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The peak duration-specific locomotor demands and concurrent collision frequencies of European Super League rugby

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ABSTRACT

Understanding the most demanding passages of European Super League competition can optimise training prescription. We established positional and match half differences in peak relative distances (m·min^{-1}) across durations, and the number of collisions, high-speed- and very-high-speed-distance completed in the peak 10 min period. Moving-averages (10 s, 30 s, 1 min, 5 min, 10 min) of instantaneous speed (m·s^{-1}) were calculated from 25 professional rugby league players during 25 matches via microtechnology. Maximal m·min^{-1} was taken for each duration for each half. Concurrently, collisions (n), high-speed- (5 to 7 m·s^{-1}; m) and very-high-speed-distance (> 7 m·s^{-1}; m) were coded during each peak 10 min. Mixed-effects models determined differences between positions and halves. Aside from peak 10 s, *trivial* differences were observed in peak m·min^{-1} between positions or halves across durations. During peak 10 min periods, adjustables, full- and outside-backs ran more at high-speed and very-high-speed whilst middle- and edge-forwards completed more collisions. Peak m·min^{-1} is similar between positional groups across a range of durations and are maintained between halves of the match. Practitioners should consider that whilst the overall peak locomotor "intensity" is similar, how they achieve this differs between positions with forwards also exposed to additional collision bouts.

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Rugby league; European Super League; collisions; peak locomotor demands; global positioning systems

Introduction

Rugby league is played professionally in the European Super League (ESL) and in Australasia within the National Rugby League (NRL). It is a team-sport characterised by prolonged intermittent bouts of locomotor and collision activity (Gabbett, Jenkins, & Abernethy, 2012; Johnston, Gabbett, & Jenkins, 2014; Twist et al., 2014; Waldron, Twist, Highton, Worsfold, & Daniels, 2011). Practitioners prescribe numerous training modes to develop the wide range of physical qualities (e.g. muscular strength, speed) that are needed to succeed in competition (Gabbett et al., 2012; Till, Scantlebury, & Jones, 2017; Weaving, Jones, Marshall, Till, & Abt, 2017). However, in order to improve the likelihood of positive outcomes it is important to manage the accumulation and distribution of the external and internal loads prescribed to players (Impellizzeri, Rampinini, & Marcora, 2005; Soligard et al., 2016; Vanrenterghem, Nedergaard, Robinson, & Drust, 2017). By understanding the most intense periods of competition, practitioners can improve their prescription of the external load (i.e. running, accelerating, collisions) across training modes and ensure players are appropriately exposed to these demands in training (Impellizzeri et al., 2005; Weaving, Jones, Till, et al., 2017).

Microtechnology units incorporating global positioning systems (GPS) chips and other inertial measurement devices are now widely used to quantify both the locomotor (Johnston et al., 2014) and collision demands (Gabbett et al., 2012; Hulin, Gabbett, Johnston, & Jenkins, 2017) of professional rugby league competition. Across a whole match, players typically cover between 5000 and 8000 m (Johnston et al., 2014; Twist et al., 2014; Waldron et al., 2011) and are subjected to 30–65 collision events (Hulin et al., 2017) dependent on position (Gabbett et al., 2012). Whilst whole-game data are useful to understand the accumulation of load and how it varies by position, quantifying the rate in which this activity accumulates (i.e. "intensity") is important for understanding the specificity of training.

Relative distance (m·min^{-1}) is a frequently reported measure used to quantify the overall rate of locomotor activity during competition (Johnston et al., 2014; Twist et al., 2014; Waldron et al., 2011). In a systematic review, Johnston et al. (2014) reported 23 positional relative distances from 9 manuscripts across the NRL (n = 7) and ESL (n = 2) competitions. The mean data across these studies suggests the whole-game relative distance to be ~ 94.7 ± 6.1 m·min^{-1}. However, the utility of this information as a basis to prepare players is questionable because it under-represents periods in the

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game where players complete greater relative distances for prolonged periods of time (i.e. > 5 min) (Delaney et al., 2015). Technical-tactical training is a commonly prescribed modality in professional rugby league training programmes (Gabbett, Jenkins, & Abernethy, 2011; Lovell, Sirotic, Impellizzeri, & Coutts, 2013; Weaving, Jones, Marshall, et al., 2017). Therefore, identifying the maximal relative distances across a range of time periods should provide useful information for technical-tactical coaches to evaluate their training prescription (Robertson & Joyce, 2015).

Delaney et al. (2015) used a moving-average of the instantaneous sampled speed (5Hz $m{\cdot}s^{-1}$) during NRL competition. Using this approach, the authors were able to determine the between-position differences in peak relative distances completed across 1 to 10 min moving average periods. Logically, as the duration of activity decreased, the peak relative distance for a given duration increased (Delaney et al., 2015). Interestingly, however, substantial differences in total distance between player positions have been observed using whole-game data (Johnston et al., 2014; Twist et al., 2014; Waldron et al., 2011). Delaney et al. (2015) reported that full-backs completed substantially greater peak relative distances across the range of durations compared with players in other positions (i.e. halves, outside backs, edge-forwards and hit-up-forwards), who covered similar peak relative distances. For example, the mean maximal 10 min relative distance reported across a NRL season for full-backs was 105 ±10 $m{\cdot}min^{-1}$, with halves (93±10 $m{\cdot}min^{-1}$), middle forwards (90±10 $m{\cdot}min^{-1}$), edge forwards (95±7$m{\cdot}min^{-1}$) and outside backs (97 ±14$m{\cdot}min^{-1}$) covering substantially reduced relative distances. Due to the previously reported differences in whole-game relative distances (including high-speed) between the two competitions (Twist et al., 2014), this would seem important to establish in the ESL.

