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Title: Assessing the whole-match and worst-case scenario locomotor demands of international women's rugby union match-play

Running head: Locomotor demands of international women's rugby

Abstract

Objectives: To profile the distances covered during international women's rugby union match-play and assess the duration-specific worst-case scenario locomotor demands over 60-s to 600-s epochs, whilst comparing the values determined by fixed epoch (FIXED) versus rolling average (ROLL) methods of worst-case scenario estimation and assessing positional influences.

Design: Descriptive, observational.

Methods: Twenty-nine international women's rugby union players wore 10 Hz microelectromechanical systems during eight international matches (110 observations). Total, and per-half, distances were recorded, whilst relative total and high-speed (>4.4 m·s^{-1}) distances were averaged using FIXED and ROLL methods over 60 to 600-s. Linear mixed models compared distances covered between match halves, assessed FIXED versus ROLL, and examined the influence of playing position.

Results: Players covered ~5.8 km·match^{-1}, with reduced distances in the second- versus first-half ($p<0.001$). For worst-case scenario total (~8-25%) and high-speed (~10-26%) distance, FIXED underestimated ROLL. In ROLL, worst-case scenario relative total and high-speed distances reduced from ~144-161 m·min^{-1} and ~30-69 m·min^{-1} over 60-s, to ~80-89 m·min^{-1} and ~5-16 m·min^{-1} in the 600-s epoch, respectively. Forwards performed less high-speed running over all epochs and covered less total distance during epochs of 60-s, 180-s, 420-s and 480-s, compared with backs. Front row players typically returned the lowest locomotor demands.

Conclusions: This is the first study reporting the positional and worst-case scenario demands of international women's rugby union, and indicates an underestimation in FIXED versus ROLL over 60-s to 600-s epochs. Knowledge of the most demanding periods of women's rugby union match-play facilitates training specificity by enabling sessions to be tailored to such demands.

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

Introduction

Rugby union (RU) is an intermittent team sport, characterised by repeated bouts of high-intensity activity (including high velocity collisions) interspersed with periods of reduced intensity and rest.[1] Whilst ~85% of a match may be low-intensity and/or passive in nature, anaerobically-demanding tasks, such as sprinting, tackling, scrummaging, rucking, and mauling, represent crucial facets of the game.[1] Knowledge of match demands is vital for applied practitioners when preparing athletes for the rigours of competition.[2, 3] Therefore, player monitoring using commercially available microtechnology devices incorporating Global Positioning Systems (GPS) is now commonplace within high-level team-sports. These technologies provide a valid, reliable, and practical method of quantifying players' external loads during high-intensity exercise such as training and match-play.[2, 4, 5]

The demands of men's RU have been extensively characterised, with elite players typically covering ~5-7 km·match^{-1}.[6-8] Notably, positional differences have been observed, whereby backs cover the greatest total (TD) and high-speed running (HSR) distances, whilst forwards are more involved with contacts and/or activities involving static exertion.[6-8] Although comparable research in international women's RU is limited, particularly with regards to potential positional variation, similar whole-match movement profiles (i.e., ~5-7 km·match^{-1}) have been reported.[9] However, whilst this information is useful to indicate the overall loads experienced, reporting players' responses across a whole-match or whole-half basis may not accurately reflect the heightened demands associated with certain phases within a match.[9-11] Indeed, understanding the demands experienced during the most intense periods of play (i.e., 'worst-case scenario'; WCS) may facilitate the design of specific training programmes that better prepare players for these potentially decisive moments of a game.[2, 3, 10]

In an effort to determine the most intense periods, researchers often divide team sport matches into shorter (e.g., 5-15-min) fixed epochs.[12-14] Whilst pacing strategies may differ between sports,[15] such investigations have observed transient fluctuations in movement demands throughout the course of a match. For example, in the only previous study to have quantified the demands of international women's RU via wearable microtechnology, players covered the greatest TD during the first (i.e., 0-10-min) and last (i.e., 70-80-min) 10-min periods of a match.[9] However, because events in team sports are unlikely to fall neatly within pre-defined time-periods, the use of fixed epochs may underestimate the demands elicited during the most intense passages of play.[2, 3, 16] Indeed, in international men's RU, fixed epochs have underestimated WCS by up to ~21%, compared with when rolling averages were employed.[3]

