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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

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1 **Abstract**

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

5 *Design:* Descriptive, observational.

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

11 *Results:* Irrespective of playing position or epoch duration, FIXED underestimated ROLL for total (~7-
12 10%) and high-speed (~12-25%) distance. In ROLL, worst-case scenario relative total and high-speed
13 distances reduced from $190.1 \pm 20.4 \text{ m}\cdot\text{min}^{-1}$ and $59.5 \pm 23.0 \text{ m}\cdot\text{min}^{-1}$ in the 60-s epoch, to 120.9 ± 13.1
14 $\text{m}\cdot\text{min}^{-1}$ and $14.2 \pm 6.5 \text{ m}\cdot\text{min}^{-1}$ in the 600-s epoch, respectively. Worst-case scenario total distance was
15 higher for midfielders (~9-16 $\text{m}\cdot\text{min}^{-1}$) and defenders (~3-10 $\text{m}\cdot\text{min}^{-1}$) compared with attackers. In
16 general, starters experienced higher worst-case scenario total distance than substitutes (~3.6-8.5 $\text{m}\cdot\text{min}^{-1}$
17 1), but lower worst-case scenario high-speed running over 300-s (~3 $\text{m}\cdot\text{min}^{-1}$). Greater worst-case
18 scenario total and high-speed distances were elicited during wins (~7.3-11.2 $\text{m}\cdot\text{min}^{-1}$ and ~2.7-7.9
19 $\text{m}\cdot\text{min}^{-1}$, respectively) and losses (~2.7-5.7 $\text{m}\cdot\text{min}^{-1}$ and ~1.4-2.2 $\text{m}\cdot\text{min}^{-1}$, respectively) versus draws,
20 whilst time-of-day and playing formation influenced worst-case scenario high-speed distances only.

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

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

26 **Introduction**

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

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

50 Rolling averages have been employed to assess WCS within a number of team-sports, typically over
51 durations of 10-s to 10-min.⁶ Knowing the WCS associated with their specific competitive environment
52 may be useful for practitioners when monitoring training intensity relative to the highest demands that

53 a player may be expected to face. Notably, although positional variation has been observed,¹⁰ no study
54 to date has directly compared WCS between starting and substitute players. Likewise, limited literature
55 has considered the influence of other contextual factors (e.g., match result, location, or playing
56 formation) which have previously been found to influence running patterns during professional soccer
57 match-play.^{5, 12, 13} Therefore, the aim of this investigation was to compare the fixed epoch and rolling
58 average methods of quantifying duration-specific WCS running demands of English Championship
59 soccer players over epochs ranging from 1-min to 10-min. A secondary objective was to assess the
60 influence of a number of contextual variables on the WCS observed.

61

62 **Methods**

63 Following approval from Swansea University Ethics committee (2018-107), 25 professional outfield
64 players (age: 25 ± 4 years, stature: 1.80 ± 0.08 m, body mass: 75.0 ± 7.6 kg) from an English
65 Championship soccer club were monitored during 28 matches within the 2018/2019 season, yielding
66 347 individual player observations (14 ± 9 observations·player⁻¹, range: 1-26 observations·player⁻¹). The
67 sample comprised central defenders (CD), wide defenders (WD), central midfielders (CM), central
68 defensive midfielders (CDM), wide midfielders (WM), and central (CA) and wide (WA) attackers, who
69 were in good health and injury free at the time of data-collection. All players were briefed about the
70 risks and benefits of participation before providing their written informed consent. Given the
71 observational nature of the study, no attempt was made to influence players' responses.

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

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

86 To account for the non-independence of data sampled from the same individuals across multiple
87 matches, linear mixed models were constructed to examine differences in WCS estimation as a function
88 of assessment method (i.e., FIXED or ROLL). In all models, random intercepts ('player' and 'match')
89 were included to allow for the 'nested' nature of data within individual players and matches. Initially,
90 to determine differences between ROLL and FIXED across the entire sample, separate models were run
91 for each dependant variable at every epoch duration (60-s to 600-s), with 'method' entered as a fixed
92 effect. Subsequently, to simplify the interpretation of any potential interaction effects, 'positional
93 group', 'playing position' and 'epoch length' were in turn entered as fixed effects, whilst 'method' was
94 specified as a covariate⁸. Attackers and CD were used as baseline references for the fixed effects of
95 positional group and playing position, respectively, whilst the baseline for epoch length was 600-s.
96 Using data from ROLL only, separate models were run for further covariates (i.e., 'time of day',
97 'location', 'match result', 'formation', and 'substitutes vs. starters'), to examine differences in WCS
98 between different levels of each (e.g., between home and away matches). Data are presented as mean \pm
99 standard deviation (SD), whilst magnitudes of change are demonstrated by effect estimates with 95%
100 confidence intervals (CI).

