A league-wide investigation into variability of rugby league match running from 322 Super League games

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Abstract

This study investigated sources of variability in the overall and phase-specific running match characteristics in elite rugby league. Microtechnology data were collected from 11 Super League (SL) teams, across 322 competitive matches within the 2018 and 2019 seasons. Total distance, high-speed running (HSR) distance (>5·5 $m \cdot s^{-1}$), average speed, and average acceleration were assessed. Variability was determined using linear mixed models, with random intercepts specified for player, position, match, and club. Large within-player coefficients of variation (CV) were found across whole match, ball-in-play, attack and defence for total distance (CV range = 24% to 35%) and HSR distance (37% to 96%), whereas small to moderate CVs (≤10%) were found for average speed and average acceleration. Similarly, there was higher between-player, -position, and -match variability in total distance and HSR distance when compared with average speed and average acceleration across all periods. All metrics were stable between-teams (≤5%), except HSR distance (16% to 18%). The transition period displayed the largest variability of all phases, especially for distance (up to 42%) and HSR distance (up to 165%). Absolute measures of displacement display large within-player and between-player, -position, and -match variability, yet average acceleration and average speed remain relatively stable across all match-periods.

Keywords: global positioning systems; physical performance; phase of play; variation; reliability

Introduction

Rugby league is characterised by its high-intensity running and collision elements, making it a physically demanding sport (Waldron et al., 2011). The external loads that players are exposed to during matches are commonly quantified through Global Positioning Systems (GPS) and Micro-Electro-Mechanical Systems (MEMS) microtechnology (Vanrenterghem et al., 2017). Specifically, the monitoring of match running (i.e. displacement measures including distances, speeds, or accelerations), rate of whole-body accelerations (e.g. accelerometer load), as well as collision counts, are commonly investigated variables in collision-based team sports (Johnston et al., 2014). However, these measures are likely subject to high variability, since rugby league match performance is the product of many different contextual factors such as situational, physical, technical, and tactical variables (Paul et al., 2015). It is important that the content and structure of the physical demands is known, as well as how these demands vary from match-to-match (Ward et al., 2018).

Within collision-based team sports, large variabilities are often observed for the high-intensity exercise domains, whilst total distance remains relatively stable (i.e. coefficient of variation [CV] <5%, Kempton et al., 2014). Kempton et al. (2015) found considerable match-to-match (within-player) variability in the Australian Football League (AFL) for high speed running (HSR >4 m·s^{-1}; CV range = 12% to 14%) and very high speed running (VHSR >5.5 m·s^{-1}; CV range = 15% to 21%). Kempton et al. (2014) also observed CVs of the same magnitude in the National Rugby League (NRL) for both HSR (>4.2 m·s^{-1}; CV = 15%) and VHSR (>5.8 m·s^{-1}; CV = 37%). These data outline the sensitivity of whole match displacement in the high-intensity domains, within their respective teams and contexts. It is unclear, however, whether their findings would be generalisable to the rest of their respective populations since only a single team was sampled in each study. Knowledge of the between-team variability for each of these measures would provide valuable information for practitioners looking to apply reference values given in research.

Whilst determining the whole match variability of certain measures is an important process, such metrics may have limited applicability for coaches wanting to assess the efficacy of training drills that are designed to replicate specific phases-of-play (Gabbett et al., 2014). Within international rugby league, Rennie et al. (2019) found substantial differences in displacement and collisions during attacking versus defensive phases-of-play for both forwards (e.g. average speed [$m \cdot min^{-1}$] = 24% lower in attack; collisions [$n \cdot min^{-1}$] = 60% lower in attack) and backs (e.g. average speed = 14% lower in attack; collisions = 20% higher in attack) (Rennie et al., 2019). Although these data represent the highest standard of competition, the sample was relatively small (observations = 72) and only reflect a single international rugby league team. It is therefore uncertain whether these findings are generalisable to domestic rugby league competition, such as the Super League (SL) or NRL. Importantly, it is also currently unknown just how much these measures vary between-matches. This type of variability data is important for determining statistical power in research as well as how worthwhile an intervention is (Gregson et al., 2010). Such data may also assist practitioners in interpreting what a meaningful between-match change in displacement is (Batterham & Hopkins, 2006).

