelli S, Póvoas SCA. 2019. The effects of long sprint ability–oriented small-sided games using different ratios of players to pitch area on internal and external load in soccer players. Int J Sports Physiol Perform. 14(9):1265–1272. doi:10.1123/ijspp.2018-0645.

Castellano J, Casamichana D, Dellal A. 2013. Influence of game format and number of players on heart rate responses and physical demands in small-sided soccer games. J Strength Cond Res. 27(5):1295–1303. doi:10.1519/JSC.0b013e318267a5d1.

Castillo D, Raya-González J, Weston M, Yanci J, Stone JD, Jagim AR, Jones MT. 2019. Distribution of external load during acquisition training sessions and match play of a professional soccer team. J Strength Cond Res. 33:1. doi:10.1519/JSC.0000000000002968.

Castillo-Rodríguez A, Cano-Cáceres FJ, Figueiredo A, Fernández-García JC. 2020. Train like you compete? Physical and physiological responses on semi-professional soccer players. Int J Environ Res Public Health. 17(3):756. doi:10.3390/ijerph17030756.

Clemente FM. 2018. Associations between wellness and internal and external load variables in two intermittent small-sided soccer games. Physiol Behav [Internet]. 197(September):9–14. doi:10.1016/j.physbeh.2018.09.008.

Coutinho D, Gonçalves B, Travassos B, Wong DP, Coutts AJ, Sampaio JE. 2017. Mental fatigue and spatial references impair soccer players' physical and tactical performances. Front Psychol. 8(SEP). doi:10.3389/fpsyg.2017.01645.

Cross R, Siegler J, Marshall P, Lovell R. 2019. Scheduling of training and recovery during the in-season weekly micro-cycle: insights from team sport practitioners. Eur J Sport Sci. 19(10):1287–1296. doi:10.1080/17461391.2019.1595740.

Cummins C, Orr R, O'Connor H, West C. 2013. Global positioning systems (GPS) and microtechnology sensors in team sports: a systematic review. Sports Med. 43(10):1025–1042. doi:10.1007/s40279-013-0069-2.

Curtis RM, Huggins RA, Benjamin CL, Sekiguchi Y, M. Arent S, C. Armwald B *et al*, et al. 2021. Seasonal accumulated workloads in collegiate Men's soccer: A Comparison of Starters and Reserves. J Strength Cond Res. 35 (11):3184–3189.

Dalen T, Ørgen I, Gertjan E, Geir Havard H, Ulrik WPL. 2016. Acceleration, and deceleration during forty-five competitive matches of elite soccer. J Strength Cond Res. 30(2):351–359. doi:10.1519/JSC.0000000000001063.

Dalen T, Lorås H, Hjelde GH, Kjøsnes TN, Wisløff U. 2019. Accelerations–a new approach to quantify physical performance decline in male elite soccer? Eur J Sport Sci. 19(8):1015–1023. doi:10.1080/17461391.2019.1566403.

de Hoyo M, Cohen DD, Sañudo B, Carrasco L, Álvarez-Mesa A, Del Ojo JJ, et al. 2016. Influence of football match time–motion parameters on recovery time course of muscle damage and jump ability. J Sports Sci. 34(14):1363–1370. doi:10.1080/02640414.2016.1150603.

de Hoyo M, Sañudo B, Suárez-Arrones L, Carrasco L, Joel T, Domínguez-Cobo S, et al. 2018. Analysis of the acceleration profile according to initial speed and positional role in elite professional male soccer players. J Sports Med Phys Fitness. 58(12):1774–1780. doi:10.23736/S0022-4707.17.08003-3.

Dello Iacono A, Beato M, Unnithan V. 2021. Comparative effects of game profile–based training and small-sided games on physical performance of elite young soccer players. J Strength Cond Res. 35(10):2810–2817. doi:10.1519/JSC.0000000000003225.

Di Prampero PE, Botter A, Osgnach C. 2015. The energy cost of sprint running and the role of metabolic power in setting top performances. Eur J Appl Physiol. 115(3):451–469. doi:10.1007/s00421-014-3086-4.

