Field, A., Naughton, R., Haines, M., Lui, S., Corr, L., Russell, M., Page, R., & Harper, L. D. (2020). The demands of the extra-time period of soccer: a systematic review. *Journal of Sport and Health Science*.

Document version
Peer reviewed version

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Download date: 24. Jul. 2024

Manuscript Title: The Demands of the Extra-Time Period of Soccer: A Systematic Review.

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Abstract

Soccer match-play is typically contested over 90-min, however, in some cup and tournament scenarios when matches are tied, matches proceed to an additional 30-min termed extra-time (ET). This systematic review sought to appraise the literature available on 120-min of soccer-specific exercise, with a view to identifying practical recommendations and future research opportunities. The review was conducted according to Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA). Independent researchers performed a systematic search of PubMed, CINAHL and Psych Info in May 2019 with keywords entered in various combinations: soccer, football, extra-time, extra time, 120 minutes, 120 min, additional 30 minutes and ‘additional 30 min. The search yielded an initial 73 articles and following the screening process, 11 articles were accepted for analyses. Articles were subsequently organised into five categories: ‘movement demands of extra-time’, ‘performance responses to extra-time’, ‘physiological and neuromuscular response during extra-time’, ‘nutritional inventions’, and, ‘recovery and extra-time’. The results highlighted that during competitive match-play, players cover 5–12% less distance relative to match duration (i.e., $m \cdot min^{-1}$), during ET compared to the preceding 90-min. Reductions in technical performance (i.e., shot speed, number of passes and dribbles) were also observed during ET. Additionally, carbohydrate provision may attenuate and improve dribbling performance during ET. Moreover, objective and subjective measures of recovery may be further compromised following ET when compared to 90-min. Additional investigations are warranted to further substantiate these findings and identify interventions to improve performance during ET.

Key Words Movement demands • Performance • Physiology • Neuromuscular fatigue • Nutritional intervention

Abbreviations

NEFA - Non-esterified fatty acids

IFAB - International Football Association Board

MEMS - Micromechanical-electrical systems

1. Introduction

Soccer is a self-paced, irregular, multidirectional and intermittent team sport typically contested over two 45-min halves, and interspersed by a ~15-min half time (HT) rest interval. Among the more rigorous soccer investigations, the physical response of players has been shown to progressively reduce across 90-min of match-play [1-4]. The mechanisms for such responses are likely peripheral and central in origin [5-7], although less is known regarding the fatigue profile of players during extra-time (ET). When knockout phase matches are tied during tournaments and an outright winner is required, this additional period of match-play commences five min after the 90-min match and consists of 15-min halves separated by a 2-min break whereby teams typically swap ends of the pitch.

Extra-time was introduced as far back as 1897 in the English Football Association's rules of play and has been included in the Fédération Internationale de Football Association (FIFA) set of rules for a number of years. Amid the chaos of war in the 1940's, new formats of ET were trialled when 90-min matches were tied. For instance, matches that were level following 90-min of match-play during the Football League War Cup, were decided according to the team that had the higher league position. Additionally, during the League South Cup in 1942─43, an alternative method was piloted (the first team to score or be awarded a corner after 20-min of ET would win the match), however, following much controversy, this was soon reconsidered. Consequently, the 'next goal wins' agreement was piloted during the 1946 Division Three North Cup. As such, a particular match was played for 203-min and a conclusion was never reached; thus, the match was postponed. More recently, the 'golden goal' (first team to score in ET wins the game) and 'silver goal' (the team leading at the end of the first 15-min period wins the match) rules were introduced in 1993 by soccer governing bodies. However, in late 2004 these alternative formats of ET were abolished, and the current regulations stipulate that a full 30-min ET period be played. If an outcome is not decided during this time frame, then a penalty shootout determines the winning team [8, 9].

In recent years, ET has increasingly become a deciding factor in determining the outcome of cup competitions and tournaments. Since the 1986 FIFA World Cup competition, 33% of knockout matches have required ET. At the 2014 tournament, 50% of knockout matches required ET compared to 25% of matches at the 2002 and 2010 World Cup competitions as well as 38% at the 2006 World Cup tournament. More recently, 31% of knockout matches played at the 2018 FIFA World Cup proceeded to ET, with just one of the match outcomes decided during this period. Interestingly, in the 2016 Union of European Football Associations (UEFA) championships, Portugal played ~60-min more match-time on their route to the final (which also proceeded to ET) than counterparts France.

When considering that the fatigue response associated with 90-min of soccer has been well documented (see review [10]), and that fatigue-induced changes are sufficient to impair performance and injury-risk [6, 11-13], it could be postulated that the potential of additional physical loads being placed on players during ET could further result in reduced performance and an increased risk of injury. Increasing knowledge in relation to the physical demands associated with ET periods may also be useful to ascertain whether there is a need to modify recovery strategies, manipulate nutritional intake and adapt training prescriptions for the purpose of reducing injury-risk and improving physical performance following and during ET, respectively. In addition, evidence suggests fatigue has deleterious effects on aspects of technical performance [14] which have been shown previously to correlate with team success [15]. Therefore, it may be desirable to determine the extent to which technical/skill actions are further affected by the additional exercise duration and potential fatigue imposed by ET. Furthermore, empirical evidence suggests that 67% of the soccer practitioners sampled (identified as working at professional clubs), agreed that ET was an important time period in determining tournament success [16]. Consequently, organising and appraising the ET literature is needed to determine the scientific and empirical research that is currently pertinent for practitioners use during and following soccer matches that require ET.

This review will take a systematic approach to organising the ET literature, which is warranted given that to date, and to the best of our knowledge, no systematic reviews have been published on the ET period. Therefore, this systematic review aims to synthesise the literature associated with 120-min of soccer-specific activity, identifying key themes within this topic, characterising the methodologies employed, and informing researchers about the evolving knowledge on ET. In addition, the current review will compare responses during this period to the preceding 90-min of match-play with the intention of informing practice and identifying future research opportunities.

2. Methods

2.1 Search strategy: Databases, screening process and eligibility criteria

A review of the literature was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines. Keywords were entered in various combinations that related to the topic (‘soccer’ OR ‘football’), AND variations of terms for ET (‘Extra-time’ OR ‘Extratime’ OR ‘Extra time’ OR ‘120 minutes’ OR ‘120 min’). The following databases were searched: PubMed (1950 – present), CINAHL (1981– present), Psych Info (1806 – present) during May 2019. In addition, we conducted manual searches from the reference lists of the published manuscripts retained. Filters included: original publications for which full English texts were available. Any potential articles were retrieved after the titles and abstracts were scanned. Once the screening of titles and abstracts, and removal of duplicates were complete, a systematic review strategy was employed to assess full texts. The inclusion criteria for these studies were as follows: included relevant ET data, used male (18+ years) soccer players, the ET period comprised of a full 30-min duration and the study was written in English. Articles were excluded on the basis that they used soccer-specific exercise <120-min in duration, involved participants that had no previous soccer experience, lacked an explicit description of their methodological processes, were a review article, included female participants, and were grey literature.