League-wide microtechnology deals between sporting technology companies, National Governing Bodies (NGB), and clubs means that monitoring large sample sizes over extended periods of time is now possible. Such data presents a unique opportunity to quantify the between-team variability of commonly used displacement metrics, which has not been previously possible. Therefore, our primary aim was to identify the within-player and between-player, -position, -match, and -team variability across whole match, ball-in-play, and phases-of-play (i.e. attack, defence, and transition) within the SL. Also, in light of the recent rule changes made in the 2019 SL season "to introduce more speed and on-field drama for spectators" (Rugby Football League, 2019), our secondary aim was to compare match displacement between the 2018 and 2019 SL seasons.

Methods

Data Collection

Match displacement data were collected from the 2018 and 2019 SL seasons and included 380 male professional rugby league players registered in the first-team squads of 11 teams. Two SL teams were omitted due to not participating in both seasons. Matches were only included if they were competitive, SL matches. The Middle 8s phase of the 2018 season was excluded since SL teams competed against Championship sides. Initially, 323 matches from 2018 and 2019 were included, resulting in 9553 raw 10 Hz GPS files (2018 = 160 matches, 4786 raw files; 2019 = 163 matches, 4767 raw files). Following our data pre-processing steps outlined below, the final included observations were 7617 (2018 = 159 matches, 3941 observations; 2019 = 163 matches, 3676 observations). Players were also categorised according to their starting position during each match. Interchange players were instead categorised as their usual playing position for that match, since multiple interchanges are regularly made, and it is often unclear who they are replacing. Positions were therefore classified as fullbacks (n = 47, observations = 486), wingers (n = 87, observations = 934), centres (n = 83, observations = 947), halves (n = 75, observations = 998), props (n = 128, observations = 1659), hookers (n = 50, observations = 667), second-rows (n = 96, observations = 1160), and back-rows (n = 97, observations = 766).

Players' match displacement data were recorded with the same microtechnology device (Optimeye S5, Catapult Sports, Melbourne, Australia), containing a 10 Hz GPS. A representative member of each SL team's respective strength and conditioning or sports science staff were responsible for the collection of GPS data. The devices were initially distributed at the start of the 2018 preseason period (November 2017). To ensure consistency between club practices, the club practitioners were then advised to place the microtechnology devices in the match-day jersey during matches, as is common practice. All players were fully accustomed to wearing the units prior to the data collection period. The validity and reliability of these devices to measure displacement have been investigated previously (Varley et al., 2012).

Since no personal data were accessible by the research team, and only summary statistics are presented, written informed consent was not needed by each participant, thereby conforming with the United Kingdom Data Protection Act, *2018*. Ethics approval for the study was granted by Leeds Beckett University Ethics Committee.

Data preparation

Figure 1 describes our data flow including the steps involved in data preparation, data pre-processing, and statistical analyses. All steps were completed in R (version 3.6.2). For the calculation of displacement variables, raw doppler-derived speed and acceleration for each player were downloaded through Catapult's proprietary Application Programming Interface (API). To remove erroneous data within each file, sampling points within the speed and acceleration vectors were excluded according to previously identified criteria: number of connected satellites ≤10, Horizontal Dilution of Precision (HDOP) ≥1, velocity >10 $m \cdot s^{-1}$, acceleration >±6 $m \cdot s^{-2}$ (Rennie et al., 2019). Once removed, if the duration of consecutive missing data was <10 s then missing speed and acceleration data were imputed via linear interpolation (Rennie et al., 2019). We chose to extract total distance, average speed, HSR distance (>5 $m \cdot s^{-1}$), and mean absolute acceleration ($m \cdot s^{-2}$) (Delaney et al., 2016) from each raw GPS file to represent match displacement due to their common usage within rugby league (Cummins et al., 2013; Hausler et al., 2016; Whitehead et al., 2018). A timeline of individual player actions and match events were provided by Opta (Leeds, UK), and were used to stratify these displacement variables by overall match (i.e. whole match and ball-in-play) and phases-of-play (i.e. attack, defence, transition phases). Attacking and defensive phases were defined according to Opta, whilst transition phases were defined as the duration between a zero tackle or a kick in play, and the start of the following tackle count (Rennie et al., 2019).