101

102 **Results**

103 For the whole-team analysis, effect estimates (Table 1) indicated that for all epoch lengths, FIXED
104 underestimated ROLL for both TD and HSR (all $p < 0.001$). Compared with attackers and irrespective

105 of the method used, midfielders (all $p < 0.001$) and defenders (all $p < 0.05$) experienced higher TD over
106 all epoch durations (Table 2). No interaction was observed (method*positional group) for TD at any
107 epoch duration, suggesting that positional group did not affect the between-method differences
108 observed. However, for HSR over 120-s, the increase from FIXED to ROLL was greater for attackers
109 compared with defenders ($p = 0.021$).

110

111 ****TABLE 1 HERE****

112

113 Epoch length influenced whole-team TD and HSR in both FIXED and ROLL, with a significant
114 interaction of epoch length*method observed for TD ($p < 0.001$). For both methods, TD was higher than
115 600-s across all epochs except for 540-s (all $p < 0.05$), whereas HSR in FIXED and ROLL was greater
116 than 600-s for all epoch lengths (all $p < 0.05$) .

117

118 ****TABLE 2 HERE****

119

120 As TD and HSR were consistently underestimated in FIXED, a further model was run using data from
121 ROLL only to examine differences in WCS between individual positions, using CD as a baseline
122 (Figure 1A, 1B). For TD, CDM and CM experienced higher demands than CD across all epoch
123 durations (all $p \leq 0.05$). Likewise, TD was greater for WD compared with CD during epochs less than
124 480-s in length, whilst WM had higher TD than CD over 60-s and 120-s epochs (all $p < 0.05$). For HSR,
125 each of CM, WM, and WD, returned higher values than CD across all epoch lengths, whilst WA and
126 CA performed more HSR than CD during 480-s, 540-s, and 600-s epochs (all $p < 0.05$). HSR for CDM,
127 and TD for CA and WA, remained similar to CD throughout.

128

129 ****FIGURE 1 HERE****

130

131 When considering ROLL only, starters demonstrated greater TD for all except for 60-s and 120-s
132 epochs, but smaller HSR values over 300-s (all $p < 0.05$), when compared with substitutes (Figure 1A,

133 1B). Compared with matches drawn, wins elicited more TD for all epoch durations and greater HSR
134 for 60-s and 420-s to 600-s epochs, whilst losses produced higher TD for epochs of 300-s to 600-s
135 (Figure 1A, 1B). Wins also elicited higher TD for 60-s and 540-s epochs, compared with losses (all
136 $p<0.05$). Neither TD nor HSR were influenced by match location, but more HSR was performed during
137 epochs of 240-s to 540-s when matches started at 17:30 h compared with matches that started at 15:00
138 h (all $p<0.05$). Compared with a 4-1-4-1 playing formation, 3-5-2 produced lower HSR for 300-s to
139 600-s epochs, whilst 3-4-3 elicited less HSR during 360-s and 420-s epochs (all $p<0.05$).

140

141 **Discussion**

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

155 Knowledge of the WCS associated with competitive match-play provides practitioners with useful
156 information to help optimise training prescription. By better understanding the demands of the most
157 intense periods of play, practitioners can monitor training drills to ensure that players are exposed to
158 such intensities when appropriate, particularly during technical/tactical training.^{6, 16} The current study
159 observed WCS TD ranging from ~120-190 $\text{m}\cdot\text{min}^{-1}$, and WCS HSR of ~14-60 $\text{m}\cdot\text{min}^{-1}$, depending on

160 epoch duration. Whilst similar values have been reported in Australian A-League soccer,^{10, 11} the
161 potential influence of contextual factors such as team tactics or playing formation, means that
162 practitioners prescribing training based upon ‘match-speed’ may need to consider the WCS associated
163 with their specific team and/or competition.

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

174 A player’s starting status,¹⁹ match result,⁵ match location,²⁰ and playing formation,²¹ may each
175 independently influence the global (i.e., half or whole-match) demands associated with soccer match-
176 play. In the current study, wins and losses generally produced greater WCS TD and HSR compared
177 with draws; whilst for 60-s and 540-s epochs, WCS TD during wins exceeded that experienced during
178 losses. Moreover, WCS HSR over 240-s to 540-s epochs was higher during matches starting at 17:30 h
179 compared with those starting at 15:00 h. Winning and losing score-lines have each been linked to
180 heightened match demands,^{5, 12, 13} with this relationship potentially dependent upon playing position.⁵

181 In addition, diurnal variations in physiological and performance responses have been identified amongst
182 male soccer players, with peak values for body temperature and indices of soccer-specific physical,
183 mental, and technical performance, observed between 16:00-20:00 h.^{22, 23} Although running intensity
184 may be affected by a complex interaction of technical, tactical, and physical factors,^{5, 13, 24} and thus the
185 precise reasons for these responses remain unclear, our observations extend existing research to
186 highlight contextual influences on WCS demands during professional soccer match-play. It will be

187 important for future studies to delve deeper into each of these contextual factors, to explore the
188 relationships between different variables and elucidate the mechanisms underpinning their influence.
189 Notably, the fact that a 4-1-4-1 playing formation elicited greater WCS HSR than 3-5-2 for 300-s to
190 600-s epochs, and more WCS HSR than 3-4-3 during 360-s and 420-s epochs, further highlights the
191 role of team tactics in modulating match demands; perhaps underlining the need for a population-
192 specific approach to training prescription.

