Title: Relationships between opponent ranking and locomotor activity in international field hockey

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Abstract

No research has investigated the effect of opponent world ranking (WR) on locomotor activity within modern (post-2015) men's international hockey. A retrospective analysis of 71 matches (*vs.* 24 opponents, WR# 12±11, WR# 1-86) investigated the relationships between opponent ranking at team and positional levels, on locomotor activity. Data were analysed using linear mixed modelling to; 1) explore relationships between opponent ranking and locomotor activity and 2), to compare between predefined ranking groups (WR# 1-8 'HIGHER' [n=8], WR# 9-17 'SIMILAR' [n=8] and WR >#18 'LOWER' [n=8]), relative to the reference team (WR# 11). Significant relationships were found between opponent WR and total distance (β=-6.11; p=0.003), high-speed running ([HSR], β=-4.87, p<0.001), sprint distance ([SD], β=-2.41, p<0.001), sprint efforts ([SE], β=-0.10, p<0.001), average speed (β=-0.19, p<0.001), but not low-speed running (β=-0.94, p=0.57). When analysed by ranking groups, HSR, SD and SE increased against HIGHER (+12-14% *vs*. grand mean, p<0.05) and reduced against LOWER teams (-15-18% *vs*. grand mean, p<0.05). The largest differences in SD were observed in forwards (HIGHER +14%, LOWER -19%) and defenders (HIGHER +20%, LOWER -18%). In international hockey, average speed is greatest when facing higher- rather than similarly-ranked opponents. Furthermore, high- but not low-speed activity, is modulated by opponent ranking.

Key words:

Match demands, opponent ranking, hockey, physical demands, GPS.

1. Introduction

International hockey is an intermittent, high-intensity sport [1]. Following changes to the match format, notably the introduction of 4 x 15-min quarters and the inclusion of an extra interchange player on the bench for outfield positions, modern international hockey displays greater high-speed running (HSR)[2], limiting the applicability of research pertaining to older (pre-2015) match formats. In the modern format (i.e. post 2015), ~25% of a player's total distance (TD) may be considered high-speed (>14.5 km.h^{-1}) and ~8% classified as sprinting (>19 km.h^{-1}), achieved through 21±7 sprint efforts per game [3]. At the team level, the large variability within locomotor activity such as sprint efforts (coefficient of variation: 33%), is partially reflective of a variety of playing positions (i.e. defender [DEF]: 18±6, midfielder [MID]: 23±7, forward [FWD]: 23±7 efforts). However, the locomotor activity of players may also be influenced by situational factors, such as environmental conditions [4], match scheduling [5, 6] and the standard of opponent [7]. Within international hockey, a higher world ranking (WR) affords favourable seeding for tournaments and Olympic qualification matches, as well as potential eligibility for the International Hockey Federation (FIH) *Pro-League*. Coaches of lower-ranked teams are further incentivised to compete against higher-ranked opponents by the potential to accumulate considerable ranking points, when a ranking offset occurs [8]. To date however, no research has investigated the relationships between opponent ranking and locomotor activity within contemporary international men's hockey.

Previous research indicates that playing standard may differentiate hockey players' locomotor activity. For example, Keogh et al. [9] reported inferior sprinting speed, agility, aerobic and muscular power, in club *vs*. regional players. Similarly, Jennings et al. [10] reported lower average speed (m.min^{-1}) within national league players compared to international counterparts (FWD: -8%, MID: -11% and DEF: -12%), with the largest differences within HSR volumes (>15 km.h^{-1}, FWD: -19%, MID: -19% and DEF: -32%). This indicates one attribute of higher-standard players may be the ability to produce superior physical outputs. This enables greater locomotor activity for tactical advantages during matches, as has been observed within higher-ranked teams in Rugby League [11]. Recent evidence from elite hockey supports the basis of this relationship, demonstrating aerobic fitness parameters to have positive relationships with match average speed [12, 13]. Therefore, in match situations, lower-ranked teams may be required to produce greater locomotor activity than usual, when facing teams of a higher ranking. This is supported by data from the England women's hockey league, which displayed faster average speeds when playing against the three highest-ranked teams, compared with the middle three teams (112 *vs.* 107 m·min^{-1}, respectively) [14]. Of the limited data pertaining to international men's hockey, the New Zealand team (2014 WR = #6), reported greater volume and intensity of total, high-speed and sprint distances against teams ranked #1-5, compared with playing teams with a WR >#12 [15]. It therefore appears that coaches and sport scientists can expect their team to experience greater physical demands when facing higher-ranked opponents. However, such findings are not universal with hockey or other team-sports. White and Macfarlane [7] identified a strong relationship between average speed ($m.min^{-1}$) and opponent ranking (Pearson's r=0.70), from the fifth ranked team, within a nine-team Scottish national women's hockey league. However, the relationship was not linear, with the highest average speed ($m.min^{-1}$) occurring against similarly-ranked opponents (+14% *vs.* highest ranked team and +26% *vs.* lowest ranked team), whilst no clear relationships between opposition ranking and HSR volume were found. Similar observations have been made within other team- [16] and racquet-sports [17], whereby competing against opponents of a similar ranking may yield the highest playing intensities or longest durations, respectively. In team-sports, such outcomes may arise from more frequent transition opportunities when playing against opponents of a similar standard, resulting in greater locomotor activity [16]. Therefore, at the team level, the relationship with opponent ranking within hockey is evidently complex and warrants further investigation.

