A comparison of rolling averages versus discrete time epochs for assessing the worst-case scenario locomotor demands of professional soccer match-play

Article *in* Journal of Science and Medicine in Sport · January 2020

DOI: 10.1016/j.jsams.2020.01.002


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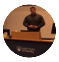
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Title: A comparison of rolling averages versus discrete time epochs for assessing the worst-case scenario locomotor demands of professional soccer match-play

Running head: Peak running demands of professional soccer

Abstract

Objectives: To compare fixed epochs (FIXED) and rolling averages (ROLL) for quantifying worst-case scenario ('peak') running demands during professional soccer match-play, whilst assessing contextual influences.

Design: Descriptive, observational.

Methods: Twenty-five outfield players from an English Championship soccer club wore 10-Hz microelectromechanical systems during 28 matches. Relative total and high-speed (>5.5 m·s^{-1}) distances were averaged over fixed and rolling 60-s to 600-s epochs. Linear mixed models compared FIXED versus ROLL and assessed the influence of epoch length, playing position, starting status, match result, location, formation, and time-of-day.

Results: Irrespective of playing position or epoch duration, FIXED underestimated ROLL for total (~7-10%) and high-speed (~12-25%) distance. In ROLL, worst-case scenario relative total and high-speed distances reduced from 190.1±20.4 m·min^{-1} and 59.5±23.0 m·min^{-1} in the 60-s epoch, to 120.9±13.1 m·min^{-1} and 14.2±6.5 m·min^{-1} in the 600-s epoch, respectively. Worst-case scenario total distance was higher for midfielders (~9-16 m·min^{-1}) and defenders (~3-10 m·min^{-1}) compared with attackers. In general, starters experienced higher worst-case scenario total distance than substitutes (~3.6-8.5 m·min^{-1}), but lower worst-case scenario high-speed running over 300-s (~3 m·min^{-1}). Greater worst-case scenario total and high-speed distances were elicited during wins (~7.3-11.2 m·min^{-1} and ~2.7-7.9 m·min^{-1}, respectively) and losses (~2.7-5.7 m·min^{-1} and ~1.4-2.2 m·min^{-1}, respectively) versus draws, whilst time-of-day and playing formation influenced worst-case scenario high-speed distances only.

Conclusions: These data indicate an underestimation of worst-case scenario running demands in FIXED versus ROLL over 60-s to 600-s epochs while highlighting situational influences. Such information facilitates training specificity by enabling sessions to be targeted at the most demanding periods of competition.

Key Words: Football; physiology; monitoring; fatigue; activity profiles; running**.**

Introduction

Soccer is a team sport characterised by intermittent bouts of high-intensity activity, interspersed with lower-intensity periods and rest.[1, 2] Whilst low-speed activities (e.g., walking, jogging etc.) dominate,[1] the most decisive moments of a match often involve explosive actions such as high-speed running (HSR; typically defined as moving at speeds >5.5 $m \cdot s^{-1}$), sprinting, and/or the execution of technical skills.[3] Professional soccer players typically cover ~10-12-km during a 90-min match, with wide midfielders covering the most, and central defenders covering the least total (TD) and HSR distance of any position.[1, 4, 5] Knowledge of match-demands is useful for practitioners when designing training programmes to prepare players for the rigours of competition, and wearable microelectromechanical systems (MEMS), incorporating global positioning systems, now provide a valid, reliable, and practical method of quantifying players' external loads during training and match-play.[6]

Whilst reporting half or whole-match movement profiles is valuable to help understand the contribution to players' overall physical loading, such data do not reflect the stochastic nature of soccer match-play.[7] Therefore, elucidating the demands associated with the most intense phases of the game (i.e., 'worst-case scenario'; WCS), may be useful when developing specific training programmes designed to condition players to cope with these potentially decisive periods of competition.[6, 8] Several studies have attempted to assess fluctuations in movement demands during competitive soccer by dividing matches into discrete 'epochs', typically 5-15-min in length.[1, 5, 9] However, because events in soccer occur randomly, and are thus unlikely to fall within such pre-defined epochs, the use of discrete, pre-determined time periods may lack sensitivity to detect the most demanding phases of play.[6, 10, 11] Indeed, Varley et al.[11] reported that analysing data based upon fixed 5-min epochs resulted in an underestimation of peak running demands by up to ~25% when compared with 5-min rolling averages. Whether this relationship is consistent across epochs of differing lengths remains to be determined in professional soccer.

Rolling averages have been employed to assess WCS within a number of team-sports, typically over durations of 10-s to 10-min.[6] Knowing the WCS associated with their specific competitive environment may be useful for practitioners when monitoring training intensity relative to the highest demands that a player may be expected to face. Notably, although positional variation has been observed,[10] no study to date has directly compared WCS between starting and substitute players. Likewise, limited literature has considered the influence of other contextual factors (e.g., match result, location, or playing formation) which have previously been found to influence running patterns during professional soccer match-play.[5, 12, 13] Therefore, the aim of this investigation was to compare the fixed epoch and rolling average methods of quantifying duration-specific WCS running demands of English Championship soccer players over epochs ranging from 1-min to 10-min. A secondary objective was to assess the influence of a number of contextual variables on the WCS observed.