Data pre-processing

Once the initial dataset was compiled, observations were then filtered for any of the following reasons; active on-field duration <20 minutes (observations = 278), poor signal quality (i.e. > 10% of the raw data filtered; observations = 1605), or removal of outliers through Tukey's Fences method (observations = 118). Twenty minutes was chosen as a conservative cut-off for the active on-field duration, as anything less than this was likely not representative of a normal playing time. The mean number of connected satellites and mean horizontal dilution of precision (HDOP) throughout the data collection period were 11.7 ± 0.5 and 0.7 ± 0.3, respectively.

Statistical Analyses

The distribution of each raw variable was initially explored through kernel density plots. Since a slight positive skew was observed in HSR distance, the median and quartile ranges (lower quartile [25%] and upper quartile [75%]) are reported for all descriptive statistics. Therefore, to reduce error arising from non-uniform residuals and to express variability as a percent standard deviation (SD; i.e. CV), all outcome measures were log-transformed prior to analysis and subsequently back-transformed post-analysis (Hopkins et al., 2009).

The between-player, -position, -match, and -team CVs were established for each displacement metric using a series of linear mixed models. A top-down model building strategy was adopted, whereby a fully specified model was initially used which included players nested within teams, and partially crossed with playing positions and match. Levels were stepwise removed either if the residual SD was reduced or if the model was improved through comparison of the Akaike Information Criterion (AIC) values (West, 2006). The remaining (i.e. residual) variability was then attributed to that of otherwise unexplained within-player variation. Differences in displacement between 2018 and 2019 seasons were also included as a fixed effect. The magnitude and direction of the difference were compared through effects sizes (ES) ± 90 confidence limit (CL) (Halsey et al., 2015), whereby the observed SDs (pooled within- and between-player SDs) were multiplied by thresholds of 0.2, 0.6 and 1.2 to anchor small, moderate and large differences (Batterham & Hopkins, 2006). Season was not considered as a random effect due to the limited levels of this variable (i.e. only two seasons).

Results

Descriptive match displacement data for overall (i.e. whole match and ball-in-play) and phases-of-play (i.e. attack, defence, and transition) are presented in Table 1A and Table 1B, respectively. Kernel density estimations for each raw displacement variable, including duration, are displayed in Figure 2 for each position.

Table 2 displays the within-player and between-player, -position, -match, and -team variability of match displacement metrics, including the raw SDs and CVs. We found large within-player variability across whole match, ball-in-play, attack and defense for absolute measures of displacement, which included total distance (CV range = 24% to 35%) and HSR distance (CV range = 37% to 96%). Within the same phases, the within-player CVs were small to moderate (i.e., CV <10%) for both average speed and average acceleration. Similarly, CVs for average speed and average acceleration also remained <10% for between-player, -position, -match, and -team and across all phases, aside from the transition phase. The between-player variability for total distance (CV range = 14% to 21%) and HSR distance (CV range = 22% to 50%) was high across all phases. The between-position variability was also high for total distance (CV range = 28% to 39%) and HSR distance (CV range = 55% to 125%) across all phases. We observed small to moderate between-match CVs for total distance in all phases (CV range = 4% to 8%) aside from transition, as well as high CVs for HSR distance in all phases (CV range = 14% to 51%). The random factor for team was dropped from the whole match distance, ball-in-play distance, and transition distance models, as well as the transition HSR distance model. The included between-team CVs were all small (i.e., CV ≤5%), aside from HSR distance in attack (CV; ±90% CI = 16.0; ±8.4%) and defense (CV; ±90% CI = 18.1; ±8.9%).

Comparisons between the 2018 and 2019 SL seasons are presented in Figure 3, including a forest plot of ES differences for each displacement variable stratified by whole match, ball-in-play, and phases-of-play. We found no substantial differences (i.e. ES <0.2) between seasons.

Discussion

For the first time, our study identified sources of variability in rugby league match displacement across whole match, ball-in-play, and phase of play from league-wide data across two seasons. This progresses previous research in rugby league, where relatively small samples (observations <300) have been used (Glassbrook et al., 2019). Therefore, rugby league practitioners can be confident in the precision of the normative values and variability data reported, and can use them in their planning and monitoring processes. Specifically, our data show large within- and between-player variability, as well as large between-position variability for total distance and HSR distance (>10% CV). Whereas average speed and average acceleration remained more stable across all phases, except transition. High CVs were particularly noticed in transition periods for all variables, aside from between-team HSR distance. A novel finding of our study was the lack of between-team variability across all phases and metrics, which has important implications for the generalisability of single-team studies regarding match running demands. Overall, these data can assist practitioners and researchers in interpreting real changes or differences in commonly used match displacement metrics.