Given varied positional match demands in hockey [3], it is possible that changes in locomotor activity against different opponents may not be experienced equally across playing positions. For example, 'pressing' strategies (i.e. 'high' vs 'low' press) to recover possession, are typically led by FWDs, whilst the number of ball turn-overs, may place greater demands on midfielders and defenders as counter-attacks occur. Positional demands may therefore be influenced by the proportion of ball possession a team experiences. Recent data from international men's hockey found non-possession phases increased the team's average speed and HSR (defined as >19.8 $km.h^{-1}$), by +13% and +41%, respectively [18]. Within this team, the largest differences were found in MIDs and DEFs, compared with FWDs, whose activity was maintained [18]. Similarly Logan [15] found the largest differences in intensity were experienced by DEFs and MIDs, with FWDs playing for longer durations and therefore primarily demonstrating differences in volume, rather than intensity variables, when the opponent was not of a similar ranking. Given that hockey tournaments are characterized by a high match density (e.g. a match every 48 h) and demonstrate progressively elevated markers of muscle damage [19], a deeper understanding of the demands associated with competing against higher or lower-ranked opponents can inform the physical preparation of players before and during important tournaments.

This study investigated the relationships between opponent ranking with whole-match and positional locomotor activity, and across the four playing quarters, in a high-ranking international men's hockey team. We hypothesised; 1) high intensity and sprint locomotor activity would reveal strong relationships with opponent ranking, 2) the demands of FWDs would reveal the smallest differences, relative to opponent ranking, compared with MIDs and DEFs and, 3) differences between higher- and lower-ranked opponents would be most apparent in HSR and sprint activity during the final playing quarter (Q4).

2. Methods

2.1 Participants

Twenty-seven male, international hockey players from the Malaysia national team (2018 WR: #12, 2019 WR: #11) participated in the study (9 DEF, 7 MID and 11 FWD; age 25±4 years, stature 172±5 cm, body mass 68±6 kg). The study had institutional ethical approval from *Institut Sukan Negara* (*ISNRP-006-2020*) and participants provided written informed consent. All analysis was conducted retrospectively on anonymous data, in accordance with the Declaration of Helsinki (2013).

2.2 Design

A retrospective analysis was undertaken of 71 international matches, against 24 different opponents (WR #12±11, range #1-86), played between March 2018 and November 2019. Each player participated in 40±20 (range 9-66) official test- or tournament matches, which included the Hockey World Cup, Asian Games and World Series Finals. Data are reported as volume (i.e. total values) and intensity (i.e. relative to playing time [per min]), and analysed from two perspectives; 1) to understand the overall relationships between opponent ranking and locomotor activity (i.e. ranking utilised as a continuous variable) and 2), to compare between predefined ranking groups. Teams were assigned to groups ('HIGHER' [n=8], 'SIMILAR' [n=8] or 'LOWER' [n=8]), based upon multiple performance criteria. This included (i) world ranking at the time of data collection (WR# 1-8 'HIGHER', WR# 9-17 'SIMILAR' and WR >#18 'LOWER', reference team #12/#11), (ii) match results versus the reference team within the data collection period. There were 33 matches against HIGHER with 5 wins, 2 draws and 25 losses (16 test matches, 16 tournament matches, mean temperature 22.1°C [range 9-40°C]). There were 29 matches against SIMILAR with 13 wins, 3 draws and 13 losses (22 tournament matches, 7 test matches, mean temperature 27.6°C [range 22-32°C]). Nine matches were played against LOWER, with 8 wins and 1 loss (all tournament matches, mean temperature 28.6°C [range 26-32°C]). (iii) 2012 & 2016 Olympic Games qualification (HIGHER 16/16 entries, SIMILAR 6/16 entries, LOWER 1/16 entry [host advantage], reference team 0 entries), and lastly, (iv) 2018 Hockey World Cup qualification (HIGHER 8 entries, SIMILAR 5 entries, LOWER; 0 entries, reference team qualified). Where multiple criteria provided contraindications, the assignment to groups was finalised by 2 highly experienced international coaches for ecological validity purposes. Based upon this, one opponent was retained in the SIMILAR group, despite a drop in WR in 2019 and lower tournament qualification, because these statistics were considered to reflect a lack of international participation, rather than a performance decrement.

2.3 Procedures

Our global positioning system (GPS) data collection and processing procedures have been previously described [3]. Following a 10-min central pitch localisation, data were collected using Catapult G5 10 Hz GPS/100 Hz triaxial accelerometer devices (Catapult Sports, Australia, firmware v.7.40). Wherever possible, players used the same device and vest. For one tournament (6 matches), players used different devices from the same manufacturer (Catapult S5, firmware v.7.32). Measures of GPS quality, horizontal dilution of precision (HDOP: 0.75±0.14) and satellite number (11.6±0.8) [20], were considered *excellent*.