Fransson D, Nielsen TS, Olsson K, Christensson T, Bradley PS, Fatouros IG, et al. 2018. Skeletal muscle and performance adaptations to high-intensity training in elite male soccer players: speed endurance runs versus small-sided game training. Eur J Appl Physiol. 118 (1):111–121. doi:10.1007/s00421-017-3751-5.

Gaudino P, Alberti G, Iaia FM. 2014. Estimated metabolic and mechanical demands during different small-sided games in elite soccer players. Hum Mov Sci [Internet]. 36:123–133. doi:10.1016/j.humov.2014.05.006.

Giménez JV, Del-Coso J, Leicht AS, MÁ G. 2018a. Comparison of the movement patterns between small-and large-sided game training and competition in professional soccer players. J Sports Med Phys Fitness. 58 (10):1383–1389. doi:10.23736/S0022-4707.17.07343-1.

Giménez JV, Liu H, Lipińska P, Szwarc A, Rompa P, Gómez MA. 2018b. Physical responses of professional soccer players during 4 vs. 4 small-sided games with mini-goals according to rule changes. Biol Sport. 35(1):75–81. doi:10.5114/biolsport.2018.70754.

Giménez JV, Gomez AG. 2019. Relationships among circuit training, small-sided and mini goal games, and competition in professional soccer players: a comparison of on-field integrated training routines. J Strength Cond Res. 33(7):1887–1896. doi:10.1519/JSC.0000000000002804.

Giménez JV, Castellano J, Lipinska P, Zasada M, MÁ G. 2020a. Comparison of the physical demands of friendly matches and different types on-field integrated training sessions in professional soccer players. Int J Environ Res Public Health. 17(8):2904. doi:10.3390/ijerph17082904.

Giménez JV, Jiménez-Linares AS, Gómez MA, Jiménez-Linares L, Leicht AS, Gómez MA. 2020b. Predictive modelling of the physical demands during training and competition in professional soccer players. J Sci Med Sport [Internet]. 23(6):603–608. doi:10.1016/j.jmst.2019.11.010.

Gómez-Carmona C, Gamonales J, Pino-Ortega J, Ibáñez S. 2018. Comparative analysis of load profile between small-sided games and official matches in youth soccer players. Sports. 6(4):173. doi:10.3390/sports6040173.

Gualtieri A, Rampinini E, Sassi R, Beato M. 2020. Workload monitoring in top-level soccer players during congested fixture periods. Int J Sports Med. 41(10):677–681. doi:10.1055/a-1171-1865.

Hader K, Mendez-Villanueva A, Palazzi D, Ahmaidi S, Buchheit M. 2016. Metabolic power requirement of change of direction speed in young soccer players: not all is what it seems. PLoS ONE. 11(3):1–21. doi:10.1371/journal.pone.0149839.

Halouani J, Ghattassi K, Bouzid MA, Rosemann T, Nikolaidis PT, Chtourou H, et al. 2019. Physical and physiological responses during the stop-ball rule during small-sided games in soccer players. Sports. 7(5):117. doi:10.3390/sports7050117.

Harper DJ, Carling C, Kiely J. 2019. High-intensity acceleration and deceleration demands in elite team sports competitive match play: a systematic review and meta-analysis of observational studies. Sports Med. 49(12):1923–1947. doi:10.1007/s40279-019-01170-1.

Hill-Haas SV, Dawson B, Impellizzeri FM, Coutts AJ. 2011. Physiology of small-sided games training in football: a systematic review. Sports Med. 41(3):199–220. doi:10.2165/11539740-000000000-00000.

Hodgson C, Akenhead R, Thomas K. 2014. Time-motion analysis of acceleration demands of 4v4 small-sided soccer games played on different pitch sizes. Hum Mov Sci. 33(1):25–32. doi:10.1016/j.humov.2013.12.002.

Holt JE, Ward P, Wallhead TL. 2006. The transfer of learning from play practices to game play in young adult soccer players. Phys Educ Sport Pedagogy. 11(2):101–118. doi:10.1080/17408980600708270.

Hulka K, Weisser R, Belka J. 2016. Effect of the pitch size and presence of goalkeepers on the work load of players during small-sided soccer games. J Hum Kinet. 50(2):175–181. doi:10.1515/hukin-2015-0180.