2.2 Data extraction

This process was conducted separately by two independent reviewers (AF and LDC). However, any disputes between authors regarding the inclusion of particular articles, were discussed and ultimately adjudicated by the senior author (LDH). The same authors also extracted data from all articles, and where appropriate, the authors of the published articles were contacted for clarification on such data.

Articles identified through other sources (e.g., known to authors) and those cited in retained articles were also considered for inclusion.

2.3 Assessment of methodological quality

As done previously by Sarmento et al. [17], the articles were each scored on a binary scale (0/1) used to assess quality in line with 16 individual quality criteria. These criteria were based on whether articles included: a clear study purpose, a review of relevant literature, an appropriate study design for the research question, a detailed description of sample, a justification of sample size, informed consent, reliable and valid outcome measures, a detailed description of methods, statistical significant findings, an appropriate method of analysis, an importance for practice, description of drop-outs (if any), appropriate conclusions given the study design, implications for given practice, limitations of research.

An option was provided for items 6 ('Was informed consent required?') and 13 ('Were any drop-outs reported?'). If these criteria were 'not applicable' to the article, then this criterion was excluded as an option. For example, it must be considered that observational studies are not always required to obtain consent and will not necessarily have drop-outs to report. Therefore, this assumption eliminates the negative impact '0' may have on the article quality as indeed, it may not be applicable to the article. A percentage was calculated for each article as the summation of the quality score, divided by the relevant criteria included for that research design, so as to allow comparisons between articles of different designs. Studies were characterised as having either low (≤50%), good (51–75%) or excellent (>75%) methodological quality.

3. Results

3.1 Study identification and selection

The initial search returned 72 articles in the specified databases used; one of which was located by the researchers during manual searches. These articles were then exported to reference managing software (Endnote X9), whereby duplicates were subsequently removed (n=4). The titles and abstracts of each entry (69 articles) were then screened for their relevance, which resulted in the rejection of 50 articles from analyses. Following this trimming, the 19 remaining full texts were read diligently and another eight were excluded due to their irrelevance to the topic area. Following the full screening process, only 11 articles were accepted for the systematic review (Figure 1).

INSERT FIGURE 1 HERE

3.2 Methodological Quality

Quality scores are reported in Table 1; 10 of the 11 studies were categorised as having excellent methodological quality, with one reported as good. A mean quality score of 80.29% was established from the 11 articles obtained from the searches. Although none of the articles attained a rating of 100%, the vast majority (10 out of 11) achieved a considerably high score (>85%). None of the studies acknowledged criterion 13 (i.e., drop outs), although four of these studies were observational and were deemed not applicable for this criterion. A paucity of information pertaining to the justification of sample size (item 5) was available in five studies and of the 11 articles ascertained, three failed to address item 16 (research limitations).

INSERT TABLE 1 HERE

3.3 Study characteristics

A total of 296 participants were used in the studies retrieved. These studies reported data on the following populations: professional (n=160; 54.1%), professional academy (n=16; 5.4%), semi-professional (n=10; 3.4%), university-standard (n=64; 21.6%) and practitioners (n=46; 15.5%). Of the 11 articles, participants age (20 ± 3 years) was identified for experimental research (n=8), although age was not disclosed for observational studies (n=4). The majority of studies were quantitative (n=10) with one study categorised as mixed methods (i.e., both quantitative and qualitative). Four of the investigations were conducted on match-play (36.4 %), six studies utilised soccer-specific simulations

(54.5 %), and one article's findings were based on practitioner perceptions of ET (9.1 %). It is evident through chronological analysis, that this area of research is contemporary, as all articles accepted in this systematic review have been published since 2014.

3.3 Organisation of data

The studies incorporated within this review included relevant information pertaining to either: observations of professional matches that included ET, a 120-min simulation (formatted as per a soccer match) or the current practices of soccer practitioners with reference to ET. In order to classify the major topics of research associated with ET, one researcher categorised the papers, with debates resolved by discussion until a consensus of the entire research team was reached. Records were subsequently categorised into five main themes, with some articles containing data related to two or more themes. These themes were as follows: movement demands of ET (three articles), performance responses during ET (eight articles), physiological and neuromuscular responses during ET (five articles), nutritional interventions (two articles) and recovery and ET (three articles).

3.4 Movement demands of Extra-time

As outlined in Table 2, three studies analysed the movements demands of ET through the use of global positioning systems (GPS), and micromechanical-electrical systems (MEMS) [18-20]. Premier League players were observed using 10Hz tracking devices and covered a distance of 14,106 ± 859 m over 120-min, with an additional 3,213 ± 286 m during ET. In the same match, players performed 50 ± 18 sprints and covered 883 ± 400 m of high-speed (HS) distance across 120-min, though 12 ± 6 of those sprints and 153 ± 105 m of the HS distance was completed during the ET period. Furthermore, the authors reported 946 ± 40 accelerations (> 0.5 $m \cdot s^{-2}$) across 120-min with 221 ± 14 during ET. A further 908 ± 36 decelerations were observed throughout the course of 120-min, in which 207 ± 16 were completed during ET [18]. Winder et al. [19] identified similar data (i.e., 15,400 ± 900 m throughout 120-min of match-play) from four professional players competing in the third tier of English soccer. In addition, lower HS distance (791 ± 99 m) was observed across 120-min of match-play. Moreover, players completed much fewer accelerations (358 ± 52) and decelerations (169 ± 38) over the course of 120-min. Peñas et al. [20] analysed the physical performance data of 99 outfield players from seven matches that required ET during the FIFA World Cup held in Brazil in 2014. During the tournament, players covered an average total distance of 12,245 m throughout 120-min of match-play with a 2,962 m performed during ET. Furthermore, this study observed 42 sprints during a 120-min match; nine of which were completed during ET.

INSERT TABLE 2 HERE

3.5 Performance responses to Extra-time

From the eight studies included in this section, four analysed physical and technical performance variables during match-play [16, 18, 20, 21], whilst the remaining four assessed performances using free-running soccer simulations [22-25] (Table 3). A 12% reduction in total distance covered during ET (107 $m \cdot min^{-1}$) compared to 90-min (121 $m \cdot min^{-1}$) was observed in reserve team Premier League players [18]. The same study examined a HS distance of 8 $m \cdot min^{-1}$ throughout 90-min and 5 $m \cdot min^{-1}$ during ET, indicating a 37.5% relative decrease in HS running activity. However, ~24% of the total number of sprints completed throughout the full 120-min match were performed during ET. When comparing ET to 90-min, these players performed ~14% fewer accelerations and 12.5% lesser decelerations; both actions were defined as number of actions completed at >0.5 $m \cdot s^{-2}$ [18]. Similarly, movement data during the 2016 UEFA European Championship from 56 professional players [21] revealed that total distance of 113 ± 10 $m \cdot min^{-1}$ (first half), 107 ± 9 $m \cdot min^{-1}$ (second half) and 98 ± 10 $m \cdot min^{-1}$ (ET); 13% less relative distance covered during ET versus the first half.