Devices were downloaded using *Openfield* software (v.2.3.3, build #52841). Data associated with large breaks in play, between playing quarters, substitutions, sin-bins, penalty corners, video referrals, major injuries and goal-scoring were excluded [2]. Therefore, analysed data pertains to situations where the game-clock was running and may be considered 'ball-in-play time'. Locomotor activities below and above 14.5 $km.h^{-1}$ were classified as low-speed running (LSR) and HSR, respectively, with >19.0 $km.h^{-1}$ classified as '*sprinting*'. We elected to utilise absolute, rather than individualised, velocity thresholds as our analysis focussed upon longitudinal, within-subject comparisons. "*High-intensity*" decelerations (>2 $m.s^{-2}$) are reported from GPS data (Catapult Gen2). Velocity and deceleration dwell times were 1.0 and 0.4 s, respectively. We discarded data not meeting the following inclusion criteria; minimum of 9 outfield players (0 cases), no data recorded or values visually identified as a technological error (2 cases), minimum of 7 satellites during match (1 case) [3]. These inclusion criteria resulted in the removal of 3 match files, leaving a total of 1106 whole-match files. We did not apply a minimum playing time threshold because only 9 playing-quarter records had a duration of <3-min per quarter (out of a total of 4399 individual playing-quarter records), which was the minimum planned on-pitch 'rotation' for any match across the 2-year period.

2.4 Statistical Analysis

Data are presented as mean ± standard deviation. A linear mixed modelling (LMM) approach was used to control for repeated measures within the dataset (i.e. same players played multiple matches) and the differences in the number of matches contained within ranking groups, as has been utilised within similar research [18]. Four sets of LMM were generated (M1, M2, M3 and M4) for our hypotheses. M1 were single-level LMM with opponent ranking as a continuous predictor of locomotor activity. M2 were single-level LMM with ranking group (LOWER, SIMILAR or HIGHER) as a categorical predictor of locomotor activity. M3 involved a two-level LMM, with ranking group and playing position (DEF, MID, FWD) as fixed effects, with the ranking group x playing position interaction. M4 was also a two-level model, with ranking group and quarters (Q1-Q4) as fixed effects, and the ranking group x playing quarters interaction. For all models, a hierarchical construction was used, beginning with the null model (i.e. intercept only and random effects), before ranking group (categorical) alone (M2), or in conjunction with playing position (M3), or in conjunction with playing quarter (M4), were added. Within all analyses, individual players (n=27) and tournaments (n=12) were entered as random effects, to control for inter-player and tournament variation. Smaller akaike information criterion, including maximal likelihood estimator via ANOVA function, indicated a better model fit [21]. Where additional random, fixed or interaction effects did not improve model fit, these were not included. All models were fitted using restricted maximal likelihood estimator [22] and model residuals were visually inspected for normality using Q-Q scatter line plots. For M1, Nakagawa's r-square [23] represented the variance explained by the model. For M2, M3 and M4, estimated marginal means (EMMs) were used to report effect sizes, with Bonferroni corrected contrasts, where better model fit occurred between fixed effects. Parameter estimates are reported as beta coefficient (β), with 95% confidence intervals (CI), and a P-value <0.05 indicating statistical significance. Data were analysed within R (v.3.6.3) using *lme4* [22] and *emmeans* [24] packages.

3. Results

3.1 Team locomotor responses (M1) : opponent ranking as a continuous predictor

Significant M1 models were observed for TD (β=-6.1 [95% CI, -10.2,-2.1]; $p=0.003$), HSR (β=-4.9 [-6.3,-3.5], $p<0.001$), sprint distance (β=-2.4 [-3.1,-1.8], $p<0.001$), sprint efforts (β=-0.10 [-0.13,-0.07], $p< 0.001$) and decelerations (β=-0.05 [-0.08,-0.04], $p<0.001$). No relationships were identified for total playing time (β=-0.01 [-0.02,-0.05], $p=0.51$) or LSR (β=-0.9 [-4.2, 2.3], $p=0.57$). For intensity variables, average speed (β=0.19 [-0.23,-0.15], $p<0.001$), HSR per min (β=-0.14 [-0.18,-0.11], $p<0.001$), sprint distance per min (β=-0.07 [-0.09,-0.05), $p<0.001$), sprint efforts per min (β=-0.003 [-0.004,-0.002], $p<0.001$), decelerations per min (β=-0.001 [-0.002,-0.001], $p<0.001$) and LSR per min (β=-0.05 [-0.07,-0.02], $p<0.001$), all revealed statistically significant models. Volume and intensity variables are displayed in Figure 1 and full reporting of models is contained within Supplementary Table 1.