Ingebrigtsen J, Dalen T, Hjelde GH, Drust B, Wisløff U. 2015. Acceleration and sprint profiles of a professional elite football team in match play. Eur J Sport Sci. 15(2):101–110. doi:10.1080/17461391.2014.933879.

Issurin VB. 2010. New horizons for the methodology and physiology of training periodization. Sports Med. 40(3):189–206. doi:10.2165/11319770-000000000-00000.

Jara D, Ortega E, MÁ G-R, Weigelt M, Nikolic B, de Baranda PS. 2019. Physical and tactical demands of the goalkeeper in football in different small-sided games. Sensors. 19(16):1–13. doi:10.3390/s19163605.

Jaspers A, Kuyvenhoven JP, Staes F, Frencken WGP, Helsen WF, Brink MS. 2018. Examination of the external and internal load indicators' association with overuse injuries in professional soccer players. J Sci Med Sport. 21(6):579–585. doi:10.1016/j.jsams.2017.10.005.

Jeong TS, Reilly T, Morton J, Bae SW, Drust B. 2011. Quantification of the physiological loading of one week of "pre-season" and one week of "in-season" training in professional soccer players. J Sports Sci. 29 (11):1161–1166. doi:10.1080/02640414.2011.583671.

Los Arcos A, Mendez-Villanueva A, Martínez-Santos R. 2017. In-season training periodization of professional soccer players. Biol Sport. 34 (2):149–155. doi:10.5114/biolsport.2017.64588.

Madison G, Patterson S, Read P, Howe L, Waldron M. 2019. Effects of small-sided game variation on changes in hamstring strength. J Strength Cond Res. 33(3):839–845. doi:10.1519/JSC.0000000000002955.

Malone S, Mendes B, Hughes B, Roe M, Devenney S, Collins K, et al. 2018. Decrements in neuromuscular performance and increases in creatine kinase impact training outputs in elite soccer players. J Strength Cond Res. 32(5):1342–1351. doi:10.1519/JSC.0000000000001997.

Manuel Clemente F, Theodoros Nikolaidis P, Rosemann T, Knechtle B. 2019. Variations of internal and external load variables between intermittent small-sided soccer game training regimens. Int J Environ Res Public Health. 16(16): 1–11. https://www.mdpi.com/1660-4601/16/16/2923

Mara JK, Thompson KG, Pumpa KL, Ball NB. 2015. Periodisation and physical performance in elite female soccer players. Int J Sports Physiol Perform. 10(5):664–669. doi:10.1123/ijspp.2014-0345.

Mara JK, Thompson KG, Pumpa KL. 2016. Physical and physiological characteristics of various-sided games in elite women's soccer. Int J Sports Physiol Perform. 11(7):953–958. doi:10.1123/IJSPP.2015-0087

Martin-Garcia A, Castellano J, Diaz AG, Cos F, Casamichana D. 2019. Positional demands for various-sided games with goalkeepers according to the most demanding passages of match play in football. Biol Sport. 36 (2):171–180. doi:10.5114/biolsport.2019.83507.

Martín-García A, Casamichana D, Gómez Díaz A, Cos F, Gabbett TJ. 2018a. Positional differences in the most demanding passages of play in football competition. J Sports Sci Med. 17(4):563–570.

Martín-García A, Díaz AG, Bradley PS, Morera F, Casamichana D. 2018b. Quantification of a professional football Team's external load using a microcycle structure. J Strength Cond Res. 32(12):3511–3518. doi:10.1519/JSC.0000000000002816.

Martín-García A, Castellano J, Méndez Villanueva A, Gómez-Díaz A, Cos F, Casamichana D. 2020. Physical demands of ball possession games in relation to the most demanding passages of a competitive match. J Sports Sci Med. 19(1):1–9.

McBurnie AJ, Harper DJ, Jones PA, Dos'Santos T. 2022. Deceleration training in team sports: another potential 'vaccine' for sports-related injury? Sports Medicine 52: 1–12 [Internet]. Oct 29; https://link.springer.com/10.1007/s40279-021-01583-x

McGuinness LA, Higgins JPT. 2021. Risk-of-bias VISualization (robvis): an R package and Shiny web app for visualizing risk-of-bias assessments. Res Synth Methods. 12:55–61. doi:10.1002/jrsm.1411.