Methods

Following approval from Swansea University Ethics committee (2018-107), 25 professional outfield players (age: 25 ± 4 years, stature: 1.80 ± 0.08 m, body mass: 75.0 ± 7.6 kg) from an English Championship soccer club were monitored during 28 matches within the 2018/2019 season, yielding 347 individual player observations (14 ± 9 obervations·player^{-1}, range: 1-26 obervations·player^{-1}). The sample comprised central defenders (CD), wide defenders (WD), central midfielders (CM), central defensive midfielders (CDM), wide midfielders (WM), and central (CA) and wide (WA) attackers, who were in good health and injury free at the time of data-collection. All players were briefed about the risks and benefits of participation before providing their written informed consent. Given the observational nature of the study, no attempt was made to influence players' responses.

Players' movements were captured by MEMS (10 Hz; Optimeye S5, Catapult Sports, Melbourne, Australia) which were worn between the scapulae and were contained within the playing jersey inside a pocket designed to limit movement artefacts. This reflected routine monitoring practices at the club, and each player wore the same unit throughout the study to avoid inter-unit variation. Sampling at 10 Hz has demonstrated acceptable reliability (coefficient of variation; CV%: 2.0–5.3%) for measuring instantaneous velocity during straight-line running,[14] and good accuracy in determining TD (typical error as CV%: 1.9%) and HSR (CV%: 4.7%) during soccer-specific exercise.[15]

The MEMS units were activated at least 15-min prior to players' pre-match warm-ups, and raw data files were exported post-match using proprietary software (Openfield version 1.22.0, Catapult Sports, Melbourne, Australia). Data were subsequently processed using a bespoke analysis program. Epochs were specified in 60-s increments according to Cunningham et al.,[8] resulting in fixed and rolling periods ranging from 60-s to 600-s in length. The locomotor variables of interest were TD and HSR (defined as distance covered at speeds >5.5 m·s^{-1} [4, 5, 12]) which, to allow comparison between epochs of differing duration, were expressed relative to epoch length (i.e., m·min^{-1}).

To account for the non-independence of data sampled from the same individuals across multiple matches, linear mixed models were constructed to examine differences in WCS estimation as a function of assessment method (i.e., FIXED or ROLL). In all models, random intercepts ('player' and 'match') were included to allow for the 'nested' nature of data within individual players and matches. Initially, to determine differences between ROLL and FIXED across the entire sample, separate models were run for each dependant variable at every epoch duration (60-s to 600-s), with 'method' entered as a fixed effect. Subsequently, to simplify the interpretation of any potential interaction effects, 'positional group', 'playing position' and 'epoch length' were in turn entered as fixed effects, whilst 'method' was specified as a covariate [8]. Attackers and CD were used as baseline references for the fixed effects of positional group and playing position, respectively, whilst the baseline for epoch length was 600-s. Using data from ROLL only, separate models were run for further covariates (i.e., 'time of day', 'location', 'match result', 'formation', and 'substitutes vs. starters'), to examine differences in WCS between different levels of each (e.g., between home and away matches). Data are presented as mean ± standard deviation (SD), whilst magnitudes of change are demonstrated by effect estimates with 95% confidence intervals (CI).

Results

For the whole-team analysis, effect estimates (Table 1) indicated that for all epoch lengths, FIXED underestimated ROLL for both TD and HSR (all $p<0.001$). Compared with attackers and irrespective of the method used, midfielders (all $p<0.001$) and defenders (all $p<0.05$) experienced higher TD over all epoch durations (Table 2). No interaction was observed (method*positional group) for TD at any epoch duration, suggesting that positional group did not affect the between-method differences observed. However, for HSR over 120-s, the increase from FIXED to ROLL was greater for attackers compared with defenders ($p = 0.021$).

****TABLE 1 HERE****

Epoch length influenced whole-team TD and HSR in both FIXED and ROLL, with a significant interaction of epoch length*method observed for TD ($p<0.001$). For both methods, TD was higher than 600-s across all epochs except for 540-s (all $p<0.05$), whereas HSR in FIXED and ROLL was greater than 600-s for all epoch lengths (all $p<0.05$) .

****TABLE 2 HERE****

As TD and HSR were consistently underestimated in FIXED, a further model was run using data from ROLL only to examine differences in WCS between individual positions, using CD as a baseline (Figure 1A, 1B). For TD, CDM and CM experienced higher demands than CD across all epoch durations (all $p\leq0.05$). Likewise, TD was greater for WD compared with CD during epochs less than 480-s in length, whilst WM had higher TD than CD over 60-s and 120-s epochs (all $p<0.05$). For HSR, each of CM, WM, and WD, returned higher values than CD across all epoch lengths, whilst WA and CA performed more HSR than CD during 480-s, 540-s, and 600-s epochs (all $p<0.05$). HSR for CDM, and TD for CA and WA, remained similar to CD throughout.