3.2 Team locomotor responses (M2): group analysis

When analysed with predefined ranking group (LOWER, SIMILAR or HIGHER), significant M2 LMM ($p<0.05$) were identified for all volume and intensity locomotor variables (Table 1). Full model information is contained within Supplementary Table 2. Most volume and intensity variables revealed differences between all ranking group comparisons ($p<0.001$) (Figure 1). However for TD, EMM revealed only HIGHER to be greater than LOWER (β=-287 [-496,-79], $p=0.003$), with no differences *vs.* SIMILAR for both LOWER ($p=0.124$) or HIGHER ($p=0.06$). Similarly, there were no differences found within LSR (all $p>1.000$), although both LOWER (β=-2.1 [-3.4, -0.7]), $p<0.001$) and SIMILAR (β=-1.9 [-2.6, 1.1], $p<0.001$) were mostly higher than HIGHER for LSR per min. Finally, volume ($p=0.232$) and intensity ($p=1.000$) of decelerations were not different between LOWER and SIMILAR, however all other group comparisons revealed differences ($p<0.001$) for both volume and intensity.

Figure 1: Panel of scatter plots demonstrating the relationship between opponent world ranking (WR) and volume (panels A-G) and intensity (panels H-L) variables. Data points assigned to HIGHER, SIMILAR and LOWER groups, are shown in red, yellow and green colours, respectively.

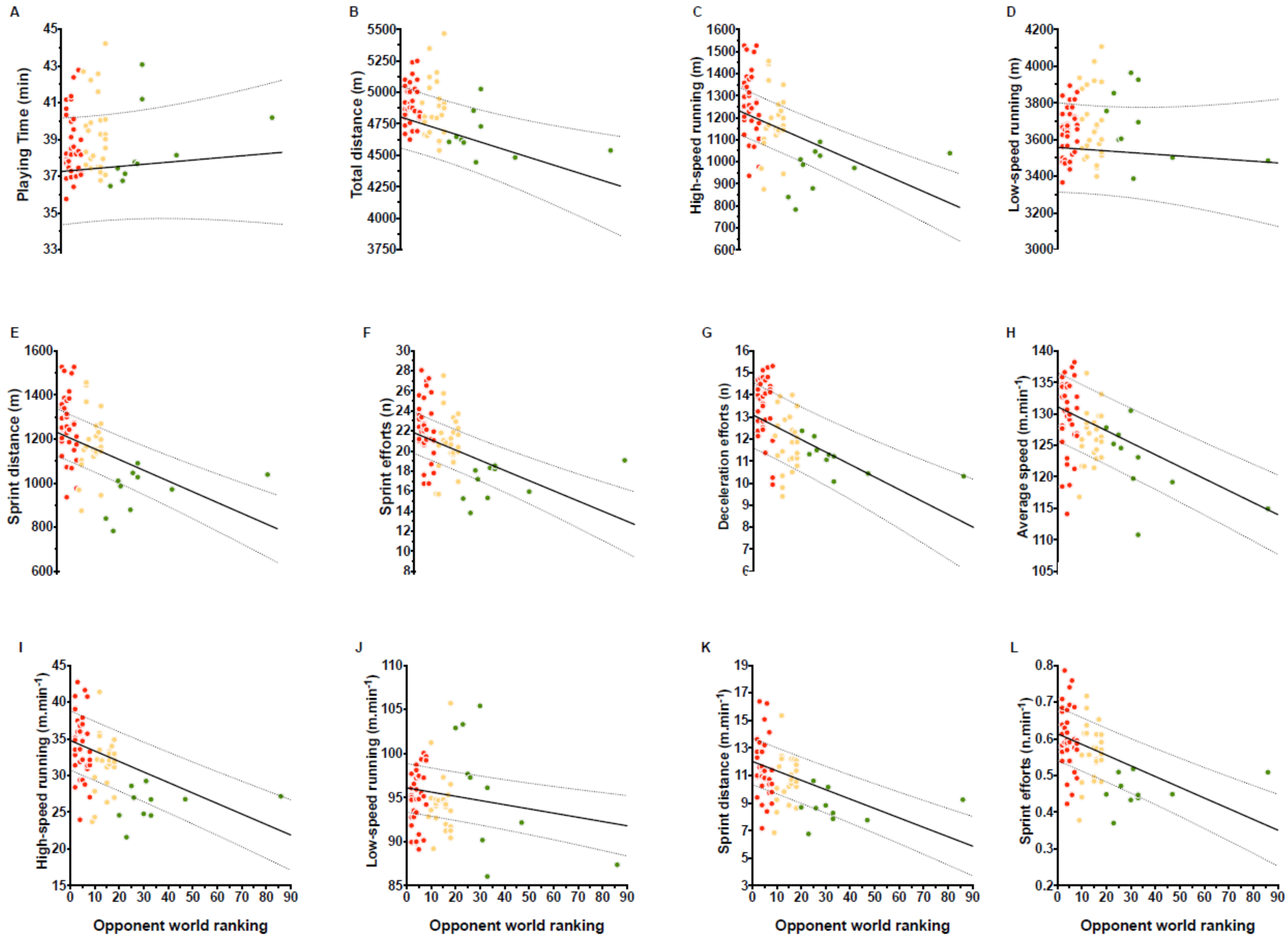


Figure 2: Mean volume and intensity of locomotor activity and opponent world ranking (WR), presented by ranking group (HIGHER, SIMILAR, LOWER). Where multiple matches took place against the same opponent, the mean of these is presented. A: Total distance (m), B: HSR distance (m), C: Sprint distance (m), D: Sprint efforts (n), E: Decelerations (n), F: Average speed ($m.min^{-1}$) G: HSR distance ($m.min^{-1}$), H: Sprint distance ($m.min^{-1}$), I: Sprint efforts ($n.min^{-1}$), J: Deceleration efforts ($n.min^{-1}$). Differences (%) between group average and grand mean are annotated beside relevant group data.