Reductions in 30 m sprint velocities (~3%) and sprint maintenance (~4%) have been observed following 120-min vs. 90-min measures of simulated-soccer exercise in Premier League academy players [25]. Similarly, a decrease in 20 m sprint velocity following ET compared to pre first half (~7%), post first half (~5%), pre-second half (~2%), and post-second half (~2%) have been observed in university-standard players [22]. Another study observed reductions in 15 m sprint velocity during ET compared to measures taken during the first and second halves of simulated match-play in a different cohort of professional academy players [24]. Regarding technical performance, Harper et al. [26] found reductions in total number of successful dribbles, and number of successful and total passes decreased by ~20% during the last 15-min of ET compared to that of the first half. Furthermore, reductions in both dribbling[23] and shooting[22] performance have been observed during ET, using soccer-specific protocols in university-standard soccer players.

INSERT TABLE 3 HERE

3.6 Physiological and neuromuscular responses during Extra-time

Five studies [22-25, 27] investigated the physiological and neuromuscular responses during ET using diverse equipment and methods (Table 4). Stevenson et al. [22] observed increases in plasma glycerol, non-esterified fatty acids (NEFA), interleukin-6, epinephrine (adrenaline) as well as reductions in blood glucose and lactate concentrations during ET compared to 90-min of simulated match-play. Findings in professional academy soccer players suggest ET has an influence on markers of bicarbonate, base excess, haemoglobin and blood pH. Similarly, significant reductions have been analysed in blood pH (0.01–0.03) levels during the final 15-min of ET vs. baseline, half time and the first 15-min of ET[24]. Furthermore, Goodall et al. [27] observed that ET provoked an additional development of neuromuscular fatigue involving mainly the central nervous system, with significant perturbations in voluntary activation of the knee extensors and maximum voluntary quadriceps force produced at 120-min vs. pre match, half-time and 90-min.

INSERT TABLE 4 HERE

3.7 Nutritional interventions

Three articles [22, 25, 28] investigated the efficacy of nutritional intervention during the ET period and one empirical observation [16] assessed the nutritional practices of soccer players in relation to ET through practitioner feedback. Harper et al. [25] observed that CHO gels had no impact on physical performance; however, a 16 ± 17% increase in blood glucose and a 29 ± 20% improvement in dribbling precision during the final 15-min of ET was delineated. Stevenson et al. [22] found that consumption of a low GI drink better maintained blood glucose concentrations by 13% compared to high GI in the second half, particularly between 75-90-min, but not during ET. Practitioners specified that hydration and energy provision (e.g., high CHO gels and drinks, high GI foods, caffeine and protein) were prioritised in the intervals prior to and during ET.

3.8 Recovery and Extra-time

Three articles sought to determine the recovery response following matches that require ET [16, 18, 19]. Creatine kinase concentrations increased at 24h (236 ± 92%) and 48h (107 ± 89%) following ET compared to baseline in Premier League players. Observations of CMJ height found reductions of 17.8 ± 11.2 % at 24 h and 7.4% ± 3.2% at 48 h during ET in the same pool of players [18]. Moreover, a case report found that ET impeded both subjective (wellness) and objective (CMJ height) measures of recovery 36 h post-match compared to following a 90-min match [19]. Additionally, the findings from a mixed-method survey suggest that practitioners working in professional soccer support more research conducted on ET, particularly on fatigue responses (including recovery) and acute injury risk [16].

4 Discussion

The purpose of this systematic review was to collate, summarise and evaluate the current ET literature in order to determine the current practices being employed within soccer, highlight common research trends and identify future research opportunities. Accordingly, the studies were grouped for the purpose of assessing the individual facets associated with this period of soccer. The main findings from this review are as follows: (a) performance (i.e., physical and technical/skill) is reduced, relative to match duration (i.e., m·min), during ET compared to 90-min, (b) consumption of CHO gels may attenuate reductions in dribbling performance, and (c) matches that require ET may delay recovery further when compared with 90-min matches.

4.1 Movement demands of extra-time

The International Football Association Board (IFAB) has approved the use of GPS technologies during competitive matches, thus allowing a method of assessing the within-match movement response of players. This is now commonplace in professional soccer and permits the measuring of variables such as distance covered, high-speed (HS) running distances, number of sprints and number of accelerations and decelerations [29, 30]. Russell et al. [18] was the first to investigate the movement demands of soccer players during ET. This seminal work influenced further investigation by which professional players were observed during a fixture congested micro cycle that incorporated an ET match [19]. The disparities in HS distance are unsurprising such that the players analysed competed two tiers apart and evidence suggests HS performance is superior in high-level players during match-play[6]. Furthermore, the match requiring ET within the fixture congested micro cycle [19] was played against a higher league opposition (47 league places at the time of the match) and contextual factors such as self-pacing strategies and match location may have influenced performance of players [31]. Furthermore, the four players used were from four discrete positions (two centre backs, one full back and one central midfielder), and when expressed relative to playing time, there were considerable differences between individuals for the aforementioned performance metrics. This data was not separated into periods of match-play (i.e., first and second halves, and ET) and as such, we were unable to ascertain whether performance was affected during ET. Moreover, small sample sizes were used within both studies, making findings difficult to extrapolate; especially when differentiating findings across playing positions.

Contrastingly, Peñas et al. [20] investigated the movement demands of a substantial number of players (n=99), thus addressing the limitation of using small samples utilised in both the aforementioned studies. These data from the seven matches analysed at the 2014 FIFA World Cup suggest that positional differences (i.e., central midfielders cover more total and HS distance than other positions) are still apparent both during 90-min and ET matches. However, irrespective of playing position, a decrease in movement during ET is evident, although it has yet to be elucidated whether this is attributable to physical fatigue as opposed to a tactical approach. Therefore, investigating performance through simulated match-play may provide novel information on the mechanisms behind the reduced movement capacity.