****FIGURE 1 HERE****

When considering ROLL only, starters demonstrated greater TD for all except for 60-s and 120-s epochs, but smaller HSR values over 300-s (all $p<0.05$), when compared with substitutes (Figure 1A, 1B). Compared with matches drawn, wins elicited more TD for all epoch durations and greater HSR for 60-s and 420-s to 600-s epochs, whilst losses produced higher TD for epochs of 300-s to 600-s (Figure 1A, 1B). Wins also elicited higher TD for 60-s and 540-s epochs, compared with losses (all $p<0.05$). Neither TD nor HSR were influenced by match location, but more HSR was performed during epochs of 240-s to 540-s when matches started at 17:30 h compared with matches that started at 15:00 h (all $p<0.05$). Compared with a 4-1-4-1 playing formation, 3-5-2 produced lower HSR for 300-s to 600-s epochs, whilst 3-4-3 elicited less HSR during 360-s and 420-s epochs (all $p<0.05$).

Discussion

This study compared the use of discrete (i.e., 'fixed') time epochs and rolling averages to determine the duration-specific WCS running demands of English Championship soccer match-play, whilst assessing the influence of several contextual variables. Compared with ROLL, FIXED consistently underestimated WCS TD and HSR irrespective of epoch length. Notably, data from Australian A-League soccer has previously indicated up to ~25% underestimation of peak 5-min running demands when discrete periods were used, compared with rolling averages.[11] Whilst the findings of the current study broadly reflect such values, it is notable that the ~12-25% underestimation of WCS HSR far exceeded the ~7-10% underestimation observed in relation to TD. Similar discrepancies have been identified amongst international rugby union players over 60-s to 300-s epochs,[8] and this investigation extends previous research to highlight between-method differences for quantifying WCS running demands over epochs ranging from 60-s to 600-s. Indeed, these data suggest that using rolling averages may be a more appropriate method of assessing WCS in professional soccer, particularly with regards to HSR.

Knowledge of the WCS associated with competitive match-play provides practitioners with useful information to help optimise training prescription. By better understanding the demands of the most intense periods of play, practitioners can monitor training drills to ensure that players are exposed to such intensities when appropriate, particularly during technical/tactical training.[6, 16] The current study observed WCS TD ranging from ~120-190 $m \cdot min^{-1}$, and WCS HSR of ~14-60 $m \cdot min^{-1}$, depending on epoch duration. Whilst similar values have been reported in Australian A-League soccer,[10, 11] the potential influence of contextual factors such as team tactics or playing formation, means that practitioners prescribing training based upon 'match-speed' may need to consider the WCS associated with their specific team and/or competition.

Across a whole-match, midfield positions typically perform the most TD and HSR of any outfield playing position,[4, 9, 17] and our observations confirm previous reports that this pattern may also exist for WCS.[10] Such variation is likely attributable to the distinctive tactical roles associated with each position,[18] and may indicate the need for a position-specific approach when using WCS to prescribe or monitor training intensity. Notwithstanding, it should be noted that the specific match-circumstances may at times require players to perform tasks that are not typically associated with their own playing position. For example, in the case of injury or poor positioning, a player may need to briefly 'fill-in' for a teammate who temporarily cannot fulfil their normal tactical role. In these situations, it may be important that all team members are suitably prepared to manage the potentially heightened physical demands associated with such actions.

A player's starting status,[19] match result,[5] match location,[20] and playing formation,[21] may each independently influence the global (i.e., half or whole-match) demands associated with soccer match-play. In the current study, wins and losses generally produced greater WCS TD and HSR compared with draws; whilst for 60-s and 540-s epochs, WCS TD during wins exceeded that experienced during losses. Moreover, WCS HSR over 240-s to 540-s epochs was higher during matches starting at 17:30 h compared with those starting at 15:00 h. Winning and losing score-lines have each been linked to heightened match demands,[5, 12, 13] with this relationship potentially dependent upon playing position.[5] In addition, diurnal variations in physiological and performance responses have been identified amongst male soccer players, with peak values for body temperature and indices of soccer-specific physical, mental, and technical performance, observed between 16:00-20:00 h.[22, 23] Although running intensity may be affected by a complex interaction of technical, tactical, and physical factors;[5, 13, 24] and thus the precise reasons for these responses remain unclear, our observations extend existing research to highlight contextual influences on WCS demands during professional soccer match-play. It will be important for future studies to delve deeper into each of these contextual factors, to explore the relationships between different variables and elucidate the mechanisms underpinning their influence. Notably, the fact that a 4-1-4-1 playing formation elicited greater WCS HSR than 3-5-2 for 300-s to 600-s epochs, and more WCS HSR than 3-4-3 during 360-s and 420-s epochs, further highlights the role of team tactics in modulating match demands; perhaps underlining the need for a population-specific approach to training prescription.