Given the interplay that occurs between locomotor and collision activity in rugby league, one limitation of the above study (Delaney et al., 2015) is that the collision activities completed by players during periods of peak locomotor intensity were not reported. Hit-up-forwards have less playing time (Johnston et al., 2014), despite Delaney et al. (2015) demonstrating little practical difference in the peak running demands for this position compared to positions which complete the full match. Increased collision activity (Gabbett et al., 2012) and body mass (Darrall-Jones et al., 2015, 2015) compared to other positions are possible mechanisms for this reduced involvement. However, whilst the frequency of collision activity of whole-match NRL competition has previously been detailed (Cummins & Orr, 2015; Gabbett et al., 2011, 2012), concurrent data relating to collision activity embedded within the peak locomotor (i.e. relative distances) distances covered during ESL competition is currently unavailable. However, provision of such data would provide practitioners with extremely useful information with which to generate a holistic understanding of the most demanding passages of play for the positional groups. These data could then be used as collective markers of "intensity" to assist practitioners to plan the incremental progression of both collision and locomotor activity during physical preparation (i.e. pre-season) and return-to-play protocols.

Based on the information above, we designed the current study with the specific aim of: 1) establishing the positional differences in duration-specific peak relative distances covered during ESL competition; 2) establishing the positional differences in high-speed-distance (5 to 7 $m{\cdot}s^{-1}$), very-high-speed-distances (> 7 $m{\cdot}s^{-1}$) and the number of concurrent collisions within the peak 10 min relative distances of ESL rugby; and 3) establishing the within-position differences in these demands between halves of the match.

Method

Participants

Data were collected from 25 male professional rugby league players (age = 27.3 ± 4.8 yrs, body mass = 96.0 ± 12.6 kg and height = 184.5 ± 6.8 cm) from the same ESL club during 25 matches during the 2017 ESL regular season (18 wins, 7 losses; mean ± SD score margin: 4 ± 21 points). Players were coded for position at the start of each match, with the number of match observations and individual player appearances for each position including: fullbacks (5 players; n = 25), outside backs (centres and wings; 9 players; n = 96), adjustables (half-back, five-eighth; hooker; 6 players; n = 72), middle-forwards (middle- and loose-forward; 10 players; n = 92) and edge-forward (6 players; n = 48). The mean ± SD number of matches per player was 16 ± 6. When a player changed position within a half their data was omitted from the dataset (n = 7). Players provided informed consent and ethics approval was gained from the institutions review board.

Microtechnology (Optimeye S5, Catapult Innovations, Melbourne, Victoria) was positioned in a customised padded pouch sewn into the players shirt which was positioned in the centre of the upper back. To reduce the influence of inter-unit error, each player was provided with the same device for the period of data collection. The test-retest reliability of Catapult 10Hz devices to measure instantaneous speed across a range of starting velocities has been reported to be acceptable (coefficient of variation: 2.0 to 5.3%) (Varley, Fairweather, & Aughey, 2012; Scott, Scott & Kelly, 2016). The number of satellites and horizontal dilution of precision (HDOP) during data collection were (mean ± SD) 15 ± 2 and 0.8 ± 0.6, respectively. Greater than 6 connected satellites and HDOP values less than 1 are considered ideal for GPS data collection (Malone, Lovell, Varley & Coutts, 2016).

Duration-specific peak relative distance ($m{\cdot}min^{-1}$)

During matches, each players period of involvement in the game was coded in real-time using proprietary software (Catapult Openfield v1.14; firmware: 7.27) (Barrett, 2017; Weaving, Whitehead, Till, & Jones, 2017). A Greenwich mean time (GMT) "time-stamp" was created to determine the "start" and "end" time of each players involvement in each half. This was also completed for interchange players to ensure that only match time were included in the analysis and to ensure appropriate coding of their involvement. For inclusion in any match half, a players involvement had to be greater than

20 min. This criteria was applied so that even if a player had two involvements in a single half, only one data entry per half per player could be included in the final analysis (Delaney et al., 2015). All natural match breaks (e.g. injury, try scored/conceded) were included in the analysis.

To establish the duration-specific running intensities ($m \cdot min^{-1}$), a players instantaneous speed ($m \cdot s^{-1}$), derived from the Doppler Shift method, was recorded every 0.1s (i.e. 10Hz). A time-series file, detailing a record of instantaneous speed every 0.1s was then exported from the proprietary software (Catapult Openfield v1.14). Therefore, the first speed sample represents the "start" of their match involvement (i.e. half or interchange period), whilst the final speed sample represents the "end" of their involvement.