4.2 Performance responses to Extra-time

The match-to-match and between-player movement metrics are inherently variable within soccer. The literature suggests that match coefficients of variation are between 26 (total distance) and 30% (HI running distance) [32-34] and player intraclass correlations are as sizeable as 32 and 39% for total and HI distance, respectively [35]. Thus, match data must be interpreted with caution, and hence the use of laboratory-controlled investigations. Specifically, free-running soccer match simulations are preferable should researchers wish to incorporate skill actions, though are limited when attempting to replicate the mechanistic demands associated with match-play [23]. Whereas, treadmill-based protocols elicit a mechanistically valid fatigue response comparable with match-play, whilst eliminating the pacing element as fixed bouts of workload can be performed [36]. This allows fatigue-induced inferences to be drawn from a change in response as opposed to a subconscious attempt to self-pace or tactical alterations often observed during match-play [37]. However, simulated match protocols are lacking in ecological validity and are unable to replicate a fatigue response comparable with match-play, especially whilst replicating the demands on a treadmill as players are unlikely to attain maximum speeds [23]. The use of soccer-specific protocols also allows the comparison of individual changes to baseline scores. Therefore, when translating sprint performance during match-play, it is important to consider the individual speed of players, as slower players may not reach the thresholds at their given maximal sprinting speed. Reduced sprint speeds observed during soccer protocols could perhaps be linked to the reduced physical capacity (i.e, HS running) as players are not able to reach and sustain these intensities. However, the extent to which the findings of simulated match-play translate to a soccer match are equivocal.

The preliminary scientific source to quantify changes in technical performance throughout 120 min of soccer did so through the empirical observations of 18 professional matches [26]. They observed a reduction in total number of passes and successful dribbles though the authors speculate that this may not be indicative of a reduction in technical proficiency *per se*. It is more likely that players lacked the physical capacity to be involved with build-up play and thus complete these technical actions, potentially related to the reduced running metrics observed previously [18, 19]. However, it is not clear whether this is ascribed to increased fatigue or due to player perceptions and subsequent pacing strategies. For example, anecdotal observations suggest that players may consciously reduce work rate during ET, and adopt a defensive approach, anticipating a penalty shootout [9]. Anecdotally, this may also explain the reason that matches are not often decided during this period. However, technical information during ET is scarce and the precise mechanisms (i.e., physical and/or mental fatigue) modulating skill proficiency need investigating further. Given the likelihood that the aforementioned performance decrements are associated with temporal and cumulative fatigue, understanding the physiological mechanisms that influence performance during ET may have important implications during tournament and cup scenarios.

4.3 Physiological and neuromuscular responses during Extra-time

Goodall et al. [27] observed that 120-min of simulated soccer elicited an additional development of central nervous system fatigue, through reductions in the maximal voluntary quadriceps force able to be produced. It has previously been suggested that increases in peripheral biomarkers influence type III and IV nerve afferents, thus initiating temporary and cumulative reductions in central motor output [38-40]. Reductions in central motor output could perhaps result in a player being at an increased risk of injury, likely attributable to impaired cognitive (e.g., reactions, decision-making and perceptions) and muscular function [41, 42]. The observed increases in central fatigue during ET could, theoretically, explain the decrements in physical performance and increased likelihood of injury risk, particularly during match-congested schedules.

It is unlikely that such trivial changes in pH (i.e., < 0.2) observed by Harper et al. [24], can be associated with acidosis or the deleterious impact on 15m sprint performance. This notion is supported by the lack of relationship observed between changes in sprint performance and blood pH in the same cohort. Investigations are required to determine whether the additional pressures of actual match-play (i.e., opposition players and environmental pressures) are likely to further exacerbate performance in comparison to simulated soccer matches.

Throughout a 90-min period of match-play, soccer players reach an average oxygen uptake of 70% $\dot{V}O_{2max}$ [43] and mean and peak heart rate values of 82% and 97%, respectively [34, 44]. To primarily fuel this exercise, glycogen is used during match-play, although evidence suggests that availability of intramuscular glycogen markedly decreases when exercise duration exceeds 90-min and fat stores are predominantly utilised [45]. The ET data suggest a temporal change in the primary energy pathway utilisation as a match progresses through 90-min and into ET (i.e., switch to predominately fat oxidation) [22]. This could be due to elevated epinephrine and diminished insulin concentrations. Increased levels of epinephrine stimulate muscle glycogenolysis through activation of phosphorylase α [46] and dampened insulin concentrations promote lipolysis as it inhibits the activation of protein kinase A and Akt [47]. As fatty acid metabolism is not the optimal energy pathway required for HS exercise, this could plausibly explain the transient impairments in physical performance observed during ET. However, before interpreting these data, it is prudent to highlight that substrate utilisation has merely been estimated during ET, and direct measurements taken during simulated match-play is a potential avenue for future research.

As epinephrine concentrations increase markedly during ET [22], it could be hypothesised that muscle glycogen decreases further during this additional 30-min period. However, to date, no study has investigated muscle glycogen during 120-min of soccer match-play (simulated or otherwise). Krustrup et al. [48] took muscle biopsies from players during a 90-min soccer match and observed significant reductions in glycogen concentrations at 90-min compared to pre-match. As these concentrations were at critically low levels for some players, any further decrease could negatively impact performance and recovery. During 120-min of cycling, Logan-Sprenger et al. [49] observed significant reductions in muscle glycogen from 80-min to 120-min, concomitant to increases in fat oxidation and circulating NEFA, and epinephrine concentrations. Although from a cycling exercise stimulus, these data support the findings of Stevenson et al. [22]. Additional work is needed to verify whether reductions in muscle glycogen are uniform with both the blood glucose and cycling data above, and whether nutritional intervention, such as CHO intake, can attenuate reductions when matches proceed to ET.

4.4 Nutritional interventions

Acute CHO provision is currently utilised in soccer in an attempt to mitigate performance decrements. The improved skill performance following CHO consumption has been associated with an increased supply of cerebral glucose (increasing oxidative metabolism) and protection of central nervous system fatigue [50, 51]. Although somewhat extraneous and not specific to soccer, empirical evidence suggests that the provision of CHO over 120-min of cycling exercise can ameliorate reductions in performance [52]. Currently, there is a dearth of scientific literature that has investigated nutritional interventions during ET in soccer players, despite soccer practitioners ranking nutritional interventions as the most important area for future research with regards to ET in an online questionnaire [16]. Furthermore, practitioners recommended that increased CHO and protein intake immediately following, and maintained up to 48 h following an ET match would accelerate recovery [16] and as a result, additional study is necessary.

4.5 Recovery following extra-time

The impact of 120-min of soccer match-play on recovery has received little attention within the literature in comparison to other facets of ET. Practitioner surveys highlighted that 67% of practitioners do not alter preparatory strategies prior to a match that may require ET, although, 89% do adjust recovery modalities. This is surprising considering that the small body of literature suggests that reductions in HS distance and, dribble and passing accuracy are evident during 90-min matches that follow (64 h) ET matches in a fixture congested micro cycle [19]. Therefore, more robust investigations are needed with larger sample sizes and the use of controlled soccer-specific protocols, with various recovery measures. Increased understanding of changes in recovery following ET and the efficacy of commonly used recovery methods, could better inform soccer practitioners of which practices may be optimal following ET.