Due to a potential loss of sampling resolution when using fixed time-periods,[3] recent research has assessed WCS using rolling averages, typically over epochs ranging from 10-s to 10-min.[2, 3, 10] In international men's RU, WCS TD of ~154-184 $m \cdot min^{-1}$ and WCS HSR of ~43-70 $m \cdot min^{-1}$ have been observed over a 1-min period, with WCS decreasing (i.e., in relative terms) as epochs increased in length.[3, 10] However, research into the GPS-derived locomotor demands of international women's RU match-play is currently limited to a single study in which detailed positional analysis was not provided. Moreover, we are unaware of any investigation to have assessed the WCS of RU match-play within an elite women's population. Therefore, the aims of this research were a) to profile the distances covered during international women's RU match-play, and b) assess the duration-specific WCS locomotor demands over 60-s to 600-s epochs, whilst comparing the fixed epoch (FIXED) versus rolling average (ROLL) methods of WCS estimation. In both cases, positional differences were investigated.

Methods

Following approval from Swansea University Ethics committee (2018-104), international women's RU players (*n* = 29, age: 24 ± 3 years, stature: 1.67 ± 0.04 m, body mass: 75.3 ± 10.8 kg) were monitored during eight international matches within the 2018/2019 season. All players were in good health and injury free at the time of data-collection, and 110 individual player observations (4 ± 3 $obervations \cdot player^{-1}$, range: 1-8 $obervations \cdot player^{-1}$) were yielded. Data related only to individuals completing ≥60 min of match-play in any given instance.[11] Players were classified as forwards (*n* = 15) or backs (*n* = 14), and further grouped into front row (*n* = 6), second row (*n* = 3), back row (*n* = 6), half-back (*n* = 4), centre (*n* = 6) and back three (*n* = 4) positions. All players were briefed about the risks and benefits of participation before providing their written consent in advance of data collection. Given the observational nature of the study, no attempt was made to influence players' responses.

Players' movements were captured by microelectromechanical systems (MEMS) incorporating GPS (10 Hz; Optimeye S5, Catapult Sports, Melbourne, Australia), which were located on the upper back between the scapulae and worn underneath the playing jersey within a vest designed to minimise movement artefacts. All players were accustomed to this form of monitoring, and individuals wore the same devices 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,[4] and good accuracy in determining TD (typical error as CV%: 1.9) and HSR (CV%: 4.7) during team sport-specific exercise.[5]

The devices were activated according to the manufacturer's guidelines and prior to the pre-match warm-up; raw data files were exported post-match using proprietary software (Openfield version 1.22.0, Catapult Sports, Melbourne, Australia). Whole-match and whole-half TD was derived directly from the software and raw data files were also processed using a bespoke analysis programme, whereby epochs were specified in 60-s increments, as per previous studies,[3] to produce FIXED and ROLL periods ranging from 60-s to 600-s. The locomotor variables profiled for this analysis were TD and HSR (defined as distance covered at speeds >4.4 $m \cdot s^{-1}$, a threshold representing approximately 60% of the average maximum running velocity across the squad). To allow comparison between epochs of differing duration, variables were expressed relative to epoch length (i.e., $m \cdot min^{-1}$).