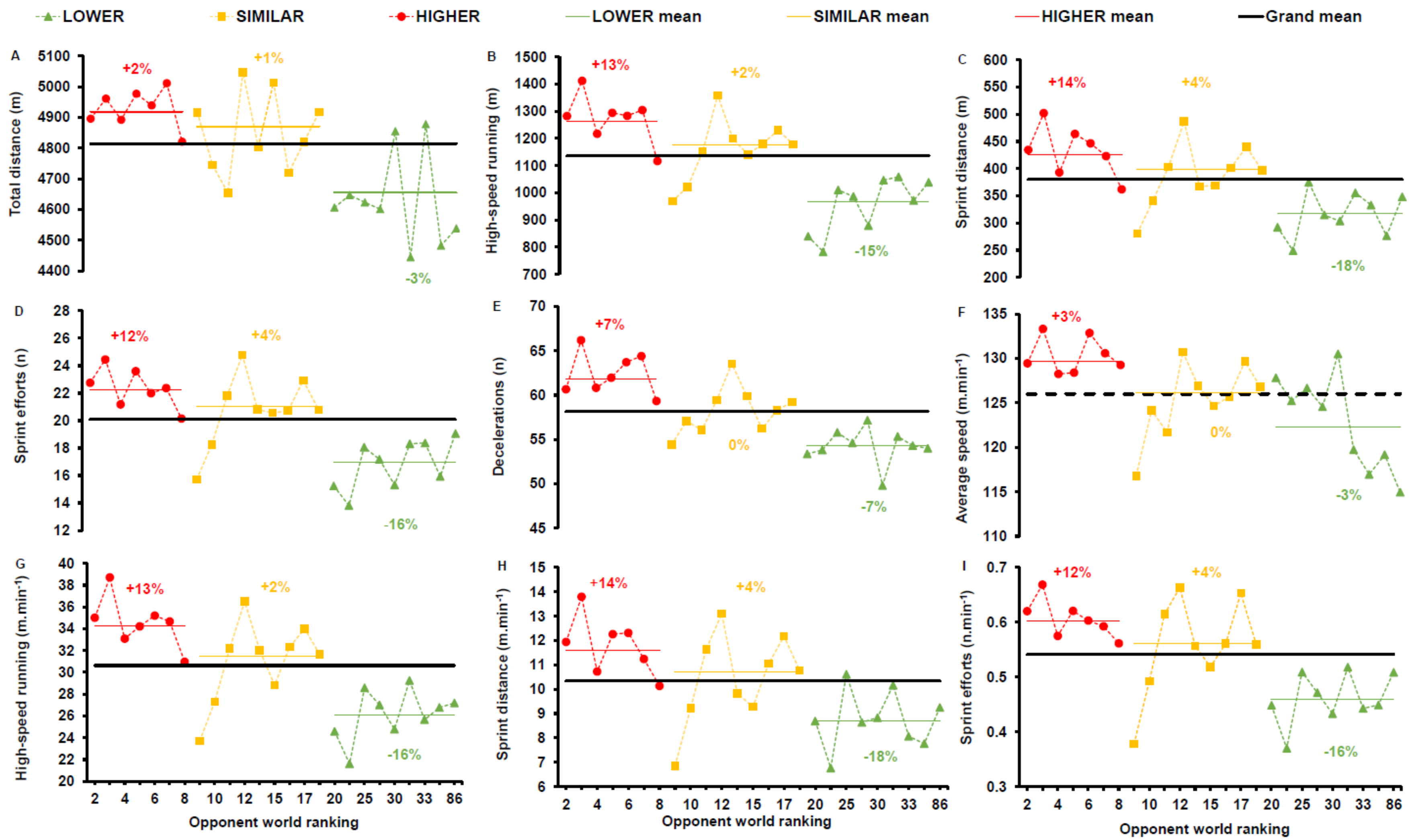


Table 1: Descriptive data for volume and intensity metrics, presented by ranking groups, with statistical outcomes for between group comparisons. * denotes difference between group (p<0.05). Final column – percentage change is presented relative to the first stated group.