A custom-built algorithm using the *zoo* package (Zeileis & Grothendieck, 2005) in R (v R-3.1.3, R Foundation for Statistical Computing, Vienna, Austria) was developed to compute a moving-average of each player's instantaneous speed across different durations. Moving-averages were calculated across five different durations (10 s, 30 s, 1 min, 5 min, 10 min) for each half. Like previous studies (Delaney et al., 2015), these durations were arbitrarily chosen to represent shorter and prolonged durations of activity due to their use in training prescription. For example, for a 10 min moving-average, the algorithm computed a moving-average for every 6000 instantaneous speed samples (i.e. 10 samples per second for 600 seconds [10 min]). This process was repeated for each of the respective "durations" in the study. For each player and half, the respective computed moving-average values for each duration were then concatenated into a data frame (with the columns representing the different moving average durations [i.e. 10 s to 10 min] and the rows representing the moving average instantaneous speed value). This was then exported to Microsoft Excel to determine the maximum moving-average for each duration. This was multiplied by the moving-average duration to determine a players maximal moving-average of relative distance ($m \cdot min^{-1}$).

Concurrent collision-, high-speed- and very-high-speed-distance within peak 10 min relative distances

The number of collisions, high-speed-distance (5 to 7 $m \cdot s^{-1}$) and very-high-speed-distance (> 7 $m \cdot s^{-1}$) were selected to provide additional information of the concurrent locomotor and collisions with the peak 10 min relative distances ($m \cdot min^{-1}$) identified during ESL competition (McLellan, Lovell, & Gass, 2011; Twist et al., 2014). The minimum effort duration for high-speed and very-high-speed distance was set at 1 second (Malone et al., 2017; Varley, Jaspers, Helsen, & Malone, 2017).

PlayerLoad™ was quantified as per previous methods which has demonstrated acceptable reliability (Boyd, Ball & Aughey, 2011). The number of collisions were quantified using the "tackle" algorithm provided by the manufacturer which is derived from the 100Hz tri-axial accelerometer and gyroscope also housed within the microtechnology device as per previous methods. This has been reported to possess acceptable validity to detect collision events, with specificity and sensitivity of 91.7 ± 2.5% and 93.9 ± 2.4% respectively, when short duration (< 1 second) and low-intensity (i.e. < 1 AU of PlayerLoad™) events were excluded (Hulin et al., 2017).

To export the number of collisions, high-speed- and very-high-speed-distance completed by each player, the GMT associated with the identified peak 10 $m \cdot min^{-1}$ moving-average for each half match file were coded within the proprietary software (Openfield v1.14, Catapult Innovations, Scoresby, Victoria, Australia) and exported into a customised spreadsheet.

Statistical analysis

Linear mixed-effects models were used to estimate the differences between the positional groups and match half. For the continuous variables of 10 s, 30 s, 1-min, 5 min and 10 min peak $m \cdot min^{-1}$, 10 min high-speed-distance and very-high-speed-distance, estimations were made via PROC MIXED in SAS University Edition (SAS Institute, Cary, NC). For collision data, a generalised linear mixed-effects model was used, assuming a negative binomial distribution, via the *lme4* package (Bates, Maechler, Bolker & Walker 2015) in R (version 3.3.1). In both models the (fixed) effects of playing position and match-half were estimated. The interaction between these fixed effects was also explored, by including a multiplicative term in the models. The random effects in both models were match identity (differences between average match demands not accounted for by the fixed effects), athlete identity (differences between athletes' mean match demands) and the residual (within-athlete match-to-match variability). Magnitude-based inferences were used to provide an interpretation of the real-world relevance of the outcomes. For all peak relative distance durations, a difference of 10 $m \cdot min^{-1}$ was set as the smallest worthwhile effect threshold. This was chosen based on previous research (Delaney et al., 2015) as practitioners are unlikely to utilise between-position training prescription that is more specific than a 10 metre difference. For collisions, high-speed- and very-high-speed-distance comparisons, a value equivalent to a difference in means of 0.20 was set as the smallest worthwhile effect threshold. For all comparisons, effects were classified as *unclear* if the percentage likelihood that the true effect crossed both positive and negative smallest worthwhile effect thresholds were both greater than 5%. Otherwise, the effect was deemed clear, and was qualified with a probabilistic term using the following scale: < 0.5%, *most unlikely*; 0.5–5%, *very unlikely*; 5–25%, *unlikely*; 25–75%, *possible*; 75–95%, *likely*; 95–99.5%, *very likely*; > 99.5%, *almost certainly* (Hopkins, Marshall, Batterham, & Hanin, 2009).

Results

Duration-specific peak relative distance ($m \cdot min^{-1}$)

Table 1 details the mean ± SD for peak relative distances from 10 s to 10 min by 1st and 2nd half. Between halves of the match (1st *vs* 2nd) there were *likely* to *most likely* trivial differences in these variables for all within-position comparisons.

Table 2 details the raw least square means positional differences and magnitude based inferences for these variables. Although, full backs, outside backs and adjustables

Table 1. The mean ± standard deviation of duration-specific peak 1st and 2nd half relative distances of European Super League rugby and the concurrent number of collisions, and high-speed- and very-high-speed-distances covered during the peak 10-minute relative distances.