Due to the nesting of data sampled from repeated observations of individuals across multiple matches, linear mixed models with random intercepts ('player' and 'match') were used to determine differences in WCS estimation as a function of method (i.e., FIXED vs. ROLL), and to assess the influence of unit (i.e., forwards vs. backs) and playing position (i.e., front row vs. second row, back row, half-back, centre, and back three) on overall and WCS demands. Whole-half TD was also compared between the first- and second-half. With regards to overall TD, separate models were constructed to include 'half' (i.e., first-half vs. second-half), 'unit', and 'position' as fixed effects. For the fixed effect of position, FR was used as the baseline for comparison.[3] To determine differences in WCS estimation between FIXED and ROLL, models were run for TD and HSR for each epoch (i.e., 60-600s), with 'method' specified as a fixed effect. Further models were constructed in which first 'unit' and then 'position' were in turn entered as fixed effects, whilst 'method' was included as a covariate.[3] Lastly, as ROLL consistently displayed greater TD and HSR compared with FIXED, a final set of models examined positional differences in WCS (i.e., 'position' as a fixed effect) considering data from ROLL only. Analyses were conducted using IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp, α was set at 0.05, and data are presented as mean ± standard deviation unless otherwise stated.

Results

Overall TD was similar between forwards and backs, with players covering 5784 ± 569 $m \cdot match^{-1}$. Reductions from first- to second-halves were observed for the whole team (2984 ± 312 m vs. 2797 ± 358 m, $p < 0.001$), forwards (2896 ± 336 m vs. 2719 ± 326 m, $p = 0.006$), and backs (3060 ± 272 m vs. 2865 ± 376 m, $p = 0.012$). No differences were observed between forwards and backs for either match half. Across a whole match, front row players covered less TD than all other positions, whilst front row covered less first-half TD than all except for second row, and less second-half TD than all positions except for half-backs (all $p \leq 0.05$).

With regards to WCS, FIXED underestimated ROLL ($p < 0.001$) for TD and HSR, irrespective of epoch (Tables 1 & 2). This was the case for the whole team, forwards, and backs (Table 2). Forwards consistently returned lower HSR values, and covered less TD during 60-s, 180-s, 420-s and 480-s epochs (all $p < 0.001$), compared with backs (Table 2). Whilst no interaction effects (unit*method) were observed for TD, significant interactions ($p \leq 0.05$) existed for HSR over 360-s, 480-s, 540-s and 600-s. For these epochs, effect estimates highlighted that backs experienced a greater increase in HSR from FIXED to ROLL, compared with that demonstrated by forwards.

****INSERT TABLE 1 HERE****

****INSERT TABLE 2 HERE****

When positional variation was assessed, fixed effects demonstrated a significant main effect of position for both dependant variables at each epoch duration ($p < 0.001$), indicating between-position differences in WCS TD and HSR, irrespective of epoch length or assessment method. Considering data from ROLL only (Figure 1), half-back and back three positions covered more TD than the front row at all epoch durations, and centres surpassed the TD of front row players for all except 240-s and 480-s epochs. In addition, second row returned greater TD values than front row during 60-s, 120-s, 300-s, and 360-s epochs, whilst TD for back row positions exceeded that of front row players over 60-s and 120-s epochs only (all $p \leq 0.05$). All positions performed more HSR than the front row at all epoch durations ($p \leq 0.05$).

****INSERT FIGURE 1 HERE****

Discussion

This study reported overall TD and assessed the duration-specific WCS locomotor demands of international women's RU match-play over epochs ranging from 60-s to 600s, while also comparing the FIXED versus ROLL methods and assessing positional influences. In line with previous reports,[9] TD of ~5.6-6.1 km·match^{-1} broadly reflected the values of elite men's RU match-play,[6-8] whilst significant between-half declines were also observed. Similarly, as has been the case across a range of team sports,[2, 3, 16] WCS TD and HSR were underestimated in FIXED across all epochs assessed when compared with ROLL. Specifically, FIXED underestimated WCS TD by ~8-25% and HSR by ~10-26% depending on epoch length and playing position. Although this discrepancy for HSR broadly parallels data from international men's RU over epochs of 60-s to 300-s,[3] the underestimation of WCS

TD demonstrated considerably greater variability than, and at times exceeded, the values of ~10-13% reported previously.[3] Whilst the latter observation may be attributable to various match-specific contextual factors, the 300-s epoch in the current study demonstrated substantially greater underestimation of WCS TD compared with all other epochs (i.e., ~23-25% vs. ~10-15%). Given such underestimations, this study builds upon existing research by highlighting that rolling averages may be a more appropriate method of quantifying WCS in international women's RU, compared with fixed epochs.