Our findings show that higher running intensities had the highest CVs, which somewhat support previous work undertaken in rugby league (Kempton et al., 2014), rugby union (McLaren et al., 2016), AFL (Kempton et al., 2015), and soccer (Gregson et al., 2010). For example, the between-match CVs (i.e. the true match-to-match variability assuming all players were the same) ranged from 4% to 29% for total distance and 14% to 51% for HSR distance. However, the within-player variability (i.e. the true match-to-match variability assuming all match-related sources of variability were the same) of total distance during whole match (936 m [24%]) and ball-in-play (748 m [24%]) was much higher than those previously observed in rugby league for whole match only (3.6%, Kempton et al., 2014). This could be due to our playing time cut-off of 20 minutes versus 90% participation in a given period, as in Kempton et al. (2014). Whilst 20 minutes is more conservative, we deemed it to be a more ecologically valid cut-off. Any duration less than this was not considered representative of usual playing time, and any duration higher would filter out observations for interchanges. High within-player CVs for total distance and HSR distance were also observed across phases-of-play, and especially for transition periods (total distance = 115 m [42%]; HSR distance = 38 m [165%]). Conversely, when accounting for duration average acceleration and average speed remained relatively stable (≤10%) for all sources of variability and phases-of-play, apart from the transition phase. Such findings indicate that exposures to absolute measures of displacement from match-to-match will be inconsistent, but players may nonetheless self-regulate their speed irrespective of phase of play (Waldron et al., 2013).

As expected, there was large between-position variability for whole match, ball-in-play, and phases-of-play. This is likely attributed to key differences in positional roles. For example, the variability of HSR distance was 87% in attack. Whilst attacking the props will predominantly lead the carries within confined spaces, due to the 10 m defensive rule (Hausler et al., 2016). Conversely, the outside backs look to create and exploit space in much larger areas of the pitch meaning there is more opportunity to accumulate HSR (Hausler et al., 2016). The increased collision-rates completed by forwards (Johnston et al., 2019) also means they may take longer to recover between bouts. This random effect could also account for some differences in physical characteristics between positions, such as body composition, speed, and strength qualities (Gabbett et al., 2008). The differences between players within a given position may be captured by the between-player random effect. Indeed, the large between-player variability seen for total distance and HSR distance may be attributed to within-positional differences in attacking and defensive responsibilities, technical proficiencies, and physical characteristics (Johnston et al., 2014). Furthermore, not all teams may utilise their positions in the same way. A back-row, for example, is typically used as a middle but may be preferred as an edge by some coaches.

We found little variability between-teams, for total distance, average speed, and average acceleration in any phase, as well as HSR distance in whole match, ball-in-play, and transition (CV ≤5%). This is somewhat surprising given the expected differences in playing styles, tactical organisation, and team success or form. Nonetheless, this means practitioners and researchers investigating displacement in rugby league match play can be confident in using the presented reference values. Although it is still unclear whether these findings are generalisable to other rugby league competitions such as the NRL, given that differences were previously found between a SL and an NRL team in terms of match displacement (Twist et al., 2014). However, we did observe high between-team CVs for HSR distance across attacking (16%) and defensive (18%) phases. This suggests that the differences in match displacement between teams may be captured by the higher intensity efforts performed. This is likely due to the interaction with technical performance indicators such as line breaks, missed tackles, or offloads, which have shown to discriminate successful teams in the NRL (Woods et al., 2017). Indeed, previous literature indicates that more successful teams, defined by final ladder position, tend to record lower HSR distances than their less successful counterparts whilst differences in average speed are trivial (Kempton et al., 2017). Although the final ladder position may not accurately describe the state of the team at the time of the match, these results still indicate differences in HSR exist between teams.

Another important source of error may arise from technical variability, which may include any error from the microtechnology devices, differences in data filtering methods, or differences in software and firmware used. We took a number of steps to reduce this error which included a) all clubs being given the same microtechnology devices, b) all raw data being cut according to Opta timestamps, c) all raw data being post-processed using custom-built filters, and d) observations being removed if too much data (>10%) was lost due to poor signal. Whilst around 25% of the dataset was filtered, our number of observations (7617) still exceeded those previously reported in rugby league using microtechnology by almost 20-fold. Even so, an inherent limitation of our study is the potential error arising from the unknown inter- and intra-rater reliability of the Opta coders. Also, because we could not ensure that each player wore the same device throughout the data collection period, there may have been technical variability from the microtechnology devices (Buchheit & Simpson, 2017).