4.6 Methodological Limitations

We acknowledge that confounding factors, methodological inconsistencies within the literature (i.e., standard of player and HS thresholds), and measurement error (i.e., GPS devices, HR monitors etc.) were perhaps overlooked within the review. However, given the limited number of ET studies, all applicable studies were included despite some lacking the aforementioned experimental rigour. Even still, according to our quality appraisal, 10 of the 11 studies were classified as excellent. Another potential flaw of the review is the exclusion of female players. However, comparisons between sexes are difficult given the physiological differences [53], and the fact that the only published ET research in females, includes a shorter duration of match-play (i.e., two 10-min periods) [54]. Furthermore, searching for merely English publications may have eliminated other potentially relevant manuscripts written in other languages.

5. Conclusions and directions for future research

To conclude, a paucity of research has investigated soccer matches that require the additional period of ET, despite the fact that some major tournament and cup matches may require ET. In conclusion, investigations using 120-min soccer simulations and actual match-play have observed decreases in physical, technical, and physiological parameters and compromised recovery. The lower intensities identified during ET could partly be due to the change in predominant substrate pathway (aerobic glycolysis to fat oxidation) used for energy production. However, further investigations are necessary as mechanical fatigue may cause these reductions in intensity, altering the predominant fuel source. Accordingly, this further justifies the need to use bouts of standardised workload under controlled conditions to profile the fatigue and recovery responses of soccer players. This should be undertaken with the intention of eliminating fatigue-related injury across successive matches during fixture congested periods that involve ET scenarios.

Competitive match-play may yield ecologically valid performance responses, however; it is likely that individual profiles during a soccer match may vary, given the influence of situational variables, as well as between-match and inter-individual variation in soccer. Similarly, this premise also applies to the disparate activity profiles of each playing position. However, though there is a plethora of literature documenting match demands across various playing positions over 90 min [55-57], there is currently a lack of position-specific information during ET match-play observations. Further, the majority of simulations are based on an average profile and fail to account for positional differences. Therefore, though difficult to anticipate, researchers should endeavour to quantify external load characteristics according to playing positions during tournaments and cup competitions through the longitudinal monitoring of players. In doing so, it may be possible to collate an adequate grouping of data whereby a comprehensive assessment can be formed concerning the influence of ET on the discrete demands of each playing position.

Further investigation is also required to establish nutritional interventions that enhance physical and skill performance as well as recovery during and following ET. Empirical observations identified that hydro-nutritional consumption preceding ET was considered as important or very important by the majority of soccer practitioners and therefore, should be considered. Importantly, these ET investigations should employ a consistent methodological approach to allow meaningful comparisons between studies. Moreover, this review has highlighted the increased workload required during ET, although more research using MEMS devices and associated metrics during this period could be useful for practitioners. Such research and application would provide useful insight into the unconventional demands and subsequent adaptations experienced by soccer players during ET and the ensuing recovery period.

Many practices currently used within soccer are based on research that has considered 90-min of match-play which may lack applicability to ET. This proposition can be applied to female soccer, as an absence of research exists in this population pertaining to ET. In addition, the absence of research on the cognitive aspect of performance during ET, may be an area for future research. Consequently, there is scope for bespoke investigations into the extent to which ET has an effect on (both male and female soccer players) subsequent cognitive, physical and technical performance parameters and recovery modalities. Furthermore, with competitive tournaments often held in hot climates, the impact of playing ET in high ambient temperatures (e.g., >30°C) requires investigation, as performance, recovery and indeed even player health, may be negatively affected during and following ET. Similarly, research on the effect of playing ET at high altitudes is desired, particularly as the FIFA World Cup in 2026 may be played in cities situated at elevations ≥1500m (Mexico City *Estadio Azteca* 2915 m, Guadalajara *Estadio Akron* 1566 m and Denver *Mile High Stadium* 1610 m).

It must be considered that ET occurrence is relatively infrequent compared to typical 90-min matches, though we recommend that coaches and practitioners prepare for this possibility in tournament scenarios. It is recommended that individual players experiencing temporary fatigue during 120-min matches are replaced, especially with FIFA authorising the introduction of a fourth substitution during ET. Furthermore, we advocate carefully periodised fuelling strategies during the days leading up to matches that may require ET and that CHO provision is optimal on match-day (including 5-min prior to ET). This may require additional work with players to ensure that individual player preferences are readily available in the five min break prior to ET, which may increase athlete compliance. The administration of nutrition that has ergogenic properties and elicits faster absorption rates may be efficacious when consumed prior to ET, such as caffeine gum [58]. Additionally, the highly taxing intermittent nature of soccer reduces endogenous glycogen, and it is recommended that practitioners adapt nutritional strategies to replenish intramuscular and liver glycogen stores post-matches.

Players susceptible to fatigue can be identified through use of a number of contemporary methods including, tracking data, biochemical and hydration assessments, and sleep and wellness profiles. This data may assist with making informed decisions regarding readiness and when players should return to training following ET matches. It must be considered that the time-course of recovery may be delayed further compared with typical 90-min matches. However, if reductions in training load and intensities are warranted to aid recovery between matches, sport science practitioners and coaches must collaborate to ensure that players maintain optimal fitness. It may also be beneficial to adapt training prescription in the period prior to competitions that include matches that have the potential to progress to ET so as to better prepare players for this possibility. Although, precisely which stage this is developed and maintained during fixture congested tournaments is difficult to schedule, though crucial to reducing injury-risk whilst optimising player performance.

Author contributions

AF, RMP and LDH planned the study. AF and LDC conducted the systematic search of databases and LDH adjudicated. AF wrote the first draft and LDC, MH, RN, SL, MR, RMP and LDH reviewed the manuscript at various stages throughout the editing process and approved the final draft for publication.

Competing Interests

All authors declare that they have no competing interests applicable to the content of this review. No financial support was sought or received for this study.

Titles and Legends to Figures

Figure 1 PRISMA flow diagram highlighting the study selection process for the present systematic review