Players who started a match recorded greater WCS TD for all except for 60-s and 120-s epochs, when compared with substitutes. Such findings seem surprising given that starting players may adopt conscious or subconscious self-pacing strategies which reduce their physical outputs in an effort to preserve energy throughout the course of match.[5, 25] Indeed, the limited literature currently existing in relation to partial-match soccer players appears to suggest that substitutes entering the pitch at half-time or later typically achieve higher relative running distances, compared with whole-match players and/or those being replaced.[19] However, it is well established that the ~15-min following kick-off typically represents the most intense period of a match.[1] Whilst substitutes may also demonstrate heightened (i.e., relative to the remainder of their playing bout) physical responses immediately upon entering the pitch,[12] it is possible that tactical considerations or the influence of contextual factors such as the presence of accumulated fatigue in surrounding players (i.e., those on the same and/or opposing team), may affect substitutes' ability to 'get into the game' and thus limit the relative running distances that they are able to achieve.[19, 24, 26] That said, substitutes in the current study performed ~15% more HSR over 300-s compared with players who started a match. As the reasons underlying such responses remain unclear, future research into the WCS demands experienced by partial-match soccer players will be important to elucidate the potential influence of playing time, match score-line, and/or other contextual variables; allowing practitioners to achieve greater specificity when prescribing training for this bespoke population (e.g., during 'top-up conditioning sessions).

Consistent with observations from a range of team sports,[6] WCS running demands generally decreased (i.e., in relative terms) as epochs increased in duration from 60-s to 600-s. Although the causes of such declines cannot be identified from movement data alone, this relationship may be useful for practitioners when prescribing training drills of differing lengths. For example, based upon the current data, a 1-min training activity may require players to achieve ~190 m·min^{-1} to reflect 100% of 'match-speed', whereas an intensity of ~130 m·min^{-1} may be appropriate for drills of 5-min in length (Table 2). It should be noted that whilst WCS demands were influenced by epoch duration, practical and/or logistical considerations mean that small variations are unlikely to influence training prescription in an applied team-sport scenario.[8, 27] Although research in professional rugby league has proposed that differences in relative running intensity of ≥10 m·min^{-1} (e.g., between epochs of differing lengths) may reflect real-world significance,[27] practitioners must consider what they deem to be an appropriate threshold in their specific circumstances (e.g., based upon population, access to resources, etc.,).

Whilst this study provides valuable insight into the duration-specific WCS demands of English Championship soccer, the data presented pertain only to relative TD and HSR. A number of other metabolically demanding activities, such as high-speed accelerations/decelerations and changes of direction, are important components of soccer match-play.[1, 2, 28] Weaving et al.[29] demonstrated that multiple variables, including indices of both internal and external loading, were required to appropriately quantify the physical demands imposed on other team sports athletes (i.e., rugby league players), and further work should take a more holistic approach to quantifying WCS by incorporating a range of physical performance indicators. In addition, the execution of technical skills is fundamental to team success.[28] Research incorporating video analysis alongside MEMS data would be useful to elucidate the relationships between WCS physical and technical demands. Finally, direct comparison of WCS between different competitions and/or between academy and first-team soccer may assist practitioners in planning for longer-term player development.

Conclusion

This study compared discrete epochs and rolling averages for determining WCS TD and HSR during professional soccer match-play, over durations from 60-s to 600-s. Irrespective of epoch length or playing position, FIXED significantly underestimated WCS TD and HSR compared with ROLL.

Knowledge of duration-specific WCS match demands provides useful information for prescribing and monitoring training loads, as practitioners can ensure that all players are exposed to appropriate stimuli over any given period. Moreover, novel findings highlighting contextual influences on WCS are presented. Whilst TD and HSR are variables commonly employed in the assessment of match demands, including a range of physical and technical performance metrics may provide additional insight.

Practical implications

- Fixed epochs underestimated rolling averages by ~7-10% for worst-case scenario total distance, and ~12-25% for high-speed running distance. Such findings suggest that rolling averages may be a more appropriate method of assessing the worst-case scenario movement demands of professional soccer.
- Worst-case scenario relative total and high-speed running distance ranged from ~120-190 $m \cdot min^{-1}$ and ~14-60 $m \cdot min^{-1}$, respectively, with relative running demands being influenced by a range of contextual factors and decreasing as epochs increased in duration.
- Whilst other physical and technical activities should also be considered, knowledge of worst-case scenario demands may help to design specific training programmes that prepare players for the most intense periods of match-play.
- These data suggest that for the current population, covering ~190 $m \cdot min^{-1}$, and/or performing ~60 $m \cdot min^{-1}$ of high-speed running, may be an appropriate target for a 1 min training activity conducted at 'peak match intensity'.

Acknowledgments

The authors would like to thank players and staff at Swansea City Association Football Club for their cooperation and participation in this study. No financial support was received in the completion of this research.