193 Players who started a match recorded greater WCS TD for all except for 60-s and 120-s epochs, when
194 compared with substitutes. Such findings seem surprising given that starting players may adopt
195 conscious or subconscious self-pacing strategies which reduce their physical outputs in an effort to
196 preserve energy throughout the course of match.^{5, 25} Indeed, the limited literature currently existing in
197 relation to partial-match soccer players appears to suggest that substitutes entering the pitch at half-time
198 or later typically achieve higher relative running distances, compared with whole-match players and/or
199 those being replaced.¹⁹ However, it is well established that the ~15-min following kick-off typically
200 represents the most intense period of a match.¹ Whilst substitutes may also demonstrate heightened (i.e.,
201 relative to the remainder of their playing bout) physical responses immediately upon entering the
202 pitch,¹² it is possible that tactical considerations¹² or the influence of contextual factors such as the
203 presence of accumulated fatigue in surrounding players (i.e., those on the same and/or opposing team),
204 may affect substitutes' ability to 'get into the game' and thus limit the relative running distances that
205 they are able to achieve.^{19, 24, 26} That said, substitutes in the current study performed ~15% more HSR
206 over 300-s compared with players who started a match. As the reasons underlying such responses
207 remain unclear, future research into the WCS demands experienced by partial-match soccer players will
208 be important to elucidate the potential influence of playing time, match score-line, and/or other
209 contextual variables; allowing practitioners to achieve greater specificity when prescribing training for
210 this bespoke population (e.g., during 'top-up conditioning sessions).

211 Consistent with observations from a range of team sports,⁶ WCS running demands generally decreased
212 (i.e., in relative terms) as epochs increased in duration from 60-s to 600-s. Although the causes of such
213 declines cannot be identified from movement data alone, this relationship may be useful for

214 practitioners when prescribing training drills of differing lengths. For example, based upon the current
215 data, a 1-min training activity may require players to achieve $\sim 190 \text{ m}\cdot\text{min}^{-1}$ to reflect 100% of ‘match-
216 speed’, whereas an intensity of $\sim 130 \text{ m}\cdot\text{min}^{-1}$ may be appropriate for drills of 5-min in length (Table 2).
217 It should be noted that whilst WCS demands were influenced by epoch duration, practical and/or
218 logistical considerations mean that small variations are unlikely to influence training prescription in an
219 applied team-sport scenario.^{8, 27} Although research in professional rugby league has proposed that
220 differences in relative running intensity of $\geq 10 \text{ m}\cdot\text{min}^{-1}$ (e.g., between epochs of differing lengths) may
221 reflect real-world significance,²⁷ practitioners must consider what they deem to be an appropriate
222 threshold in their specific circumstances (e.g., based upon population, access to resources, etc.).

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

235

236 **Conclusion**

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

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

245

246 **Practical implications**

- 247 • Fixed epochs underestimated rolling averages by ~7-10% for worst-case scenario total distance,
248 and ~12-25% for high-speed running distance. Such findings suggest that rolling averages may
249 be a more appropriate method of assessing the worst-case scenario movement demands of
250 professional soccer.
- 251 • Worst-case scenario relative total and high-speed running distance ranged from ~120-190
252 $\text{m} \cdot \text{min}^{-1}$ and ~14-60 $\text{m} \cdot \text{min}^{-1}$, respectively, with relative running demands being influenced by
253 a range of contextual factors and decreasing as epochs increased in duration.
- 254 • Whilst other physical and technical activities should also be considered, knowledge of worst-
255 case scenario demands may help to design specific training programmes that prepare players
256 for the most intense periods of match-play.
- 257 • These data suggest that for the current population, covering ~190 $\text{m} \cdot \text{min}^{-1}$, and/or performing
258 ~60 $\text{m} \cdot \text{min}^{-1}$ of high-speed running, may be an appropriate target for a 1 min training activity
259 conducted at ‘peak match intensity’.

260

261

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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 \pm 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	Team			Defenders			Midfielders			Attackers		
length (s)	ROLL	FIXED	% Diff	ROLL	FIXED	% Diff	ROLL	FIXED	% Diff	ROLL	FIXED	% Diff
TD (m·min ⁻¹)												
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·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.