To our knowledge, this is the first investigation to assess WCS locomotor demands and to highlight positional variation with regards to women's RU match-play. Depending upon playing position and epoch duration, WCS TD of ~80-161 $m\cdot min^{-1}$ were observed. Unsurprisingly, these values are substantially higher than the average speeds (i.e., <70 $m\cdot min^{-1}$) recorded over the full duration of a match, and also exceed the ~73 $m\cdot min^{-1}$ previously reported during the opening 10-min of competition.[9] In addition to allowing practitioners to design and monitor training drills to ensure that players are exposed to such intensities when necessary, particularly during technical/tactical training,[2, 17] , these insights may enable the formulation of tailored recovery strategies based upon the highest demands experienced during match-play.

As with observations in men's RU,[2, 3, 10] WCS generally decreased in relative terms as epochs increased in length between 60-s to 600-s. Knowledge of this relationship allows practitioners to determine the appropriate running intensity when prescribing training drills of differing lengths. For example, based upon the data in Table 2, ~154 $m\cdot min^{-1}$ may represent an appropriate intensity target for 1-min training activity conducted at WCS speed. It should be noted, however, that whilst WCS may be influenced by factors such as playing position and epoch duration, logistical/practical considerations mean that small variations are unlikely to influence training prescription in an applied rugby scenario.[3, 18] Although research in men's rugby league has suggested that a difference in WCS of ≥10 $m\cdot min^{-1}$ may reflect 'real-world' significance,[18] practitioners should decide upon an appropriate threshold in their own specific circumstances (e.g., depending upon the sport, playing population, session aims, access to resources, etc.).

Whilst this study confirms that women may cover similar absolute TD throughout 80-min of international RU match-play compared with men,[7, 9, 19] the current findings suggest that the similarities may not extend to WCS. Indeed, WCS TD of ~143-161 $m \cdot min^{-1}$ over a 60-s period falls below the ~154-184 $m \cdot min^{-1}$ reported in international men's RU, a statement which holds across all positions and epoch lengths (i.e., 60-s to 600-s).[3, 10] Notwithstanding, the absolute difference in WCS TD between men's and women's players appears less for forwards compared with backs.[3] Whilst any explanation of the reasons underlying this observation remains speculative, it seems plausible that marked differences in tactical roles between forwards and backs may have been influential. Indeed, due to their increased involvement in contact and the amount of time spent in close proximity to other players,[6, 9, 19] forwards' running demands may be limited primarily by a lack of space and/or opportunity to cover ground. Conversely, because backs typically operate in more space, there may exist greater opportunity for additional factors, such as physiological differences between men and women or inherent differences in playing style, to exert an influence. Comparison of women's and men's WCS HSR is made difficult by disparities in the thresholds used to denote HSR. Whereas in the men's game, HSR is typically defined as moving at speeds >5 $m \cdot s^{-1}$,[3] the current study employed a HSR threshold of 4.4 $m \cdot s^{-1}$. This represented approximately 60% of the average maximum running velocity across the squad, and falls within published guidelines for HSR categorisation in women's sport.[20, 21] Notwithstanding, values for WCS HSR in the current study fall below those reported from international men's RU.[3]

As noted, forwards and backs assume vastly different tactical responsibilities. Whereas backs primarily use possession or defensive actions to gain territory, a forward's principal function is to contest possession through rucks, mauls, and set-pieces.[6] Indeed, over the course of a whole match, forwards typically cover less TD and HSR compared with backs.[6, 9, 22] Although this was not the case for whole-match or whole-half TD in the current study, WCS did differ between these groups. Whilst this observation is both useful and novel, it is important to note that forwards are typically heavier, involved in more contacts, and spend longer under static exertion.[6, 9, 19] Indeed, it has been suggested that when contacts and static exertion are accounted for, forwards may perform more overall 'high-intensity activity' during a match, than backs.[22] Such reports highlight the potential importance of future research considering additional physical performance indictors (e.g., collisions, acceleration metrics, etc.) beyond purely locomotor activities, when seeking to quantify the demands of RU training and/or match-play.