References

1. Mohr M, Krustrup P, Bangsbo J. Match performance of high-standard soccer players with special reference to development of fatigue. J Sports Sci 2003; 21(7):519-528.
2. Bangsbo J, Mohr M, Krustrup P. Physical and metabolic demands of training and match-play in the elite football player. J Sports Sci 2006; 24(7):665-674.
3. Stølen T, Chamari K, Castagna C, et al. Physiology of soccer: An update. Sports Med 2005; 35(6):501-536.
4. Di Salvo V, Gregson W, Atkinson G, et al. Analysis of high intensity activity in Premier League soccer. Int J Sports Med 2009; 30(03):205-212.
5. Bradley PS, Noakes TD. Match running performance fluctuations in elite soccer: Indicative of fatigue, pacing or situational influences? J Sports Sci 2013; 31(15):1627-1638.
6. Whitehead S, Till K, Weaving D, et al. The use of microtechnology to quantify the peak match demands of the football codes: A systematic review. Sports Med 2018; 48(11):2549-2575.
7. Barrett S, Midgley A, Reeves M, et al. The within-match patterns of locomotor efficiency during professional soccer match play: Implications for injury risk? J Sci Med Sport 2016; 19(10):810-815.
8. Cunningham DJ, Shearer DA, Carter N, et al. Assessing worst case scenarios in movement demands derived from global positioning systems during international rugby union matches: Rolling averages versus fixed length epochs. PloS one 2018; 13(4):e0195197.
9. Bradley PS, Di Mascio M, Peart D, et al. High-intensity activity profiles of elite soccer players at different performance levels. J Strength Cond Res 2010; 24(9):2343-2351.
10. Delaney JA, Thornton HR, Rowell AE, et al. Modelling the decrement in running intensity within professional soccer players. Sci Med Foot 2018; 2(2):86-92.
11. Varley MC, Elias GP, Aughey RJ. Current match-analysis techniques' underestimation of intense periods of high-velocity running. Int J Sports Physiol Perform 2012; 7(2):183-185.
12. Hills SP, Barrett S, Feltbower RG, et al. A match-day analysis of the movement profiles of substitutes from a professional soccer club before and after pitch-entry. PloS one 2019; 14(1):e0211563.
13. Paul DJ, Bradley PS, Nassis GP. Factors affecting match running performance of elite soccer players: Shedding some light on the complexity. Int J Sports Physiol Perform 2015; 10(4):516-519.
14. Varley MC, Fairweather IH, Aughey RJ. Validity and reliability of GPS for measuring instantaneous velocity during acceleration, deceleration, and constant motion. J Sports Sci 2012; 30(2):121-127.
15. Rampinini E, Alberti G, Fiorenza M, et al. Accuracy of GPS devices for measuring high-intensity running in field-based team sports. Int J Sports Med 2015; 36(01):49-53.
16. Weaving D, Sawczuk T, Williams S, et al. The peak duration-specific locomotor demands and concurrent collision frequencies of European Super League rugby. J Sports Sci 2019; 37(3):322-330.
17. Di Salvo V, Baron R, Tschan H, et al. Performance characteristics according to playing position in elite soccer. Int J Sports Med 2007; 28(3):222-227.
18. Carling C, Bloomfield J, Nelsen L, et al. The role of motion analysis in elite soccer. Sports Med 2008; 38(10):839-862.
19. Hills SP, Barwood MJ, Radcliffe JN, et al. Profiling the responses of soccer substitutes: A review of current literature. Sports Med 2018; 48(10):2255-2269.
20. Castellano J, Blanco-Villaseñor A, Alvarez D. Contextual variables and time-motion analysis in soccer. Int J Sports Med 2011; 32(6):415-421.
21. Tierney PJ, Young A, Clarke ND, et al. Match play demands of 11 versus 11 professional football using Global Positioning System tracking: Variations across common playing formations. Hum Mov Sci 2016; 49:1-8.

22. Reilly T, Atkinson G, Edwards B, et al. Diurnal variation in temperature, mental and physical performance, and tasks specifically related to football (soccer). Chronobiol 2007; 24(3):507-519.
23. Hammouda O, Chtourou H, Chaouachi A, et al. Time-of-day effects on biochemical responses to soccer-specific endurance in elite Tunisian football players. J Sports Sci 2013; 31(9):963-971.
24. Bradley PS, Ade JD. Are current physical match performance metrics in elite soccer fit for purpose or is the adoption of an integrated approach needed? Int J Sports Physiol Perform 2018; 13(5):656-664.
25. Waldron M, Highton J. Fatigue and pacing in high-intensity intermittent team sport: An update. Sports Med 2014; 44(12):1645-1658.
26. Carling C, Espié V, Le Gall F, et al. Work-rate of substitutes in elite soccer: A preliminary study. J Sci Med Sport 2010; 13(2):253-255.
27. Delaney JA, Scott TJ, Thornton HR, et al. Establishing duration-specific running intensities from match-play analysis in rugby league. Int J Sports Physiol Perform 2015; 10(6):725-731.
28. Rampinini E, Impellizzeri FM, Castagna C, et al. Technical performance during soccer matches of the Italian Serie A league: Effect of fatigue and competitive level. J Sci Med Sport 2009; 12(1):227-233.
29. Weaving D, Jones B, Marshall P, et al. Multiple measures are needed to quantify training loads in professional rugby league. Int J Sports Med 2017; 38(10):735-740.