1	WR group	Mean ± SD	% Δ *vs.* grand mean		Group comparison	P value	T value	Effect size [95% CI]	% Δ between ranking groups
Total Distance (m)	LOWER	4655 ± 930	-3%		Lower vs Similar	0.124	-2.05	-0.23 [-0.46, 0.00]	-4%
	SIMILAR	4851 ± 873	1%		Similar vs Higher	0.060	-2.33	-0.19 [-0.35, -0.02]	-2%
	HIGHER	4926 ± 836	2%		Lower vs Higher *	0.003	-3.32	-0.42 [-0.67, -0.16]	-6%
High-speed running (m)	LOWER	961 ± 281	-15%		Lower vs Similar *	0.001	-5.46	-0.63 [-0.87, -0.40]	-21%
	SIMILAR	1162 ± 319	2%		Similar vs Higher *	0.001	-4.87	-0.34 [-0.56, -0.23]	-10%
	HIGHER	1280 ± 312	13%		Lower vs Higher *	0.001	-7.81	-1.03 [-1.30, -0.76]	-33%
Low-speed running (m)	LOWER	3684 ± 851	0%		Lower vs Similar	1.000	0.08	0.01 [-0.22, -0.24]	0%
	SIMILAR	3679 ± 791	0%		Similar vs Higher	1.000	-0.97	-0.08 [-0.24, -0.09]	1%
	HIGHER	3638 ± 742	-1%		Lower vs Higher	1.000	-5.33	-0.07 [-1.32, -0.19]	1%
Sprint distance (m)	LOWER	311 ± 115	-18%		Lower vs Similar *	0.001	-5.97	-0.69 [-0.93, -0.45]	-26%
	SIMILAR	393 ± 146	4%		Similar vs Higher *	0.001	-4.33	-0.35 [-0.52, -0.19]	-10%
	HIGHER	432 ± 139	14%		Lower vs Higher *	0.001	-7.92	-1.05 [-1.32, -0.77]	-39%
Sprint efforts (n)	LOWER	17 ± 6	-16%		Lower vs Similar *	0.001	-5.49	-0.63 [-0.87, -0.34]	-23%
	SIMILAR	21 ± 7	4%		Similar vs Higher *	0.001	-3.89	-0.36 [-0.48, -0.15]	-8%
	HIGHER	23 ± 7	12%		Lower vs Higher *	0.001	-7.25	-0.95 [-1.22, -0.69]	-34%
Decelerations (n)	LOWER	54 ± 13	-7%		Lower vs Similar	0.232	-1.77	-0.18 [-0.39, -0.04]	-7%
	SIMILAR	58 ± 14	0%		Similar vs Higher *	0.001	-5.09	-0.36 [-0.51, -0.20]	-7%
	HIGHER	62 ± 14	7%		Lower vs Higher *	0.001	-5.58	-0.54 [-0.76, -0.31]	-15%
Intensity									
Average speed (m.min^{-1})	LOWER	122 ± 13	-3%		Lower vs Similar *	0.002	-3.40	-0.71 [-0.94, -0.47]	-4%
	SIMILAR	127 ± 14	0%		Similar vs Higher *	0.001	-7.54	-0.60 [-0.77, -0.44]	-2%
	HIGHER	130 ± 15	3%		Lower vs Higher *	0.001	-9.08	-1.31 [-1.58, -1.03]	-6%
High-speed running (m.min^{-1})	LOWER	26 ± 8	-16%		Lower vs Similar *	0.001	-7.20	-0.84 [-1.08, -0.60]	-21%
	SIMILAR	31 ± 10	2%		Similar vs Higher *	0.001	-4.94	-0.41 [-0.57, -0.23]	-10%
	HIGHER	35 ± 11	13%		Lower vs Higher *	0.001	-9.36	-1.24 [-1.52, -0.97]	-34%
Low-speed running (m.min^{-1})	LOWER	96 ± 10	1%		Lower vs Similar	1.000	-0.39	-0.05 [-0.28, -0.19]	1%
	SIMILAR	95 ± 7	0%		Similar vs Higher *	0.001	-5.43	-0.45 [-0.61, -0.28]	0%
	HIGHER	95 ± 7	0%		Lower vs Higher *	0.001	-3.68	-0.49 [-0.76, -0.22]	1%
Sprint distance (m.min^{-1})	LOWER	8 ± 4	-18%		Lower vs Similar *	0.001	-6.75	-0.79 [-1.02, -0.55]	-26%
	SIMILAR	11 ± 5	4%		Similar vs Higher *	0.001	-3.83	-0.31 [-0.48, -0.15]	-10%
	HIGHER	12 ± 4	14%		Lower vs Higher *	0.001	-8.28	-1.10 [-1.37, -0.83]	-38%
Sprint efforts (n.min^{-1})	LOWER	0.5 ± 0.2	-16%		Lower vs Similar *	0.001	-6.57	-0.76 [-1.00, -0.53]	-23%
	SIMILAR	0.6 ± 0.2	4%		Similar vs Higher *	0.001	-3.84	-0.31 [-0.48, -0.15]	-9%
	HIGHER	0.6 ± 0.2	12%		Lower vs Higher *	0.001	-8.15	-1.07 [-1.35, -0.81]	-34%
Decelerations (n.min^{-1})	LOWER	1.4 ± 0.4	-6%		Lower vs Similar	1.000	-0.96	-0.11 [-0.33, 0.12]	-6%
	SIMILAR	1.5 ± 0.4	0%		Similar vs Higher *	0.001	-5.23	-0.40 [-0.56, -0.25]	-7%
	HIGHER	1.6 ± 0.4	7%		Lower vs Higher *	0.001	-4.29	-0.51 [-0.75, -0.27]	-14%

* denotes difference between group (p<0.05). Final column – percentage change is presented relative to the first stated group.