In general terms, front row players returned the lowest overall and WCS demands of any position. These findings reflect reports in which men's players occupying 'tight five' positions experienced the lowest WCS, irrespective of epoch length.[10] Whilst the precise reasons remain unclear, frequent involvement in static activities such as scrums, rucks, and mauls,[6] in addition to the close proximity of other players, may somewhat explain these observations. Moreover, the increased body mass of front row players compared with those in other positions, coupled with a greater emphasis on non-running activities during training, may also have contributed.[1] Notably for practitioners, the fact that front row responses differed significantly from those of other forward positions supports a position-specific approach when prescribing training intensities based upon match running demands.

Although this study has presented novel information with regards to the whole-match and WCS locomotor demands of international women's RU, these data relate only to TD and HSR. Further research investigating WCS in relation to additional variables, such as collision and/or acceleration-based metrics would provide valuable insight into the 'true' demands experienced,[10, 17, 23] and may highlight further key distinctions between positions. Similarly, RU is a sport in which the execution of technical skills may be fundamental to team success.[24, 25] Incorporating video/technical analysis alongside microtechnology data would be useful to elucidate the relationships between physical and technical demands, and thus assist in the integration of physical and technical training within the preparation programme.[26] Finally, research comparing match demands between international and domestic women's RU, may help to prepare players for the higher standard of play.

Conclusion

This study reported whole-match TD and compared FIXED with ROLL for determining WCS TD and HSR during international women's RU match-play. Players covered ~5.8 km·match^{-1} , with TD decreasing from the first- to second-half. Irrespective of epoch length or playing position, FIXED significantly underestimated WCS compared with ROLL. Forwards generally experienced lower WCS locomotor demands than backs, but covered similar whole-match and whole-half TD. In relative terms, WCS decreased as epochs increased in length, whilst the lowest overall and WCS values were typically observed for front row positions. These position- and duration-specific locomotor demands provide valuable information for prescribing and monitoring training loads, as practitioners can ensure that all players are exposed to appropriate stimuli over any given time-frame. Future research which includes a range of physical and technical performance metrics, and/or considers the influence of additional contextual factors (e.g., the responses of substitutes), may provide further valuable insight.

Practical Implications

- International women's rugby union players covered ~5.1-6.1 km·match^{-1}, depending upon playing position, with reductions observed from first-half to second-half.
- Worst-case scenario relative total and high-speed running distance ranged from ~80-161 m·min^{-1} and ~5-69 m·min^{-1}, respectively, depending upon playing position and epoch length.
- Irrespective of method, worst-case scenario relative running demands decreased as epoch duration increased between 60-s and 600-s.
- Backs experienced greater worst-case scenario demands, but similar whole-match and whole-half locomotor demands compared with forwards, whilst front row players returned the lowest whole-match and worst-case scenario values of any position. These data may be useful to inform position-specific training prescription.