	10s ($m{\cdot}min^{-1}$)	30s ($m{\cdot}min^{-1}$)	1-min ($m{\cdot}min^{-1}$)	5-min ($m{\cdot}min^{-1}$)	10-min ($m{\cdot}min^{-1}$)	10-min HSD (m)	10-min VHSD (m)	Collisions (n)
Fullback								
1st Half	320.8 ± 10.6	209.7 ± 5.2	169.7 ± 3.8	118.7 ± 2.8	102.9 ± 2.3	89.2 ± 8.4	9.3 ± 2.1	5.2 ± 3.0
2nd Half	331.4 ± 10.9	209.5 ± 5.3	167.7 ± 3.8	115.2 ± 2.8	101.6 ± 2.3	80.9 ± 8.6	4.8 ± 2.2	5.7 ± 3.6
Outside back								
1st Half	325.2 ± 6.3	200.5 ± 3.3	169.7 ± 3.8	110.9 ± 1.9	96.1 ± 1.8	82.6 ± 5.2	10.1 ± 1.1	5.1 ± 2.6
2nd Half	325.2 ± 6.3	203.1 ± 3.3	167.7 ± 3.8	106.4 ± 1.9	92.3 ± 1.8	64.5 ± 5.2	5.9 ± 1.1	4.9 ± 2.5
Adjustable								
1st Half	313.0 ± 7.1	200.3 ± 3.7	160.7 ± 2.4	113.8 ± 2.1	99.9 ± 2.0	70.1 ± 5.9	5.5 ± 1.3	5.5 ± 3.3
2nd Half	322.5 ± 6.9	205.8 ± 3.6	159.5 ± 2.4	111.6 ± 2.1	96.9 ± 1.9	65.7 ± 5.8	6.5 ± 1.2	5.2 ± 3.2
Middle forward								
1st Half	291.5 ± 6.2	195.5 ± 3.2	163.1 ± 2.4	111.1 ± 1.9	99.0 ± 1.8	48.7 ± 5.1	1.9 ± 1.1	9.7 ± 2.6
2nd Half	281.7 ± 6.3	195.8 ± 3.2	160.8 ± 2.4	106.0 ± 1.9	94.2 ± 1.8	39.2 ± 5.1	0.7 ± 1.2	9.1 ± 2.8
Edge forward								
1st Half	296.2 ± 7.9	191.8 ± 3.9	159.9 ± 2.9	110.0 ± 2.2	99.3 ± 2.0	60.6 ± 5.4	2.0 ± 1.5	8.9 ± 2.7
2nd Half	298.3 ± 7.7	197.8 ± 3.8	160.4 ± 2.8	105.9 ± 2.1	95.1 ± 1.9	53.9 ± 6.1	2.4 ± 1.5	8.2 ± 2.7

HSD = high-speed-distance (5–7 $m{\cdot}s^{-1}$); VHSD = very-high-speed-distance (> 7 $m{\cdot}s^{-1}$)

Table 2. Raw mean positional differences [90% confidence limits] and likelihoods in peak relative distances across durations.

	10s (m·min^{-1})	30s (m·min^{-1})	1 min (m·min^{-1})	5 min (m·min^{-1})	10 min (m·min^{-1})
FB vs. OB	0.96 [−14.2 to 16.1] *Unclear*	7.8 [0.4 to 15.2] *Possibly trivial*	8.6 [3.2 to 14.1] *Possibly trivial*	8.3 [4.4 to 12.1] *Likely trivial*	8.0 [5.2 to 10.9] *Likely trivial*
FB vs. ADJ	8.38 [−7.7 to 24.4] *Unclear*	6.5 [−1.5 to 14.6] *Likely trivial*	5.3 [−0.7 to 11.3] *Likely trivial*	4.2 [−0.1 to 8.5] *Very likely trivial*	3.8 [0.5 to 7.1] *Almost certainly trivial*
FB vs. MF	39.6 [24.2 to 55.0] *Almost Certainly* ↑	14.0 [6.3 to 21.7] *Likely* ↑	6.7 [1.0 to 12.5] *Likely trivial*	8.4 [4.3 to 12.6] *Possibly trivial*	5.7 [2.3 to 9.1] *Very likely trivial*
FB vs. EF	28.9 [12.3 to 45.4] *Very likely* ↑	14.8 [6.6 to 23.0] *Likely* ↑	8.5 [2.4 to 14.7] *Possibly trivial*	9.0 [4.6 to 13.4] *Possibly trivial*	5.0 [1.4 to 8.6] *Very likely trivial*
OB vs. ADJ	7.4 [−3.8 to 18.6] *Possibly Trivial*	−1.3 [−7.0 to 4.4] *Very likely trivial*	−3.3 [−7.6 to 1.0] *Almost certainly trivial*	−4.0 [−7.1 to −1.0] *Almost certainly trivial*	−4.2 [−6.6 to 1.8] *Almost certainly trivial*
OB vs. MF	38.6 [27.8 to 49.4] *Almost Certainly* ↑	6.2 [0.5 to 11.8] *Likely trivial*	−1.9 [−6.2 to 2.5] *Almost certainly trivial*	0.1 [−3.1 to 3.4] *Almost certainly trivial*	−2.4 [−5.3 to 0.6] *Almost certainly trivial*
OB vs. EF	27.9 [15.6 to 40.2] *Very likely* ↑	7.0 [0.7 to 13.3] *Likely trivial*	−0.1 [−4.9 to 4.7] *Almost certainly trivial*	0.7 [−2.8 to 4.2] *Almost certainly trivial*	−3.0 [−6.1 to 0.1] *Almost certainly trivial*
ADJ vs. MF	31.2 [19.6 to 42.8] *Almost certainly* ↑	7.4 [1.4 to 13.5] *Likely trivial*	1.4 [−3.2 to 6.1] *Almost certainly trivial*	4.2 [0.71 to 7.6] *Almost certainly trivial*	1.83 [−1.3 to 5.0] *Almost certainly trivial*
ADJ vs. EF	20.5 [7.5 to 33.5] *Likely* ↑	8.3 [1.6 to 15.0] *Possibly trivial*	3.2 [−1.9 to 8.3] *Very likely trivial*	4.7 [1.0 to 8.5] *Very likely trivial*	1.17 [−2.2 to 4.5] *Almost certainly trivial*
MF vs. EF	−10.7 [−22.0 to 0.7] *Possibly* ↓	0.9 [−4.7 to 6.4] *Almost certainly trivial*	1.8 [−2.3 to 5.9] *Almost certainly trivial*	0.6 [−2.3 to 3.5] *Almost certainly trivial*	−0.7 [−2.8 to 1.47] *Almost certainly trivial*