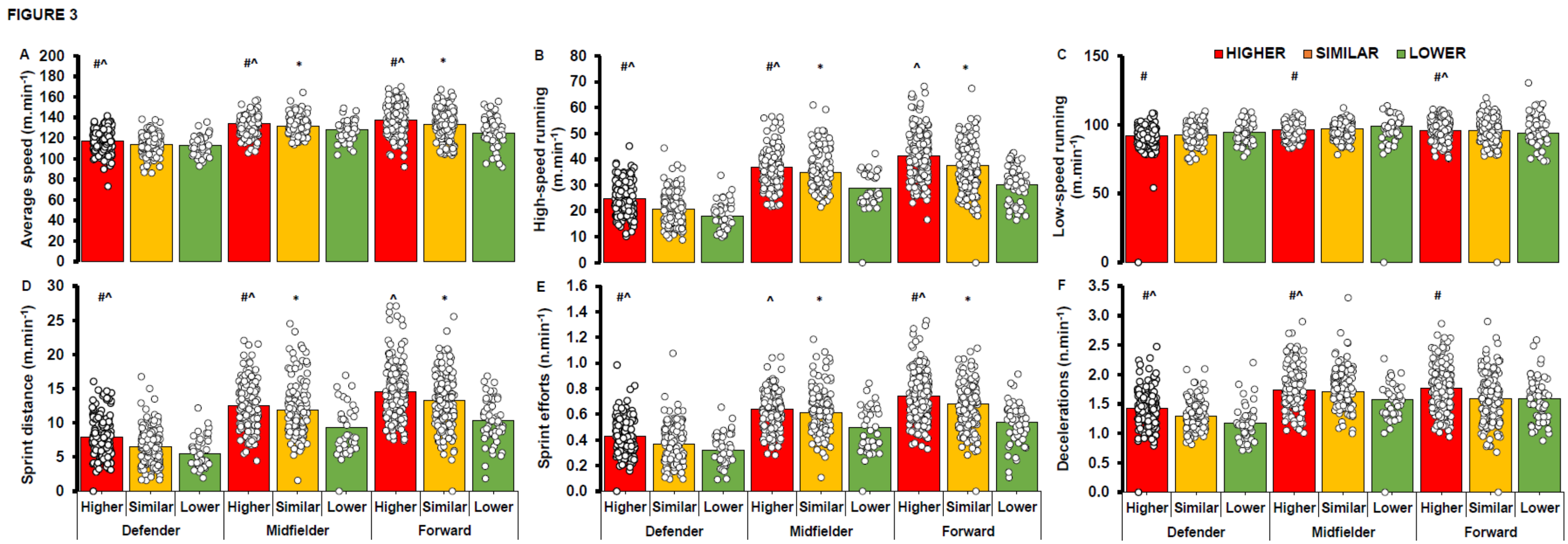
3.3 Positional locomotor responses (M3)

Within DEFs, EMM generated contrasts revealed differences between SIMILAR and HIGHER for all volume and intensity variables (all $p<0.02$), aside from LSR ($p=0.641$) (Figure 3). Differences were also found between LOWER and HIGHER for all variables (all $p<0.001$), aside of total distance ($p=0.061$) and LSR ($p=1.000$). However, no differences were found in any variables between LOWER and SIMILAR opponents.

For MIDs, aside of sprint efforts ($p=0.112$), all intensity variables displayed differences between SIMILAR and HIGHER (all $p<0.02$). Decelerations were the only volume metric to show a difference between SIMILAR and HIGHER, with more decelerations completed against opponents in HIGHER ($p=0.005$). All variables displayed differences between LOWER and HIGHER (all $p\leq0.01$), apart from TD ($p=1.000$), LSR ($p=0.248$), LSR per min ($p=0.115$) and total decelerations ($p=0.094$). MIDs' locomotor activity differed between LOWER and SIMILAR, for all variables (all $p\leq0.01$), apart from TD ($p=1.000$), LSR ($p=1.000$), LSR per min ($p=1.000$), decelerations ($p=1.000$) and decelerations per min ($p=1.000$).

For FWDs, only decelerations ($p=0.046$), average speed ($p<0.001$), LSR per min ($p=0.001$), number of sprints per min ($p=0.026$) and decelerations per min ($p=0.004$) were different between SIMILAR and HIGHER. All variables revealed differences between LOWER and HIGHER ($p<0.001$), apart from LSR ($p=0.089$) and decelerations per min ($p=0.056$). All variables were different between SIMILAR and LOWER (all $p<0.002$) apart from LSR (volume: $p=0.224$, intensity: $p=0.279$) and decelerations (both volume and intensity: $p=1.000$). Positional comparisons are displayed in Figure 3 and models reported within Supplementary Table 3.

Figure 3: Mean volume and intensity of locomotor activity presented by position (DEF, MID and FWD) and opponent world ranking (HIGHER, SIMILAR, LOWER). Panels represent A: Average speed (m.min^{-1}), B Sprint distance (m.min^{-1}), C: HSR distance (m.min^{-1}), D: Sprint efforts (n.min^{-1}), E: LSR (m.min^{-1}) and F: Deceleration efforts (n.min^{-1}).