Legends

Figure 1: Worst-case scenario total (TD; Panel A) and high-speed running (HSR; Panel B) distance over rolling epochs of 60-s to 600-s in length. Comparison between each playing position, starters and substitutes, and according to match results. Data derived from the rolling average method and presented as mean ± SD. CD: Central defenders, WD: Wide defenders, CM: Central midfielders, CDM: Central defensive midfielders, WM: Wide midfielders, CA: Central attackers, WA: Wide attackers. [a]: WD significantly different from CD, [b]: WM significantly different from CD, [c]: CM significantly different from CD, [d]: CDM significantly different from CD, [e]: CA significantly different from CD, [f]: WA significantly different from CD *: Starters and substitutes significantly different at the $p < 0.05$ level. †: Wins significantly different from draws, ‡: Losses significantly different from draws (all differences at the $p \leq 0.05$ level).

Table 1: Effect estimates for between-methods differences in worst-case scenario total distance and high-speed running distance using the rolling averages method as a baseline.

Table 2: Worst-case scenario total distance and high-speed running distance for whole-team and each positional group, with percentage differences between methods.

Table 1: Effect estimates for between-methods differences in worst-case scenario total distance and high-speed running distance using the rolling averages method as a baseline

Epoch length (s)	Estimate	t	Sig.	95% Confidence Interval	
				Lower Bound	Upper Bound
TD (m·min^{-1})					
60	-17.0	-11.2	<0.001	-19.9	-14.0
120	-13.0	-10.5	<0.001	-15.4	-10.6
180	-10.7	-9.5	<0.001	-12.9	-8.5
240	-10.7	-9.9	<0.001	-12.8	-8.6
300	-9.1	-8.7	<0.001	-11.1	-7.0
360	-9.4	-8.9	<0.001	-11.4	-7.3
420	-8.5	-8.1	<0.001	-10.5	-6.4
480	-7.6	-7.3	<0.001	-9.6	-5.5
540	-7.9	-7.6	<0.001	-9.9	-5.8
600	-7.1	-6.8	<0.001	-9.2	-5.1
HSR (m·min^{-1})					
60	-5.8	-11.8	<0.001	-6.8	-4.8
120	-5.1	-13.5	<0.001	-5.9	-4.4
180	-4.6	-18.2	<0.001	-5.1	-4.1
240	-4.1	-17.4	<0.001	-4.5	-3.6
300	-3.6	-15.8	<0.001	-4.1	-3.2
360	-3.1	-18.1	<0.001	-3.5	-2.8
420	-3.0	-17.1	<0.001	-3.3	-2.6
480	-2.6	-20.0	<0.001	-2.8	-2.3
540	-2.4	-19.4	<0.001	-2.7	-2.2
600	-2.6	-21.1	<0.001	-2.8	-2.3

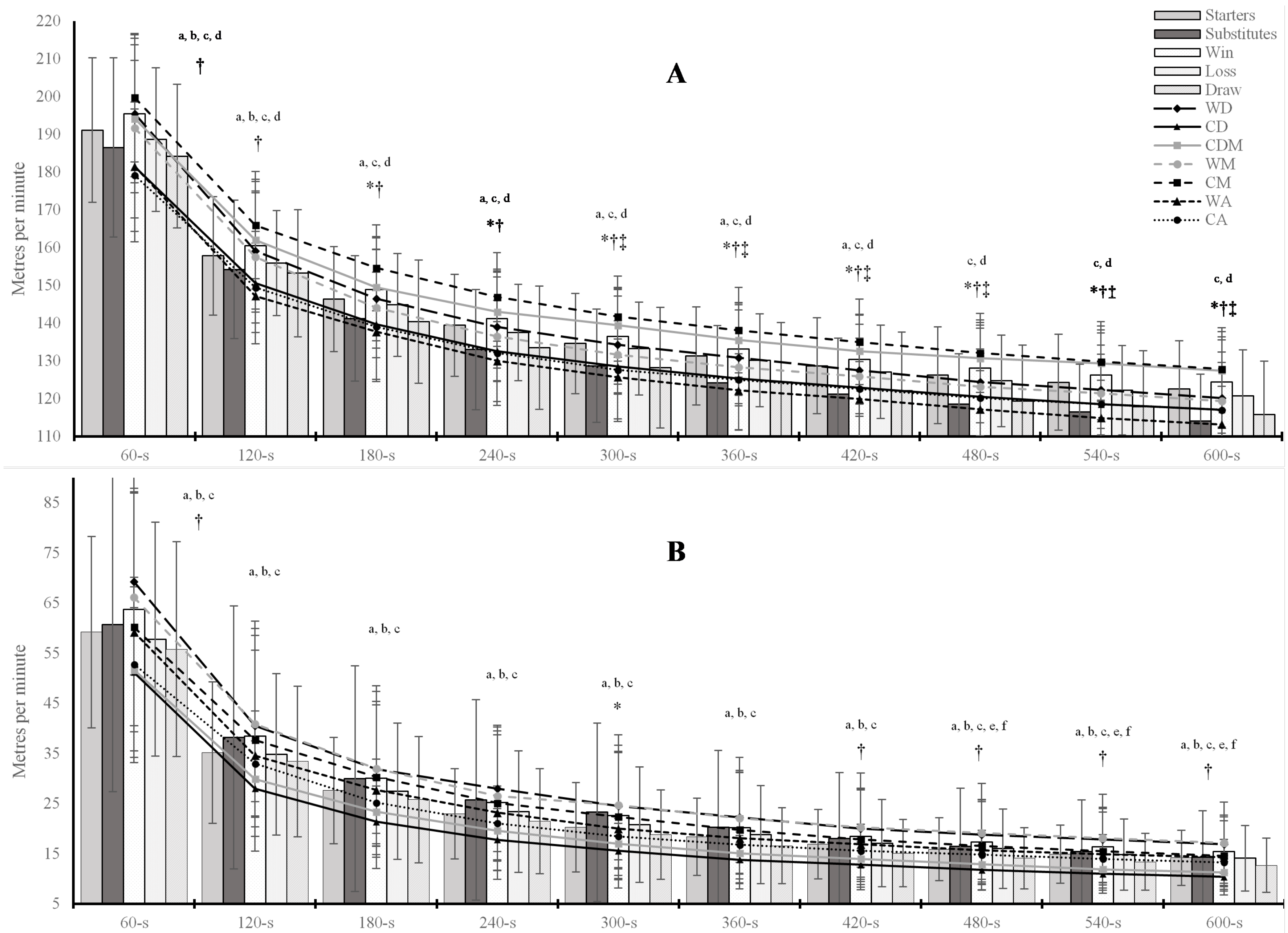
HSR: High-speed running distance, TD: Total distance