FB = fullback; OB = outside back; ADJ = adjustables; MF = middle forward; EF = edge forward. The direction of difference is in relation to the first named positional group.

covered substantially greater relative distances across 10 s periods, there were *possibly* to *almost certainly* trivial differences between all positional groups in peak 1, 5 and 10 min relative distances.

Concurrent collisions, high-speed- and very-high-speed-distances within peak 10 min relative distances (m·min^{-1})

Table 1 displays the mean ± SD for peak 10 min relative distance and concurrent number of collisions, high-speed- and very-high-speed-distance for each positional group.

Figures 1, 2 and 3 displays the standardised mean difference plus 90% confidence intervals for positional differences in the concurrent number of collisions, high-speed- and very-high-speed-distance completed during the peak 10 min relative distances.

Whilst there were *unclear* differences in the number of collisions between full backs, adjustables and outside backs, edge and middle forwards completed a substantially greater number of collisions compared to these three positional groups.

Between 1st and 2nd halves there were *possibly* reductions in high-speed distance for full-backs (ES: 0.25 [–0.20 to 0.69]), *very likely* reductions for outside backs (ES: 0.54 [0.32 to 0.76]), *possibly* trivial reductions for adjustables (ES: 0.13 [–0.12 to 0.38]), *possibly* reductions for middle forwards (ES: 0.29 [0.06 to 0.51]) and *likely* reductions for edge forwards (ES: 0.40 [0.09 to 0.71]). For very-high-speed-distance, there were *likely* reductions between 1st and 2nd halves for full backs (ES: 0.44 [–0.03 to 0.92]) and outside backs (ES: 0.40 [0.16 to 0.64]) and *possibly* trivial differences for adjustables (ES: –0.10 [–0.36 to 0.17]) and middle forwards (ES: 0.12 [–0.13 to 0.36]). *Unclear* differences were observed for wide-forwards (ES: –0.04 [–0.37 to 0.29]). For collisions, there were *likely* trivial differences between 1st and 2nd halves for all positional groups.

Discussion

The primary aim of the study was to establish the positional differences in peak duration-specific relative distances and the number of collisions, high-speed-, and very-high-speed-distances completed within the peak 10 min locomotor period of ESL competition. A secondary aim was to determine whether these peak demands differed between the 1st half and 2nd half of competition within positional groups.

The main findings were that whilst adjustables, outside- and full-backs completed greater peak running "intensities" during 10 s locomotor bouts, *likely* to *almost certainly* trivial differences were observed between all the positional groups as the duration increased (30 s to 10 min). Although, during the peak 10 min locomotor period, adjustables outside- and full-backs covered greater high-speed and very-high-speed-distances than middle- and edge-forwards, the latter positional groups completing a substantially greater number of collisions. The difference in demands between 1st and 2nd halves were *likely* to *almost certainly* trivial across the majority of variables, although there were small decreases in high-speed- and very-high-speed-distance across all positional groups during the peak 10 min locomotor period of the 2nd half. Collectively this suggests for prolonged periods of an ESL match (i.e. 2 × 10 min periods), the positions demonstrate limited practical differences in overall relative distance, although middle- and edge-forwards complete a greater number of collisions, whereas fullbacks, outside backs and adjustables complete greater distances at high-speed during this time. This study is the first to provide data of the peak locomotor and concurrent collision activity of ESL rugby by halves of the match. The findings suggest that it is important for coaches to prescribe periods of training that provide positional groups with similar exposures to relative distance, while still ensuring that the respective positions achieve this in a different manner (i.e. backs more high-speed running) and that they are concurrently exposed to varying collision activity (i.e. forwards more collisions).