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Legends

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, forwards, and backs, with percentage differences between methods

Figure 1: Rolling average-derived worst-case scenario total distance (panel A) and high-speed running distance (panel B) by playing position

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

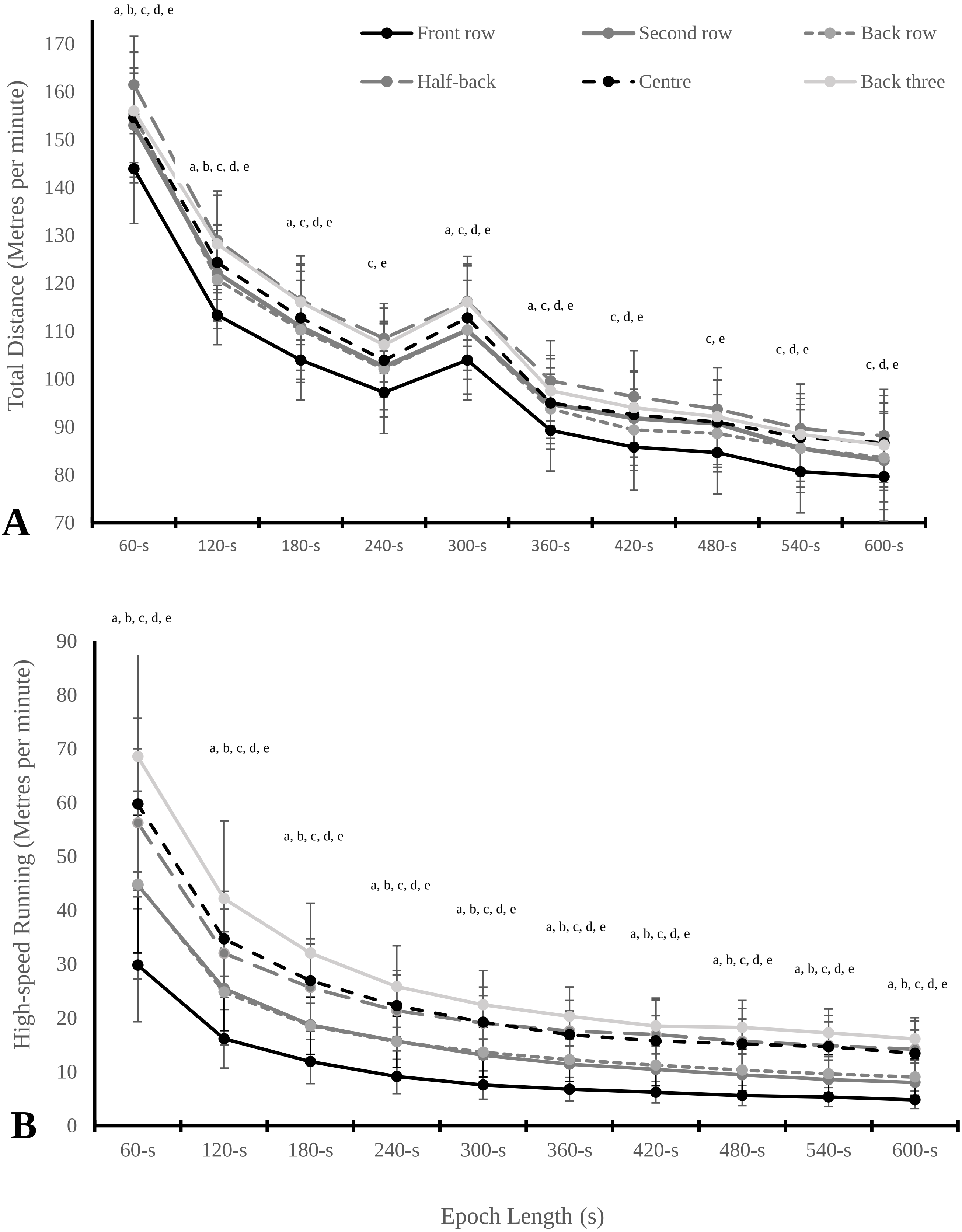
Epoch length (s)	Effect Estimate (m·min^{-1})	t	Sig.	95% Confidence Interval (m·min^{-1})	
				Lower Bound	Upper Bound
TD					
60	-16.98	-16.98	<0.001	-18.96	-15.00
120	-10.36	-16.30	<0.001	-11.62	-9.10
180	-11.48	-16.77	<0.001	-13.83	-10.12
240	-10.20	-17.72	<0.001	-11.35	-9.07
300	-21.08	-32.15	<0.001	-22.38	-19.78
360	-8.16	-13.61	<0.001	-9.35	-6.97
420	-6.46	-16.40	<0.001	-7.24	-5.68
480	-9.82	-18.40	<0.001	-10.87	-8.76
540	-8.07	-14.82	<0.001	-9.14	-6.99
600	-6.19	-13.77	<0.001	-7.08	-5.30
HSR					
60	-5.59	-7.52	<0.001	-7.07	-4.12
120	-4.03	-7.74	<0.001	-5.06	-2.99
180	-3.04	-7.88	<0.001	-3.81	-2.28
240	-2.23	-8.10	<0.001	-2.77	-1.68
300	-1.56	-9.27	<0.001	-1.89	-1.23
360	-1.92	-9.45	<0.001	-2.18	-1.51
420	-1.83	-10.24	<0.001	-2.18	-1.47
480	-1.47	-8.38	<0.001	-1.82	-1.12
540	-1.90	-9.14	<0.001	2.32	-1.49
600	-1.57	-8.54	<0.001	-1.95	-1.21