Mendes B, Palao JM, Silvério A, Owen A, Carriço S, Calvete F, et al. 2018. Daily and weekly training load and wellness status in preparatory, regular and congested weeks: a season-long study in elite volleyball players. Res Sports Med. 26(4):462–473. doi:10.1080/15438627.2018.1492393.

Moher D, Liberati A, Tetzlaff J, Altman DG. 2010. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Int J Surg. 8(5):336–341. doi:10.1016/j.ijsu.2010.02.007.

Moreno-Pérez V, Malone S, Sala-Pérez L, Lapuente-Sagarra M, Campos-Vazquez MA, Del Coso J. 2020. Activity monitoring in professional soccer goalkeepers during training and match play. Int J Perform Anal [Internet]. 20(1):19–30. doi:10.1080/24748668.2019.1699386.

Nedelec M, McCall A, Carling C, Legall F, Berthoin S, Dupont G. 2014. The influence of soccer playing actions on the recovery kinetics after a soccer match. J Strength Cond Res. 28(6):1517–1523. doi:10.1519/JSC.0000000000000293.

Oliva-Lozano JM, Gómez-Carmona CD, Pino-Ortega J, Moreno-Pérez V, Rodríguez-Pérez MA. 2020. Match and training high intensity activity-demands profile during a competitive mesocycle in youth elite soccer players. J Hum Kinet. 75(1):195–205. doi:10.2478/hukin-2020-0050.

Osgnach C, Poser S, Bernardini R, Rinaldo R, Di Prampero PE. 2010. Energy cost and metabolic power in elite soccer: a new match analysis approach. Med Sci Sports Exerc. 42(1):170–178. doi:10.1249/MSS.0b013e3181ae5cfd

Otte FW, Millar SK, Klatt S. 2020. How does the modern football goalkeeper train?–An exploration of expert goalkeeper coaches' skill training approaches. J Sports Sci. 38(11–12):1465–1473. doi:10.1080/02640414.2019.1643202.

Owen A, Twist C, Ford P. 2004. Small-sided games: the physiological and technical effect of altering pitch size and player numbers. Insight. 7(2):50–53.

Owen AL, Lago-Penñs C, MÁ G, Mendes B, Dellal A. 2017. Analysis of a training mesocycle and positional quantification in elite European soccer players. Int J Sports Sci Coach. 12(5):665–676. doi:10.1177/1747954117727851.

Owen AL, Newton M, Shovlin A, Malone S. 2020. The use of small-sided games as an aerobic fitness assessment supplement within elite level professional soccer. J Hum Kinet. 71(1):243–253. doi:10.2478/hukin-2019-0086.

Passos Ramos G, Datson N, Mahseredjian F, Lopes TR, Coimbra CC, Prado LS, et al. 2019. Activity profile of training and matches in Brazilian Olympic female soccer team. Sci Med Footb [Internet]. 3(3):231–237. doi:10.1080/24733938.2019.1615120.

Praça GM, de Custódio IJO, Greco PJ. 2015. Numerical superiority changes the physical demands of soccer players during small- sided games. Rev Bras de Cineantropometria e Desempenho Hum. 17(3):269–279. doi:10.5007/1980-0037.2015v17n3p269.

Praça G, Bredt S, Torres J. 2018. Influence of numerical superiority and Players' tactical knowledge on perceived exertion and physical and physiological demands in soccer. J Sport Psychol [Internet]. 27(2):29–36. https://www.researchgate.net/publication/325302340

Querido SM, Clemente FM. 2020. Analyzing the effects of combined small-sided games and strength and power training on the fitness status of under-19 elite football players. J Sports Med Phys Fitness. 60(1):1–10. doi:10.23736/S0022-4707.19.09818-9.

Rábano-Muñoz A, Asian-Clemente J, Sáez de Villarreal E, Nayler J, Requena B. 2019. Age-related differences in the physical and physiological demands during small-sided games with floaters. Sports. 7(4):79. doi:10.3390/sports7040079.

Rebelo ANC, Silva P, Rago V, Barreira D, Krustrup P. 2016. Differences in strength and speed demands between 4v4 and 8v8 small-sided football games. J Sports Sci. 34(24):2246–2254. doi:10.1080/02640414.2016.1194527.