Compared to previous literature (Delaney et al., 2015), the peak duration-specific relative distances of ESL competition appear comparable to those reported within the NRL. This

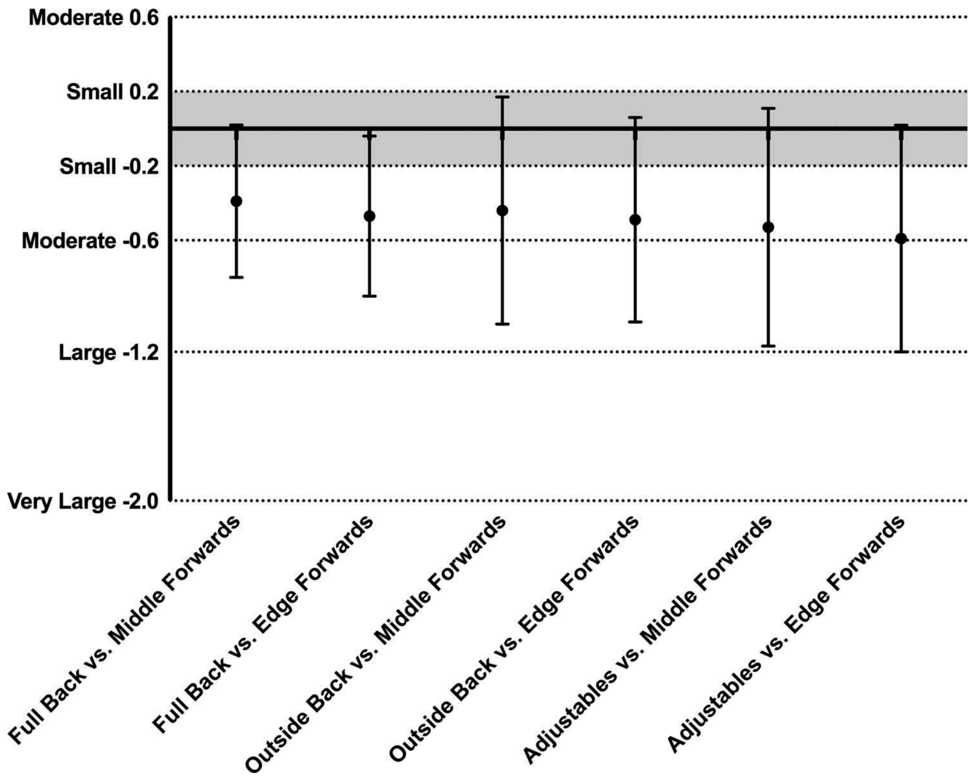

Figure 1. The standardised mean positional differences plus 90% confidence intervals for the number of collisions completed during the peak 10 min of European Super League rugby. Only substantial differences are detailed. Outside backs vs. fullbacks (−0.07 [−0.47 to 0.34]), adjustables vs. fullbacks (−0.15 [−0.61 to 0.32]), outside backs vs. adjustables (0.09 [−14.59 to 14.76]) and middle forwards vs. edge forwards (−0.06 [−3.76 to 3.64]) were all *unclear*.

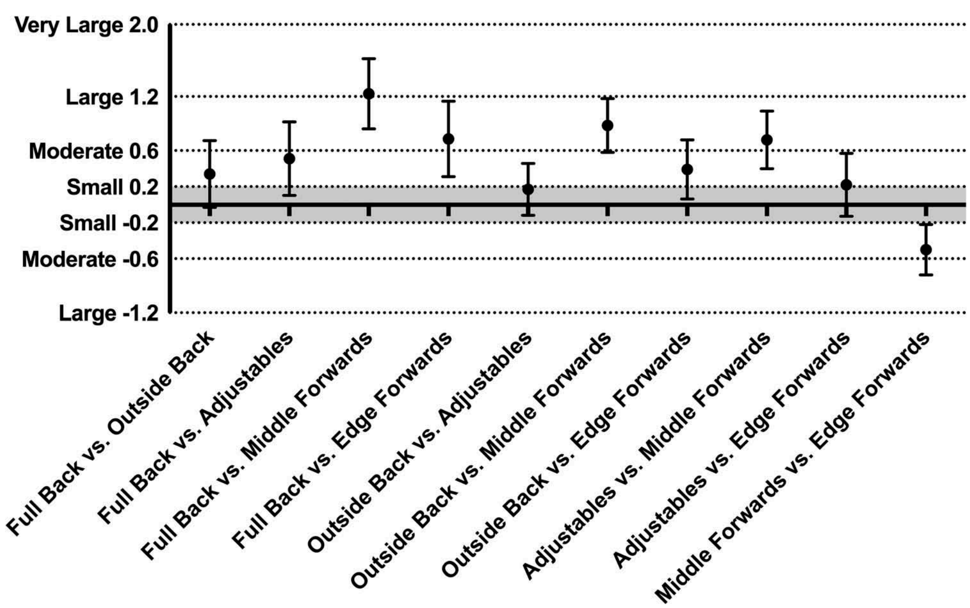

Figure 2. Standardised mean positional differences plus 90% confidence intervals in high-speed-distance (5 to 7 m·s^{-1}) completed during the peak 10 min of European Super League rugby.