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

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

Epoch length (s)	Team			Forwards			Backs		
	ROLL	FIXED	% Diff	ROLL	FIXED	% Diff	ROLL	FIXED	% Diff
TD (m·min^{-1})									
60	153.5 ± 12.6*	136.5 ± 13.2	-12.9 ± 8.5	150.3 ± 13.1* [a]	131.7 ± 11.9 [a]	-14.5 ± 9.7	157.3 ± 11.1*	142.1 ± 12.4	-11.0 ± 6.7
120	122.6 ± 10.6*	112.2 ± 10.3	-9.5 ± 6.3	118.3 ± 9.6*	109.5 ± 11.0	-8.4 ± 6.4	127.5 ± 9.7*	115.3 ± 8.7	-10.8 ± 5.9
180	111.4 ± 10.4*	99.9 ± 9.0	-11.7 ± 7.6	108.0 ± 10.3* [a]	96.9 ± 98.5 [a]	-11.6 ± 7.0	115.4 ± 9.1*	103.5 ± 8.3	-11.8 ± 8.3
240	103.3 ± 9.2*	93.1 ± 10.1	-11.4 ± 7.3	100.3 ± 9.4*	90.6 ± 10.2	-11.2 ± 7.0	106.7 ± 7.7*	96.0 ± 9.2	-11.6 ± 7.8
300	111.3 ± 10.7*	90.2 ± 9.3	-23.7 ± 8.4	107.8 ± 10.8*	88.0 ± 9.3	-22.8 ± 7.8	115.3 ± 9.1*	92.8 ± 8.8	-24.8 ± 9.0
360	94.7 ± 8.5*	86.6 ± 8.8	-9.8 ± 8.1	92.3 ± 8.5*	84.6 ± 8.4	-9.4 ± 7.6	97.5 ± 7.7*	88.8 ± 8.7	-10.3 ± 8.7
420	91.3 ± 9.3*	84.8 ± 10.4	-8.0 ± 5.4	88.6 ± 9.2* [a]	82.0 ± 10.5 [a]	-8.5 ± 5.5	94.4 ± 8.5*	88.1 ± 9.5	-7.5 ± 5.2
480	89.9 ± 8.8*	80.0 ± 11.2	-13.1 ± 8.4	87.6 ± 8.8* [a]	77.2 ± 11.3 [a]	-14.4 ± 8.4	92.3 ± 8.2*	83.2 ± 10.3	-11.6 ± 8.2
540	86.0 ± 8.9*	77.9 ± 9.7	-10.9 ± 8.4	83.6 ± 8.8*	75.5 ± 9.3	-11.3 ± 9.0	88.7 ± 8.3*	80.6 ± 9.4	-10.4 ± 7.6
600	84.2 ± 9.7*	78.0 ± 9.5	-8.2 ± 6.6	81.9 ± 9.6*	76.0 ± 9.5	-8.1 ± 6.4	86.9 ± 9.2*	80.4 ± 8.9	-8.3 ± 6.8
HSR (m·min^{-1})									
60	50.0 ± 20.5*	44.4 ± 18.5	-14.6 ± 19.7	39.0 ± 15.0* [a]	33.5 ± 12.8 [a]	-17.8 ± 22.3	62.7 ± 18.6*	56.9 ± 16.1	-11.0 ± 15.6
120	28.9 ± 13.1*	24.9 ± 10.7	-16.9 ± 20.0	21.6 ± 8.7* [a]	18.5 ± 7.0 [a]	-17.8 ± 21.1	37.3 ± 12.3*	32.3 ± 9.3	-15.9 ± 18.8
180	22.0 ± 10.0*	18.9 ± 8.6	-17.7 ± 21.3	16.0 ± 6.3* [a]	14.1 ± 5.8 [a]	-15.6 ± 20.8	28.9 ± 8.9*	24.5 ± 8.0	-20.1 ± 21.8