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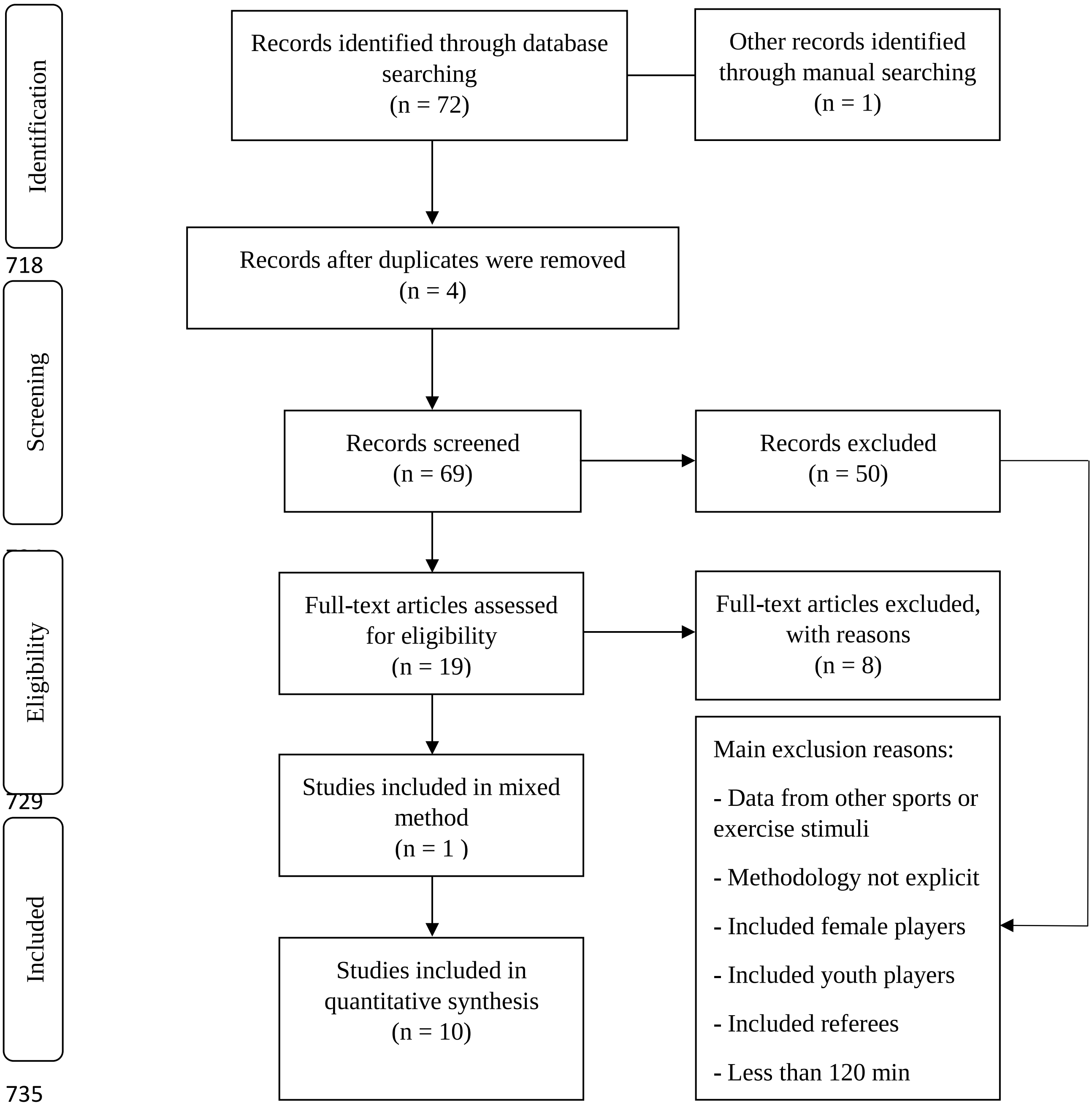
Identification
Screening
Eligibility
Included
Records identified through database searching (n = 72)
Other records identified through manual searching (n = 1)
Records after duplicates were removed (n = 4)
Records screened (n = 69)
Records excluded (n = 50)
Full-text articles assessed for eligibility (n = 19)
Full-text articles excluded, with reasons (n = 8)
Main exclusion reasons:
- Data from other sports or exercise stimuli
- Methodology not explicit
- Included female players
- Included youth players
- Included referees
- Less than 120 min
Studies included in mixed method (n = 1)
Studies included in quantitative synthesis (n = 10)

Table 1. Quality assessment of the articles for the review according to Sarmento et al.[15].

Reference	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Score	%
Russell et al.[16]	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	14/16	87.5
Peñas et al.[18]	1	1	1	1	0	n/a	1	1	1	1	1	1	n/a	1	0	1	12/14	85.7
Winder et al.[17]	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	14/16	87.5
Harper et al.[24]	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	15/16	93.8
Harper et al.[21]	1	1	1	1	1	1	1	1	1	0	1	1	n/a	1	1	1	14/15	93.3
Stevenson et al.[20]	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	15/16	93.8
Kubayi and Toriola[19]	1	0	1	1	0	1	1	1	1	1	1	0	n/a	1	1	0	11/15	73.3
Harper et al.[23]	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	14/16	87.5
Harper et al.[22]	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	14/16	87.5
Goodall et al.[25]	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	14/16	87.5
Harper et al.[14]	1	1	1	1	1	1	1	1	1	0	1	1	n/a	1	1	1	14/15	93.3

Note. Low methodological quality (≤50%), good methodological quality (51 - 75%) and excellent methodological quality (>75%).

Table 2. Studies investigating movement demands of soccer during the ET period.

Reference	**Matches/ players**	**Data collection method**	**Variables measured**	**Key results**
Russell et al.[16].	One reserve ET match/ English Premier League outfield players (n=5).	10 Hz GPS units. Data collected across time points (I1, I2, I3, I4, I5, I6, I7, I8).	TD (m). Distance covered ($m \cdot min^{-1}$). HS distance covered (m). Total number of sprints, Total number of Acc (>0.5 $m \cdot s^{-2}$) and Dec (>0.5 $m \cdot s^{-2}$).	TD: 14,106 ± 859 m across 120-min; 3213 ± 286 m during ET. HS distance: 883 ± 400 m across 120-min; 153 ± 105 m during ET. Number of sprints: 50 ± 18 across 120-min; 12 ± 6 during ET. Number of Acc: 946 ± 40 across 120-min; 221 ± 14 during ET. Number of Dec: 908 ± 36 across 120-min; 207 ± 16 during ET.
Peñas et al.[18].	Seven ET matches from 2014 Fifa World Cup / International outfield players (n=99).	Official FIFA World Cup website: https://www.fifa.com/worldcup/archive/brazil2014/statistics/players/distance.html.	TD ($m \cdot min^{-1}$), Distances covered at low, medium and high speeds ($km \cdot h^{-1}$). Top speed ($km \cdot h^{-1}$) and avg number of sprints ($reps \cdot min^{-1}$).	TD: 12,245m across 120-min; 2,962m during ET. Top sprint speeds: 24.06 ± 3.31 $km \cdot h^{-1}$ during ET.

		Data collected across 1st,2nd half & ET).		Avg number of sprints per min: 0.31 ± 0.14 reps·min^{-1} during ET.
Winder et al.[17].	Three matches (2 league and 1 cup) - only 1 ET match/English Championship outfield players (n=4).	10 Hz GPS units. Data collected from MD1, MD2 (120-min) and MD3.	TD (m). HS distance covered (>18 km·h^{-1}; m·min^{-1}). Number of accelerations (>2m·s^{-2}) and decelerations (>2m·s^{-2}).	TD: 15,400 ± 900 m across 120-min. HS distance: 791 ± 99 m across 120-min. Number of Acc: 358 ± 52 across 120-min. Number of Dec:169 ± 38 across 120-min.