suggests that the peak locomotor demands of the two competitions are consistent. Consequently, there appears to be a growing body of evidence to suggest that the peak duration-specific relative distances of professional rugby league competition are consistent across teams and competitions and therefore, when controlling for contextual influences, there appears to be a "ceiling" requirement of relative distance that professional rugby league players are required to complete. Importantly, it must be considered that the data in the current study represents the average of the maximal relative distances covered by players per half, per game. Therefore, detailing the range of peak demands experienced by players,

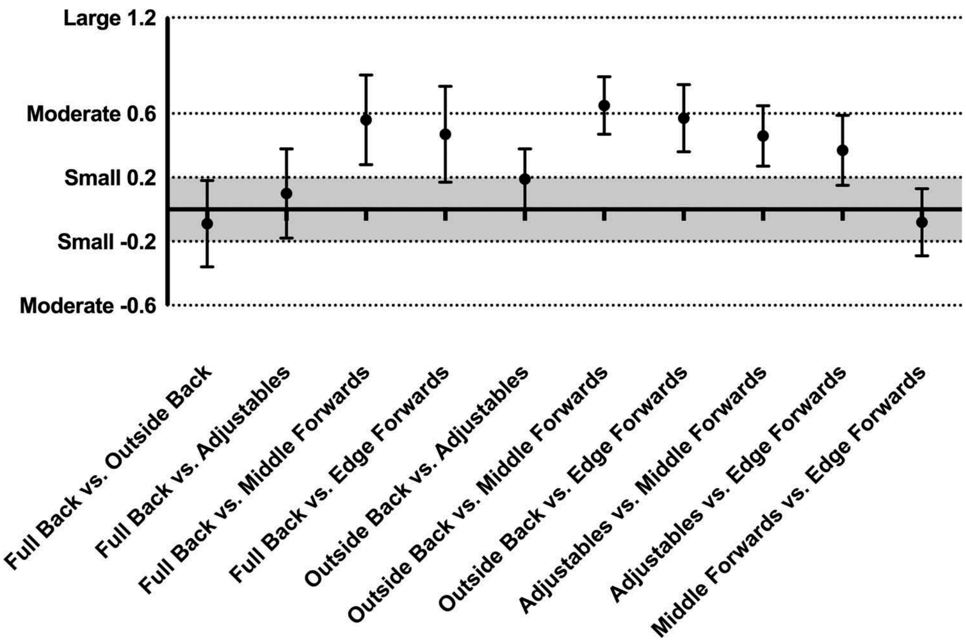

Figure 3. Standardised mean differences plus 90% confidence intervals for the positional differences in very-high-speed-distance (> 7 m·s^{-1}) completed during the peak 10 min of European Super League rugby.

including the maximal recorded exposure during competition can also provide useful information of the highest recorded demands (Table 1). For example, whilst whole-game relative distances are ~ 94.7 m·min^{-1} (Johnston et al., 2014), at least 10% of the match (i.e. 2 × 5 min) is spent covering relative distances between 107 and 116 m· min^{-1}. Depending on position, this rose to between 134 to 165 m·min^{-1} during some matches (Table 1). Practitioners should therefore aim to ensure players receive an appropriate exposure to technical-tactical activities at these maximal competition "intensities".

Due to the importance of "winning" the collision contest and its interplay with locomotor activity, a novel aspect of the current investigation was the detail and positional comparison of the frequency of collision bouts during the peak 10 min locomotor periods of ESL competition. These appear similar to the whole-game collision frequencies (number·min^{-1}) reported in the NRL (Gabbett et al., 2012) which revealed middle-forwards (mean [range]: 1.09 [0.96 to 1.22]) to exhibit the greatest frequency of collisions, with differences also observed between wide-running-forwards (0.76 [0.69 to 0.84]), adjustables (0.58 [0.45 to 0.71]) and outside backs (0.38 [0.32 to 0.43]). This suggests that during the peak locomotor passages of ESL competition, the frequency of collision activity is maintained at whole-game "intensities". Therefore, practitioners should consider the amalgamation of collision activity whilst aiming to replicate the "peak" relative distances reported in the current study. However, it is important to note that the current study quantified the collisions embedded within the peak locomotor demands and it is plausible that the peak frequency of collisions for a given duration could be substantially greater than those reported. Future research should therefore seek to establish the peak collision frequencies experienced by the positional groups for a range of durations to further strengthen the understanding between locomotor and collision activity during professional rugby league competition.