Despite the match-play rule changes in the 2019 season that were made "to introduce more speed and on-field drama for spectators" (Rugby Football League, 2019), we noted no meaningful differences in match displacement between seasons. The principal rule changes included the reduction in the number of maximum interchanges from 10 to 8, as well as the introduction of the ‘shot clock’, which reduces the allowed time between scrums (35 s), drop-outs (30 s), and kick-at-goal attempts (80 s) (Rugby Football League, 2019). This is a pertinent finding for NGBs and should have implications for future rule changes. Though it must be noted that the measures of speed used in our study may not represent “speed” as intended by the NGB, nor may it represent what spectators enjoy watching. Furthermore, our findings should not be used to interpret how rule changes affect players responses to match locomotor characteristics (i.e., the internal load). Future work should therefore seek to establish the key aspects of a match that comprise these latent constructs, in order to gain a full appraisal of the rule changes.

Conclusion

We found large variability between-players, -positions, and -matches for absolute displacement measures (i.e. total distance and HSR distance) across eleven teams and two seasons in the SL. However, relative displacement metrics that account for active match duration (i.e. average acceleration and average speed) remained as relatively stable metrics. Similarly, the large residual variability left over for total distance and HSR distance, interpreted as the true match-to-match variability, suggests these measures are sensitive to change and are affected by a multitude of unknown contextual factors. This is irrespective of the phase of play but is largest during transition phases. We also observed a notable lack of between-team variability for our identified metrics, aside from HSR distance whilst in attack and defence. Except HSR distance, the relatively small observed variability between-teams suggests that single team studies in the rugby league match running demands literature may be generalisable to other clubs. Finally, we noted trivial differences between 2018 and 2019 SL seasons, suggesting the effect of the 2019 rule change on match displacement was minimal.

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Figure Captions

Figure 1. Data-flow diagram, including 3 stages: (a) the data preparation stage involves feature extraction, (b) the data pre-processing stage involves cleaning the dataset, and (c) the statistical analyses stage involves extracting the variances (i.e. the CVs).

Figure 2. Continuous kernel density estimations for match displacement variables, stratified by phases-of-play. The dashed lines represent the median value within each distribution. Abbreviations: FB = Fullbacks, SRs = Second-rows, BRs = Back-rows.

Figure 3. Forest plot of ES (±90% confidence interval) differences between 2018 and 2019 SL seasons for common match displacement variables, stratified by whole match, ball-in-play, and phases-of-play. Abbreviations: HSR = High-Speed Running.

Table 1A. Match displacement, stratified by whole match and ball-in-play, for each positional group (median [lower quartile – upper quartile])