Note. ET= Extra- Time, n= number of players, Hz= Hertz, GPS= Global positioning system, I1 = 00:00–14:59 min, I2 = 15:00–29:59 min, I3 = 30:00–44:59 min, I4 = 45:00–59:59 min, I5 = 60:00–74:59 min, I6 = 75:00–89:59 min, I7 = 90:00–104:59 min and I8 = 105:00–119:59 min, MD1= Match day 1, MD2= Match day 2, MD3= Match day 3, m= metres, TD = total distance, HS= High-speed, reps= repetitions, AU= Arbitrary unit, km= Kilometres, min= minutes, h= hour, Avg= Average, Acc= Acceleration, Dec= Deceleration ↓ decreased/ lower than, ↑= increased, higher than.

Table 3. Studies investigating performance responses during the ET period of soccer.

Reference	Matches/Protocol/ Players	Data collection method	Variables measures	Key results
Harper et al.[24].	18 matches. European soccer teams (specified as ranging from 1st to 3rd tier of their domestic leagues) and International teams. Number of outfield players per match (n=15 ± 1).	Footage was obtained from television recordings and soccer clubs. Data collected was manually coded by an experienced performance analyst. Data collected across time points (I1, I2, I3, I4, I5, I6, I7, I8).	Successful passes, unsuccessful passes, total passes, pass accuracy (%), successful dribbles, unsuccessful dribbles, total dribbles, dribble accuracy (%), shots on target, shots off target, total Shots, shot accuracy (%), successful crosses, unsuccessful crosses, total crosses, cross accuracy (%), ball time in play (s).	Successful passes: ↓ I8 vs. I1, I2, I3, I4, I7. Total passes: ↓ I8 vs. I1, I3, I4, I7. Successful dribbles: ↓ I8 vs. I1, I3. Ball in play: ↓ I8 vs. I1. All other technical performance variables: ↔ were observed.
Peñas et al.[18].	Seven ET matches from 2014 Fifa World Cup / International outfield players (n=99).	Official FIFA 2014 World Cup website: https://www.fifa.com/world cup/archive/brazil2014/statistics/player s/distance.html.	TD ($m·min^{-1}$). Distances covered at low, medium and high speeds ($km.h^{-1}$). Time spent in low (≤11.0 $km·h^{-1}$), medium (11·1-14.0 $km·h^{-1}$) and high (≥14.1 $km·h^{-1}$) speed activities (%). Top sprint speed ($km·h^{-1}$) and number of sprints (reps/ min^{-1}).	TD: ↓ during ET and 2nd half vs.1st half. Top sprint speeds: ↓ during ET vs. 2nd half and 1st half. Avg number of sprints per min: ↑ during 1st half vs. 2nd half and ET.

		Data collected across 3 different match periods (1st half, 2nd half & ET).		
Russell et al.[16].	One reserve ET match/ English Premier League outfield players (n=5).	10 Hz GPS units. Data collected across time points (I1, I2, I3, I4, I5, I6, I7, I8).	TD (m). Distance covered ($m \cdot min^{-1}$). HS distance covered (m). Total number of sprints, total number of accelerations (>0.5 $m \cdot s^{-2}$ / >3.0 $m \cdot s^{-2}$) and decelerations (>0.5 $m \cdot s^{-2}$ / >3.0 $m \cdot s^{-2}$).	TD: 121 $m \cdot min^{-1}$ across 90-min and 107 $m \cdot min^{-1}$ during ET (12% ↓). HS distance: 8 $m \cdot min^{-1}$ during 90-min and 5 $m \cdot min^{-1}$ across ET (37.5% ↓). Accelerations: 6 $\cdot min^{-1}$ throughout 90-min and 7 $m \cdot min^{-1}$ during ET (~14% ↓). Decelerations: 8 $m \cdot min^{-1}$ during 90-min and 7 $m.min^{-1}$ throughout ET (12.5% ↓).
Harper et al.[21].	120-min of soccer simulated match-play. University-standard outfield soccer players (n=10).	No information available on data collection methods. Data collected across 4 time points: Post–first half, prior to second half, FT, and following ET.	CMJ height (cm), 20-m sprint (s) and 15-m sprint ($m \cdot s^{-1}$).	During final 15-min of ET: 15 m sprints speeds ↓ vs. all other time points. Following ET: 20 m sprint speeds ↓ vs. baseline and post–first half. CMJ height ↓ vs. with baseline.

Harper et al.[22].	120-min of simulated soccer match-play / English Premier League academy soccer outfield players (n=8).	15 m sprint velocities measured during first half, second half and ET.	15 m sprint velocity ($m \cdot s^{-1}$).	Sprint velocities: ↓ by 6% during ET vs. first half.
Harper et al.[23].	120-min of a modified version of the soccer match simulation. English Premier League academy soccer outfield players (n=8)	Video footage. (Data collected across time points (I1, I2, I3, I4, I5, I6, I7, I8).	30 m sprint velocities (ms^{-1}), 30 m repeated sprint maintenance (%), CMJ height (cm).	30 m sprint velocities: ↓. 30 m repeated sprint maintenance: ↓. CMJ height: ↓. (Comparisons are post ET measures vs. post 90-min measures).

Stevenson et al.[20].	120-min soccer match simulation. University-standard soccer players (n=22).	Electronic Opto Jump system, timing gates and methods similar to that of Russell, Benton, Kingsley [52] were used to assess skill performance. Assessments were completed pre 1st half, post 1st half, pre 2nd half, Post 2nd half, post ET.	Peak 20m sprint velocity ($m{\cdot}s^{-1}$), sprint decrement index (%), jump height (cm), shot speed ($m{\cdot}s^{-1}$), shot precision (cm), mean 15m sprint velocity, ($m{\cdot}s^{-1}$), dribbling speed ($m{\cdot}s^{-1}$), dribbling precision (cm), dribbling success (%).	Jump height: ↓ following ET vs. Pre 1st half & Post 2nd half. Sprint performance: Relatively ↓ during ET vs. 75-90-min. Shot speed: ↓ following ET vs pre-values (4.3%) and Post 2^{nd} half (2.9%). Dribbling speed: Were slower during ET vs. 0-15-min. Shooting performance: ↔ during ET.
Kubayi and Toriola[19].	Four matches from 2016 European Championship, six teams/ European players (n=59).	InStat camera tracking system. Data collected across 120-min and categorised into 1^{st} half, 2^{nd} half and ET.	Total distance ($m{\cdot}min^{-1}$), walking ($m{\cdot}min^{-1}$) jogging ($m{\cdot}min^{-1}$), running ($m{\cdot}min^{-1}$), high-speed running ($m{\cdot}min^{-1}$), sprinting ($m{\cdot}min^{-1}$). Walking (0–7 $km{\cdot}h^{-1}$), jogging (7.1–14.5 $km{\cdot}h^{-1}$), running (14.6–20 $km{\cdot}h^{-1}$), high-speed running (20.1–25 $km{\cdot}h^{-1}$), and sprinting (>25 $km{\cdot}h^{-1}$).	TD: ↓ during 1st half vs. ET by 13%. TD covered by wide midfield players: ↓ by 17% during 1^{st} half vs. ET. Sprinting performance ↓ during ET vs. 1st half. Greater ↓ were observed in attacking players vs. all other positions.