In professional rugby league it is commonplace for forwards (particularly middle-forwards) to complete reduced time on the pitch during matches (Johnston et al., 2014; Twist et al., 2014; Waldron et al., 2011). This has previously been attributed to forwards possessing reduced prolonged intermittent running capacity (Scott et al., 2017), greater body mass (Darrall-Jones et al., 2016; Jones et al., 2015) and greater collision activity compared to backs (Gabbett et al., 2012). Our study suggests that this is likely because middle-forwards complete similar peak locomotor intensities to backs whilst concurrently completing substantially more collisions for prolonged periods of the match (i.e. 2 × 10 min). When locomotor bouts are controlled, the addition of collisions have been reported to increase a players rating of perceived exertion, blood lactate concentration and heart rate (Johnston & Gabbett, 2011; Mullen, Highton, & Twist, 2015; Norris, Highton, Hughes, & Twist, 2016), suggesting that the internal physiological cost of competition would be greater in the forwards position. In addition, the total number of contacts in the forwards position has previously been reported to relate to decrements in perceptual muscle soreness (r = 0.62), perceptual fatigue (r = 0.69) and countermovement jump flight time (r = −0.55) 24 hours post ESL competition (Twist, Waldron, Highton, Burt, & Daniels, 2012). Despite this, such substantial relationships appear to be absent in the backs (soreness: r = 0.20; fatigue: r = 0.11; jump flight time: r = −0.25) (Twist et al., 2012). Collectively, this suggests that rugby league forwards are subjected to greater psycho-physiological and biomechanical loads (Soligard et al., 2016; Vanrenterghem et al., 2017) per min of competition than backs, leading to similar amounts of "fatigue" in the days following competition, despite forwards competing for a reduced amount of time (Johnston et al., 2014; Twist et al., 2012). Therefore, practitioners should ensure that training prescription and recovery periodisation reflect this, particularly when forwards complete substantially greater playing times than typically accustomed to.

Whilst this study is the first to detail the interplay between locomotor and collision activity during the peak passages of competition and how they differ between position and halves of the match, the study is not without limitations. Firstly, the data were collected from a single ESL club, which may not be representative of the differences observed with other teams in the competition. Secondly, the collision, high-speed- and very-high-speed-distance demands embedded within the peak 10 min duration were extracted on the assumption that the measurement of instantaneous speed ($m \cdot s^{-1}$) provides a valid representation of the peak locomotor demands of professional rugby league competition (Delaney et al., 2015). Acceleration and deceleration events are prevalent in professional rugby league, due to the spatial constraints imposed by the 10-metre rule separating the opposing structures of the attacking and defending teams. Therefore, determining the collisions, high-speed- and very-high-speed distances completed within the peak acceleration demands could arguably provide a more valid representation of the peak locomotor demands of competition.

Despite this, for the practitioner wishing to optimise training prescription, it is important to find the balance between the validity of the measurement and practical/actionable data. In particular, during the planning and prescription of training a fundamental strategy adopted by practitioners is to control and manipulate the overall distance covered per unit of time (i.e. relative distance). This warrants consideration, as technical-tactical training is the most frequently prescribed modality in professional rugby league, particularly during the in-season period which lasts the majority of the calendar year (Gabbett et al., 2012; Lovell et al., 2013; Weaving, Jones, Till, et al., 2017). Therefore, it would be preferable to appropriately expose players to these peak demands (e.g. 10 min continuous bouts) within this mode of training to concurrently satisfy both the physical and technical-tactical requirements of training. Achieving this would allow practitioners to prescribe an appropriate range of training stimuli whilst also ensuring players are contained within an appropriate overall accumulation of training load (Gabbett, 2016). Furthermore, instantaneous speed can also be monitored in real-time (Barrett et al., 2017; Weaving, Whitehead, et al., 2017). This is unlike acceleration data, which can only be monitored post-session. Consequently, acceleration variables can be difficult for the practitioner to translate into the actionable manipulation of training content. Regardless, previous work has reported the peak duration-specific acceleration and relative distance demands to occur at different periods within a match (Delaney et al., 2016). This highlights that the retrospective analysis of acceleration demands during specific training drills is warranted. In particular, within a specific duration of rugby league activity, it is likely that the interplay between the magnitude of instantaneous speed and acceleration plus collision activity would provide the best representation of the "most demanding" durations of professional rugby league competition.

It is therefore recommended that further research be undertaken in order to better understand the interaction between these three components coupled with their own individual peak demands (which may occur at different times to each other) during the peak passages of competition. Ideally, future research should look to the link the peak interactions between these three modes of activity and the associated technical-tactical/skill activities that are completed within such periods.

Conclusions

Aside from very-short-duration bouts (i.e. 10 s), there are trivial differences in the peak relative distances covered between positions during ESL competition. However, adjustables, outside- and full-backs cover substantially greater high-speed- and very-high-speed-distances during the peak 10 min relative distance period than middle- and edge-forwards whilst the forwards positional groups complete a greater number of collisions. There are likely trivial differences between these demands between halves of competition, suggesting that players are likely to be exposed to similar peak intensities for each given period in both halves of the match.

Practical applications

- To simulate the peak running intensities of ESL competition, practitioners should expose positional groups to similar peak relative distances and durations during training.
- Given the similarities between match halves across durations, programming multiple peak bouts within a training session could help to prepare players for competition.
- How positions achieve this overall relative distance should differ, with adjustables, outside- and full-backs completing greater high-speed- and very-high-speed-distances.
- During the peak 10 min running "intensity" of ESL, forwards complete a greater frequency of collisions and should be exposed to these demands whilst completing similar relative distances.

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