Phase	Variable	Fullbacks	Wingers	Centres	Halves	Props	Hookers	Second-rows	Back-rows
Whole match	Duration (min)	93.6 [89.6 - 97.3]	94.5 [90.2 - 97.4]	94.1 [90.3 - 97.3]	94.0 [89.6 - 97.3]	51.0 [41.4 - 60.4]	71.0 [54.7 - 89.4]	90.6 [84.4 - 95.4]	56.6 [48.1 - 64.6]
	Distance (m)	7943 [7626 - 8311]	7029 [6739 - 7403]	7137 [6812 - 7463]	7702 [7384 - 8017]	4073 [3282 - 4714]	6164 [4689 - 7465]	7039 [6402 - 7440]	4544 [3804 - 5190]
	Avg speed ($m \cdot min^{-1}$)	84.7 [80.7 - 89.4]	75.2 [71.0 - 79.4]	76.3 [72.7 - 80.3]	82.1 [78.4 - 86.3]	79.4 [75.4 - 84.6]	85.6 [80.1 - 89.8]	77.5 [73.6 - 81.3]	80.1 [75.2 - 85.7]
	HSR distance (m)	773 [657 - 896]	626 [543 - 733]	623 [539 - 715]	543 [453 - 632]	216 [168 - 274]	285 [215 - 372]	494 [414 - 575]	250 [191 - 322]
	Avg acceleration ($m \cdot s^{-2}$)	0.38 [0.35 - 0.40]	0.36 [0.33 - 0.38]	0.38 [0.36 - 0.41]	0.40 [0.37 - 0.43]	0.40 [0.37 - 0.43]	0.42 [0.39 - 0.44]	0.39 [0.37 - 0.42]	0.41 [0.38 - 0.44]
Ball-in-play	Duration (min)	57.5 [54.7 - 61.2]	57.7 [55.0 - 61.3]	57.8 [55.1 - 61.5]	57.5 [54.1 - 61.3]	31.6 [25.3 - 36.9]	44.5 [33.8 - 54.9]	55.8 [49.9 - 60.1]	34.4 [28.8 - 40.8]
	Distance (m)	6141 [5814 - 6547]	5240 [4912 - 5603]	5521 [5214 - 5872]	5955 [5629 - 6284]	3225 [2631 - 3779]	4906 [3756 - 5981]	5561 [4955 - 5930]	3615 [3025 - 4240]
	Avg speed ($m \cdot min^{-1}$)	107.5 [102.1 - 112.2]	91.0 [86.1 - 95.9]	95.4 [90.8 - 100.3]	103.8 [99.2 - 108.2]	103.7 [98.3 - 109.5]	111.6 [105.6 - 117.2]	100.1 [94.8 - 104.4]	105.0 [99.0 - 110.6]
	HSR distance (m)	717 [597 - 833]	569 [489 - 658]	577 [500 - 666]	507 [425 - 589]	210 [162 - 262]	268 [202 - 351]	470 [395 - 545]	239 [184 - 305]
	Avg acceleration ($m \cdot s^{-2}$)	0.52 [0.49 - 0.56]	0.47 [0.44 - 0.51]	0.53 [0.49 - 0.57]	0.55 [0.52 - 0.59]	0.58 [0.54 - 0.62]	0.60 [0.56 - 0.63]	0.55 [0.52 - 0.59]	0.59 [0.55 - 0.63]

Avg = average; HSR = High speed running

Table 1B. Match displacement, stratified by phases-of-play, for each positional group (median [lower quartile – upper quartile])