240	18.0 ± 8.4*	15.8 ± 7.5	-15.3 ± 19.5	13.1 ± 5.8* [a]	11.7 ± 5.1 [a]	-12.8 ± 19.6	23.6 ± 7.3*	20.4 ± 7.1	-18.1 ± 19.2
300	15.5 ± 7.4*	14.0 ± 7.0	-13.0 ± 15.4	11.1 ± 5.1* [a]	10.0 ± 4.9 [a]	-13.5 ± 17.4	20.6 ± 6.2*	18.6 ± 6.1	-12.3 ± 13.0
360	14.0 ± 6.5*	12.0 ± 5.7	-16.7 ± 17.6	9.9 ± 4.4* [a]	8.8 ± 4.1 [a]	-14.3 ± 17.1	18.6 ± 5.4*	15.8 ± 5.0	-19.5 ± 18.0
420	12.9 ± 6.3*	11.1 ± 5.5	-18.1 ± 18.8	9.1 ± 4.1* [a]	7.8 ± 3.6 [a]	-18.4 ± 20.3	17.3 ± 5.5*	14.9 ± 4.8	-17.8 ± 17.1
480	12.2 ± 6.3*	10.7 ± 5.4	-13.5 ± 15.3	8.3 ± 3.9* [a]	7.6 ± 3.5 [a]	-9.8 ± 14.2	16.7 ± 5.3*	14.3 ± 4.9	-17.9 ± 15.5
540	11.5 ± 5.9*	9.6 ± 4.7	-19.8 ± 21.2	7.7 ± 3.5* [a]	6.8 ± 3.0 [a]	-14.6 ± 20.2	15.9 ± 4.9*	12.9 ± 4.2	-25.7 ± 20.8
600	10.7 ± 5.5*	9.1 ± 4.6	-17.1 ± 19.4	7.1 ± 3.4* [a]	6.2 ± 2.7 [a]	-14.1 ± 18.7	14.9 ± 4.5*	12.5 ± 3.9	-20.5 ± 19.9

% Diff: Mean percentage difference between methods within the same group (i.e., whole-team, forwards, or backs), FIXED: Fixed average method, HSR: High-speed running distance, ROLL: Rolling average method, TD: Total Distance, *: significantly different from ROLL within the same group at the $p < 0.001$ level, [a]: Significantly different from backs when using the same method at the $p < 0.001$ level.



[a]: Second row significantly different from front row, [b]: Back row significantly different from front row, [c]: Half-back significantly different from front row, [d]: Centre significantly different from front row, [e]: Back three significantly different from front row (all at the $p \leq 0.05$ level).

Figure 1: Rolling average-derived worst-case scenario total distance (panel A) and high-speed running distance (panel B) by playing position