Table 2: Worst-case scenario total distance and high-speed running distance for whole-team and each positional group, with percentage differences between methods

Epoch length (s)	Team			Defenders			Midfielders			Attackers		
TD ($m \cdot min^{-1}$)	ROLL	FIXED	% Diff	ROLL	FIXED	% Diff	ROLL	FIXED	% Diff	ROLL	FIXED	% Diff
60	190.1 ± 20.4*	173.1 ± 19.7*	-10.1 ± 7.7	187.8 ± 19.0 [a]	170.7 ± 18.3 [a]	-10.4 ± 8.2	196.5 ± 19.5 [b]	178.6 ± 18.8 [b]	-10.3 ± 7.4	180.3 ± 19.0	165.5 ± 20.0	-9.4 ± 7.7
120	157.0 ± 16.6*	144.0 ± 16.0*	-9.3 ± 6.9	154.6 ± 13.6 [a]	142.8 ± 13.6 [a]	-8.5 ± 5.9	162.6 ± 16.5 [b]	148.6 ± 15.3 [b]	-9.8 ± 7.5	148.9 ± 15.2	136.4 ± 15.9	-9.4 ± 6.8
180	145.3 ± 14.8*	134.6 ± 14.8*	-8.2 ± 5.6	142.6 ± 11.5 [a]	132.7 ± 11.7 [a]	-7.7± 5.0	150.3 ± 14.8 [b]	139.0 ± 14.6 [b]	-8.3 ± 5.8	138.7 ± 14.8	128.1 ± 15.7	-8.6 ± 6.0
240	137.9 ± 14.2*	127.2 ± 14.3*	-8.7 ± 6.0	135.8 ± 11.2 [a]	125.9 ± 10.5 [a]	-8.1 ± 6.1	142.7 ± 14.2 [b]	131.7 ± 14.0 [b]	-8.6 ± 5.5	131.3 ± 14.8	120.0 ± 14.3	-9.8 ± 6.8
300	133.3 ± 13.9*	124.2 ± 13.7*	-7.5 ± 6.1	131.1 ± 10.6 [a]	122.0 ± 9.6 [a]	-7.5 ± 4.9	137.8 ± 14.0 [b]	128.7 ± 13.5 [b]	-7.4 ± 5.9	127.0 ± 14.5	118.0 ± 14.2	-7.9 ± 7.6
360	129.8 ± 13.7*	120.4 ± 14.0*	-8.1 ± 5.8	127.6 ± 10.2 [a]	118.8 ± 9.6 [a]	-7.5 ± 4.6	134.1 ± 13.7 [b]	124.3 ± 13.5 [b]	-8.2 ± 6.6	123.9 ± 14.9	114.6 ± 15.7	-8.5 ± 5.5
420	127.1 ± 13.2*	118.6 ± 13.8*	-7.4 ± 5.4	124.7 ± 9.9 [a]	117.0 ± 10.6 [a]	-6.7 ± 4.2	131.3 ± 13.5 [b]	122.1 ± 13.7 [b]	-7.9 ± 6.4	121.6 ± 14.8	113.5 ± 15.1	-7.3 ± 4.4
480	124.6 ± 13.2*	117.1 ± 13.9*	-6.8 ± 5.3	122.3 ± 10.0 [a]	115.7 ± 9.3	-5.7 ± 4.0	128.9 ± 13.2 [b]	121.0 ± 14.3 [b]	-7.0 ± 5.8	119.1 ± 14.3	110.8 ± 15.4	-7.8 ± 5.6
540	122.7 ± 13.1	114.8 ± 13.9	-7.2 ± 5.7	120.3 ± 9.5 [a]	113.5 ± 9.6 [a]	-6.1 ± 3.8	126.9 ± 13.1 [b]	118.0 ± 14.9 [b]	-8.1 ± 6.8	117.2 ± 14.5	110.1 ± 15.2	-6.8 ± 5.2
600	120.9 ± 13.1	113.6 ± 13.9	-6.7 ± 5.7	118.6 ± 9.5 [a]	112.2 ± 9.6 [a]	-5.8 ± 3.3	125.0 ± 13.3 [b]	117.7 ± 13.9 [b]	-6.6 ± 5.0	115.6 ± 14.2	107.7 ± 16.5	-8.1 ± 8.6
HSR ($m \cdot min^{-1}$)												
60	59.5 ± 23.0*	53.7 ± 20.1*	-11.7 ± 18.4	59.9 ± 21.1	54.4 ± 18.3	-10.7 ± 17.8	61.0 ± 25.7	54.9 ± 22.3	-12.2 ± 18.6	56.0 ± 19.2	50.5 ± 17.4	-12.0 ± 18.8
120	35.9 ± 17.5*	30.7 ± 13.6*	-17.1 ± 19.2	34.3 ± 15.6	30.5 ± 12.7	-11.7 ± 14.5	37.7 ± 20.5	32.2 ± 15.5	-17.5 ± 19.3	34.3 ± 12.5	28.1 ± 9.6	-23.5 ± 22.1
180	28.1 ± 14.1*	23.5 ± 12.3*	-21.1 ± 19.7	26.7 ± 12.7	22.6 ± 11.3	-19.1 ± 17.9	29.8 ± 16.3	24.7 ± 14.2	-22.7 ± 20.7	26.6 ± 10.6	22.3 ± 8.9	-20.4 ± 20.0
240	23.6 ± 12.3*	19.5 ± 10.0*	-21.9 ± 20.3	22.8 ± 11.8	19.2 ± 8.7	-18.1 ± 19.9	24.7 ± 13.8	20.6 ± 11.6	-21.8 ± 20.8	22.4 ± 9.7	17.7 ± 7.4	-27.2 ± 18.7