Phase	Variable	Fullbacks	Wingers	Centres	Halves	Props	Hookers	Second-rows	Back-rows
Attack	Duration (min)	23.5 [21.4 - 26.1]	23.7 [21.6 - 26.1]	23.7 [21.5 - 26.1]	23.7 [21.7 - 26.0]	12.6 [10.2 - 15.5]	17.5 [12.6 - 22.1]	22.1 [19.1 - 25.2]	14.3 [11.7 - 17.2]
	Distance (m)	2496 [2265 - 2754]	1942 [1780 - 2137]	1959 [1774 - 2146]	2333 [2142 - 2549]	1104 [887 - 1337]	1791 [1267 - 2278]	1826 [1557 - 2059]	1261 [1040 - 1524]
	Avg speed ($m \cdot min^{-1}$)	106.1 [100.6 - 112.0]	81.4 [76.4 - 87.6]	82.3 [76.9 - 88.7]	98.2 [93.1 - 103.6]	88.2 [82.1 - 94.2]	103.5 [96.8 - 108.7]	83.0 [77.0 - 88.3]	89.8 [83.7 - 96.8]
	HSR distance (m)	305 [253 - 382]	188 [147 - 248]	207 [164 - 254]	187 [135 - 243]	62 [43 - 88]	52 [26 - 79]	138 [108 - 185]	67 [47 - 95]
	Avg acceleration ($m \cdot s^{-2}$)	0.51 [0.47 - 0.56]	0.44 [0.40 - 0.48]	0.45 [0.41 - 0.49]	0.50 [0.45 - 0.54]	0.49 [0.45 - 0.54]	0.51 [0.46 - 0.55]	0.44 [0.40 - 0.48]	0.50 [0.45 - 0.54]
Defence	Duration (min)	23.6 [21.4 - 26.1]	23.8 [21.6 - 26.2]	23.7 [21.5 - 26.0]	23.6 [21.5 - 26.0]	12.5 [10.3 - 15.2]	17.0 [12.1 - 21.5]	21.7 [18.5 - 24.6]	13.7 [11.0 - 16.6]
	Distance (m)	2600 [2409 - 2871]	2169 [1999 - 2385]	2441 [2244 - 2640]	2566 [2357 - 2795]	1564 [1299 - 1872]	2139 [1538 - 2649]	2568 [2141 - 2895]	1692 [1359 - 2061]
	Avg speed ($m \cdot min^{-1}$)	110.8 [104.1 - 118.4]	91.5 [85.0 - 98.8]	103.4 [97.2 - 109.7]	110.0 [102.4 - 115.9]	125.8 [117.7 - 133.0]	126.6 [119.0 - 134.0]	118.3 [111.6 - 124.5]	125.5 [117.8 - 132.7]
	HSR distance (m)	216 [165 - 276]	93 [64 - 138]	110 [78 - 148]	113 [82 - 148]	54 [37 - 80]	82 [52 - 120]	107 [74 - 145]	62 [40 - 89]
	Avg acceleration ($m \cdot s^{-2}$)	0.47 [0.43 - 0.51]	0.49 [0.44 - 0.54]	0.61 [0.56 - 0.65]	0.61 [0.56 - 0.65]	0.69 [0.64 - 0.74]	0.70 [0.66 - 0.74]	0.68 [0.63 - 0.72]	0.70 [0.66 - 0.74]
Transition	Duration (min)	4.9 [3.8 - 5.9]	5.0 [3.8 - 6.0]	4.9 [3.9 - 6.0]	5.0 [3.8 - 6.0]	2.4 [1.7 - 3.2]	3.4 [2.3 - 5.0]	4.3 [3.3 - 5.4]	2.6 [1.9 - 3.7]
	Distance (m)	611 [505 - 720]	669 [566 - 780]	625 [534 - 741]	603 [497 - 716]	264 [195 - 346]	405 [295 - 541]	502 [401 - 617]	300 [227 - 393]
	Avg speed ($m \cdot min^{-1}$)	128.6 [109.6 - 142.3]	140.8 [120.4 - 158.0]	134.5 [114.2 - 148.4]	126.6 [109.1 - 143.3]	115.3 [98.9 - 129.6]	122.1 [104.8 - 138.2]	121.6 [103.9 - 137.6]	116.5 [100.6 - 132.6]
	HSR distance (m)	122 [89 - 156]	153 [115 - 199]	126 [95 - 167]	89 [60 - 126]	17 [5 - 35]	41 [20 - 66]	83 [54 - 117]	30 [12 - 51]
	Avg acceleration ($m \cdot s^{-2}$)	0.63 [0.56 - 0.70]	0.64 [0.58 - 0.70]	0.58 [0.52 - 0.64]	0.55 [0.49 - 0.61]	0.45 [0.39 - 0.52]	0.48 [0.43 - 0.54]	0.50 [0.44 - 0.56]	0.47 [0.40 - 0.53]

Avg = average; HSR = High speed running

Table 2. Within-player and between-player, -position, -team, and -match variability of match displacement metrics. Data are presented as raw SD; ±90% CL (CV [%]; ±90% CL)