Note. *ET= Extra- Time, FT= Full-time, n= number of players, FWC= Fifa World Cup, Hz= Hertz, I1 = 00:00–14:59 min, I2 = 15:00–29:59 min, I3 = 30:00–44:59 min, I4 = 45:00–59:59 min, I5 = 60:00–74:59 min, I6 = 75:00–89:59 min, I7 = 90:00–104:59 min and I8 = 105:00–119:59 min, E1 = 00:00–14:59 min, E2 = 15:00–29:59 min, E3 = 30:00–44:59 min, E4 = 45:00–59:59 min, E5 = 60:00–74:59 min, E6 = 75:00–89:59 min, E7 = 90:00–104:59 min and E8 = 105:00–119:59 min, TD= Total distance, HS= High-speed, CMJ= Countermovement Jump, RSA= Repeated sprint ability, SMS= Soccer-match simulation, s= seconds, m= metres, cm= centimetres, min= minutes, Km= Kilometres, Avg = Average, h= hour, 1st = First, 2nd = second, ↓= decreased/ lower than, ↑= increased/ higher than, ↔= no difference.*

Table 4. Studies investigating physiological and neuromuscular responses during the ET period of soccer.

Reference	Matches/Protocol/ Players	Data collection method	Variables measured	Key results
Harper et al.[23].	120-min of a modified version of the soccer match simulation. English Premier League academy soccer outfield players (n=8).	Fingertip capillary blood samples. HR monitor. Data collected across time points (I1, I2, I3, I4, I5, I6, I7, I8).	Blood glucose, lactate and sodium (mmol· l^{-1}).	Blood glucose concentrations: Higher in CHO (5.6 ± 0.9) vs. PLA (4.6 ± 0.2) trials during E7. Blood lactate and sodium concentrations: ↔ were observed during ET vs. other time-points
Harper et al.[21].	120-min of soccer simulated match-play. University-standard outfield soccer players (n=10).	Fingertip capillary and venous blood samples collected across time points (I1, I2, I3, I4, I5, I6, I7, I8).	CK (U· L^{-1}). Insulin (pmol· L^{-1}). NEFA (mmol· L^{-1}). Glycerol (µl mmol· L^{-1}). IL-6 (pg· ml^{-1}). HR mean (b· min^{-1}).	CK: ↑, NEFA: ↑, Glycerol: ↑, Insulin: ↔, IL-6: ↔ during ET vs. Pre-exercise, Post–first half Pre–second half min. HR mean: ↔ were observed during ET vs. other time-points.
Goodall et al.[25].	120-min of soccer simulated exercise. University-standard and semi-professional outfield soccer players (n=10).	EMG activity was measured by Surface Ag/AgCl electrodes. HR data measured using HR monitors. Data collected	ERT (N). MVC (%). $Q_{tw,pot}$ (%). VA (%). VA_{TMS} (%). RF M_{max} amplitude (mV). RF rms EMG M^{-1}. RF MEP/M_{max} area (%). VL M_{max} amplitude (mV). VL rms EMG M^{-1}. VL MEP/M_{max} area (%).	MVC: ↓ throughout match-play with ↑ decrements found in ET vs. HT and FT. $Q_{tw.pot}$ amplitude: ↔ were observed from HT to ET. VA: ↓ following ET vs. Baseline. VA_{TMS}: ↓ during ET vs. baseline, although ↔ between ET, FT and HT.

		pre-match, HT, FT & following ET.	MRFD (N s^{-1}). CT (ms). MRR (N s^{-1}). $RT_{0.5}$ (ms). HR (bpm).	RF rms EMG M^{-1}: ↓ following ET vs. Baseline.
Harper et al.[22].	120-min of soccer match-play. Professional academy soccer players (n=8).	Capillary blood samples (170µl) were taken at: Baseline, Pre-exercise pre, HT and at 15, 30, 45, 60, 75, 90, 105 and 120-min.	Blood calcium (mmol· l^{-1}), potassium, (mmol· l^{-1}), pH (AU), base excess (mmol· l^{-1}), lactate (mmol· l^{-1}), bicarbonate (mmol· l^{-1}) and haemoglobin (mg· dl^{-1}) concentrations.	Base excess: ↓ at 120-min vs. HT (-110 ± 159%), 2nd half and 105-min (-219 ± 280%). Bicarbonate: ↓ at 120-min vs. 105-min (23.7 ± 3.3%) and ↑ at 105-min vs. HT (22.2 ± 1.4%). Haemoglobin: ↑ at 120-min vs. baseline (6.8 ±5.6%) and pre-exercise (+7.9 ± 9%).
Stevenson et al.[20].	120-min soccer match simulation. University-standard soccer players (n=22).	Venous blood samples were collected at Rest, Pre-match, 15-min, 30-min, 45-min, HT, 60-min, 75-min, 90-min, 105-min and 120-min.	Lactate (mmol· l^{-1}). Glycerol (mmol· l^{-1}). NEFA (mmol· l^{-1}). IL-6 (pg· ml^{-1}). Epinephrine (pmol· l^{-1}). HR peak (b· min^{-1}). HR mean (b· min^{-1}).	Blood lactate: ↓, Glycerol: ↑, NEFA: ↑, IL-6: ↑, Epinephrine: ↑, HR peak: ↑, HR mean: ↑ were observed during ET vs. 90-min.

Note.ET= Extra-time, min= minutes, n= number of players, HR= heart rate, I1 = 00:00–14:59 min, I2 = 15:00–29:59 min, I3 = 30:00–44:59 min, I4 = 45:00–59:59 min, I5 = 60:00–74:59 min, I6 = 75:00–89:59 min, I7 = 90:00–104:59 min and I8 = 105:00–119:59 min, ml, millilitres, EMG= Electromyography, HT= Half-time, FT= Full-time, h= hours, CK= creatine kinase, NEFA= Non-esterified fatty acids, IL-6= interleukin-6, RF= rectus femoris, Mmax= maximal M-wave, VL= Vastus lateralis, rms= root-mean-squared, MEP= Motor evoked potential, MRFD= maximum rate of force development, CT= contraction time, MRR= maximum rate of relaxation, RT0.5=Half relaxation time, CHO= Carbohydrate, PLA= Placebo, ↓= decreased/ lower than, ↑= increased/ higher than, ↔= no difference.