Reilly T, Morris T, Whyte G. 2009. The specificity of training prescription and physiological assessment: a review. J Sports Sci. 27(6):575–589. doi:10.1080/02640410902729741.

Riboli A, Semeria M, Coratella G, Esposito F. 2020. Effect of formation, ball in play and ball possession on peak demands in elite soccer. Biol Sport. 38(2):195–205. doi:10.5114/biolsport.2020.98450.

Russell M, Sparkes W, Northeast J, Cook CJ, Love TD, Bracken RM, et al. 2016. Changes in acceleration and deceleration capacity throughout professional soccer match-play. J Strength Cond Res. 30(10):2839–2844. doi:10.1519/JSC.0000000000000805.

Sannicandro I, Cofano G, Raiola G, Rosa RA, Colella D. 2020. Analysis of external load in different soccer small-sided games played with external wildcard players. J Phys Educ Sport. 20(2):672–679.

Sonderegger K, Tschopp M, Taube W. 2016. The challenge of evaluating the intensity of short actions in soccer: a new methodological approach using percentage acceleration. PLoS ONE. 11(11):1–10. doi:10.1371/journal.pone.0166534.

Sporis G, Ruzic L, Leko G. 2008. The anaerobic endurance of elite soccer players improved after a high-intensity training intervention in the 8-week conditioning program. J Strength Cond Res. 22(2):559–566. doi:10.1519/JSC.0b013e3181660401.

Sterne JA, Hernán MA, Reeves BC, Savović J, Berkman ND, Viswanathan M, et al. 2016a. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ. 355:4–10.

Sterne JAC, Hernán MA, Reeves BC, Savović J, Berkman ND, Viswanathan M, Henry D, Altman DG, Ansari MT, Boutron I, et al. 2016b. Risk Of Bias In Non-randomized Studies of Interventions (ROBINS-I): detailed guidance. Bmj. 355(October):i4919. doi:10.1136/bmj.i4919.

Stevens TGA, de Ruiter CJ, Twisk JWR, Savelsbergh GJP, Beek PJ. 2017. Quantification of in-season training load relative to match load in professional Dutch Eredivisie football players. Sci Med Footb. 1(2):117–125. doi:10.1080/24733938.2017.1282163.

Stølen T, Chamari K, Castagna C, Wisløff U. 2005. Physiology of soccer. Sports Med. 35(6):501–536. doi:10.2165/00007256-200535060-00004.

Sweeting AJ, Cormack SJ, Morgan S, Aughey RJ. 2017. When is a sprint a sprint? A review of the analysis of team-sport athlete activity profile. Front Physiol. 8(JUN):1–12. doi:10.3389/fphys.2017.00432.

Taylor JB, Mellalieu SD, James N. 2004. Behavioural comparisons of positional demands in professional soccer. Int J Perform Anal. 4(1):81–97. doi:10.1080/24748668.2004.11868294.

Tierney PJ, Young A, Clarke ND, Duncan MJ. 2016. Match play demands of 11 versus 11 professional football using global positioning system tracking: variations across common playing formations. Hum Mov Sci. 49:1–8. doi:10.1016/j.humov.2016.05.007.

Vargas Fuentes A, Urkiza Ibaibarriaga I, Gil Orozko S. 2014. Incorporation of a high-level soccer player into the team after a muscle injury: a case study. Retos Nuevas Tendencias En Educación Física, Deporte Y Recreación. (26):168–171 https://www.redalyc.org/pdf/3457/345732292031.pdf

Varley MC, Jaspers A, Helsen WF, Malone JJ. 2017. Methodological considerations when quantifying high-intensity efforts in team sport using global positioning system technology. Int J Sports Physiol Perform. 12(8):1059–1068. doi:10.1123/ijspp.2016-0534.

Vigh-Larsen JF, Dalgas U, Andersen TB. 2018. Position-specific acceleration and deceleration profiles in elite youth and senior soccer players. J Strength Cond Res. 32(4):1114–1122. doi:10.1519/JSC.0000000000001918.

Zurutuza U, Castellano J, Echeazarra I, Guridi I, Casamichana D. 2020. Selecting training-load measures to explain variability in football training games. Front Psychol. 10(January):1–8. doi:10.3389/fpsyg.2019.02897.