Phase	Displacement variable	Residual (within-player)		Between-player		Between-position		Between-match		Between-team	
		Raw SD	CV (%)	Raw SD	CV (%)	Raw SD	CV (%)	Raw SD	CV (%)	Raw SD	CV (%)
Whole match	Distance (m)	936; ±15	(24.0; ±0.4)	621; ±47	(14.1; ±1.2)	1354; ±621	(30.5; ±16.7)	256; ±31	(4.2; ±0.8)		
	Avg speed (m·min^{-1})	4.3; ±0.07	(5.9; ±0.1)	4.4; ±0.6	(4.8; ±0.3)	3.1; ±1.4	(4.0; ±1.9)	4.7; ±0.3	(6.2; ±0.5)	1.2; ±0.6	(1.5; ±0.8)
	HSR distance (m)	101; ±2	(36.5; ±0.7)	45; ±-20	(22.1; ±1.9)	166; ±76	(57.2; ±35.2)	49; ±4	(14.4; ±1.4)	18; ±12	(5.2; ±3.5)
	Avg acceleration (m·s^{-2})	0.03; ±0.00	(2.2; ±0.0)	0.02; ±0.88	(1.4; ±0.1)	0.02; ±0.01	(1.2; ±0.6)	0.02; ±0.00	(1.8; ±0.1)	0.00; ±0.00	(0.3; ±0.2)
Ball-in-play	Distance (m)	748; ±12	(23.9; ±0.4)	314; ±-183	(14.0; ±1.2)	993; ±456	(28.3; ±15.3)	342; ±30	(7.8; ±0.8)		
	Avg speed (m·min^{-1})	5.2; ±0.08	(5.3; ±0.1)	5.6; ±0.0	(5.0; ±0.4)	5.6; ±2.6	(5.8; ±2.8)	6.1; ±0.4	(6.4; ±0.5)	1.8; ±0.9	(1.9; ±0.9)
	HSR distance (m)	95; ±2	(36.7; ±0.7)	46; ±-19	(21.8; ±1.9)	150; ±69	(55.0; ±33.5)	50; ±4	(16.0; ±1.5)	16; ±11	(5.1; ±3.4)
	Avg acceleration (m·s^{-2})	0.04; ±0.00	(2.6; ±0.0)	0.03; ±1.05	(1.7; ±0.1)	0.04; ±0.02	(2.4; ±1.1)	0.03; ±0.00	(2.1; ±0.2)	0.01; ±0.00	(0.5; ±0.3)
Attack	Distance (m)	349; ±5	(35.1; ±0.6)	114; ±-66	(20.8; ±1.9)	423; ±194	(34.8; ±19.5)	126; ±12	(7.0; ±1.1)	74; ±38	(4.1; ±3.0)
	Avg speed (m·min^{-1})	7.2; ±0.11	(9.2; ±0.1)	4.7; ±0.4	(6.0; ±0.5)	7.7; ±3.5	(8.8; ±4.3)	5.1; ±0.4	(6.2; ±0.5)	1.9; ±1.0	(2.3; ±1.2)
	HSR distance (m)	51; ±1	(74.3; ±1.4)	17; ±0	(41.8; ±4.0)	69; ±32	(87.3; ±60.3)	19; ±2	(20.1; ±2.4)	17; ±8	(16.0; ±8.4)
	Avg acceleration (m·s^{-2})	0.05; ±0.00	(3.4; ±0.1)	0.03; ±1.02	(2.1; ±0.2)	0.03; ±0.01	(1.7; ±0.8)	0.03; ±0.00	(2.1; ±0.2)	0.01; ±0.01	(0.8; ±0.4)
Defence	Distance (m)	436; ±6	(31.1; ±0.5)	148; ±-86	(17.4; ±1.5)	363; ±167	(23.3; ±12.3)	164; ±16	(8.1; ±1.0)	100; ±49	(4.6; ±2.8)
	Avg speed (m·min^{-1})	8.9; ±0.13	(8.6; ±0.1)	6.5; ±-0.4	(5.1; ±0.4)	10.8; ±4.9	(10.0; ±5.1)	7.0; ±0.5	(6.8; ±0.5)	3.4; ±1.5	(3.2; ±1.4)
	HSR distance (m)	42; ±1	(95.6; ±1.9)	21; ±7	(28.0; ±3.1)	41; ±19	(52.2; ±31.7)	22; ±2	(38.3; ±3.8)	12; ±5	(18.1; ±8.9)
	Avg acceleration (m·s^{-2})	0.05; ±0.00	(3.1; ±0.0)	0.03; ±1.10	(2.1; ±0.2)	0.08; ±0.04	(5.4; ±2.5)	0.04; ±0.00	(2.2; ±0.2)	0.01; ±0.01	(0.7; ±0.4)
Transition	Distance (m)	115; ±2	(42.1; ±0.8)	100; ±-43	(20.1; ±1.9)	125; ±58	(39.4; ±22.5)	107; ±7	(29.1; ±2.5)		
	Avg speed (m·min^{-1})	16.9; ±0.25	(16.5; ±0.3)	17.4; ±-0.7	(6.9; ±0.6)	6.6; ±3.1	(5.7; ±2.8)	19; ±1	(18.6; ±1.4)	1.6; ±1.5	(1.3; ±1.3)
	HSR distance (m)	38; ±1	(165.2; ±3.8)	19; ±14	(50.3; ±5.5)	38; ±17	(125.0; ±97.2)	21; ±2	(51.4; ±5.6)		
	Avg acceleration (m·s^{-2})	0.08; ±0.00	(5.2; ±0.1)	0.04; ±1.26	(2.4; ±0.2)	0.06; ±0.03	(4.0; ±1.9)	0.04; ±0.00	(2.6; ±0.2)	0.01; ±0.01	(0.7; ±0.4)

SD = standard deviation; CL = confidence limit; CV = coefficient of variation; Avg = average; HSR = high speed running; Blank values = the level was dropped from the final model (i.e. the variability is approximately zero)