300	21.0 ± 11.5*	17.4 ± 9.3*	-22.0 ± 20.7	20.0 ± 10.3	16.5 ± 8.9	-22.2 ± 21.5	22.3 ± 13.4	18.3 ± 10.1	-21.8 ± 20.4	19.6 ± 8.2	16.5 ± 7.7	-22.1 ± 20.7
360	18.8 ± 9.9*	15.6 ± 8.7*	-21.8 ± 19.4	18.0 ± 9.2	15.3 ± 8.3	-19.8 ± 18.0	19.8 ± 11.4	16.3 ± 10.0	-23.2 ± 20.2	17.7 ± 7.0	14.8 ± 5.8	-21.8 ± 19.4
420	17.1 ± 8.7*	14.2 ± 6.9*	-21.7 ± 19.4	16.4 ± 8.1	13.7 ± 7.3	-22.0 ± 19.4	18.0 ± 9.9	14.8 ± 7.4	-21.7 ± 20.0	16.4 ± 6.3	13.5 ± 5.1	-21.1 ± 18.4
480	16.0 ± 7.8*	13.4 ± 7.1*	-21.2 ± 17.6	15.2 ± 7.3	12.7 ± 5.5	-19.6 ± 17.2	16.8 ± 8.9	14.4 ± 8.8	-20.4 ± 17.4	15.4 ± 5.7	12.4 ± 4.6	-24.9 ± 18.1
540	15.0 ± 7.1*	12.6 ± 6.4*	-21.4 ± 18.7	14.4 ± 6.8	12.0 ± 6.0	-21.5 ± 20.2	15.7 ± 8.0	13.3 ± 7.4	-20.8 ± 18.3	14.5 ± 5.3	12.0 ± 4.4	-22.5 ± 17.4
600	14.2 ± 6.5	11.7 ± 5.7	-24.8 ± 19.6	13.5 ± 6.3	11.2 ± 5.8	-23.5 ± 20.5	14.9 ± 7.3	12.1 ± 6.1	-26.1 ± 19.5	13.8 ± 5.0	11.4 ± 4.7	-23.9 ± 18.5

[a]: Significantly different from Attackers at the $p < 0.05$ level, [b]: Significantly different from Attackers at the $p < 0.001$ level, FIXED: Fixed average method, HSR: High-speed running distance, ROLL: Rolling average method, TD: Total distance, *: Significantly different from 600-s epoch at the $p < 0.05$ level (whole-team only analysis), % Diff: Mean percentage (± standard deviation) difference between methods.


A
B
Metres per minute
Starters
Substitutes
Win
Loss
Draw
WD
CD
CDM
WM
CM
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CA
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120-s
180-s
240-s
300-s
360-s
420-s
480-s
540-s
600-s
a, b, c, d
a, c, d
c, d
a, b, c
a, b, c, e, f