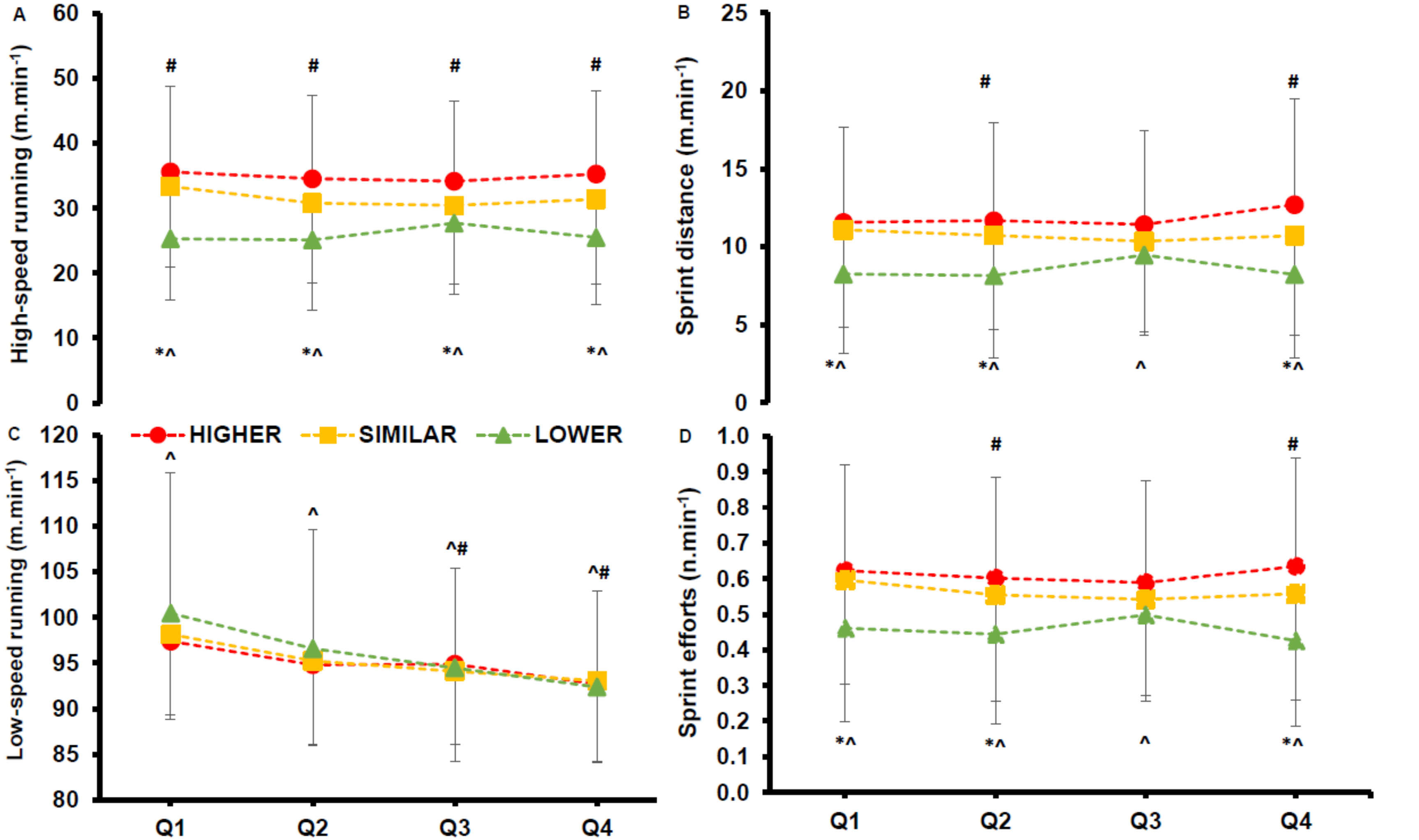


*Significant differences (p<0.05) are denoted by: * between LOWER and SIMILAR, ^ between LOWER and HIGHER, and, # between SIMILAR and HIGHER.*

3.4 Locomotor responses across playing quarters (M4)

The interaction of ranking group and playing quarter improved the model fit for sprint distance (volume and intensity), sprint efforts (volume and intensity), HSR per min and LSR per min. Differences were found across all four playing quarters between LOWER and HIGHER for sprint distance and sprint efforts (both volume and intensity: $p<0.001$). For sprint variables, Q2 and Q4 revealed the most differences between ranking groups (Figure 4). For HSR per min, differences were found between all ranking groups, across all playing quarters, with the largest differences appearing between Q1 and Q4, with Q1 greater than Q4. LSR per min was greatest when playing LOWER teams during Q1 and Q2, but comparable to SIMILAR and HIGHER during Q3 and Q4. No interactions were found between ranking and playing quarters for total distance, HSR, LSR, average speed or decelerations (volume and intensity). Playing quarter comparisons are displayed in Figure 4 and models within Supplementary Table 4.

Figure 4: Mean and SD of intensity of locomotor activity across match quarters (Q1-Q4) and opponent world ranking (WR). Plotted variables all revealed interaction effects between ranking group and playing quarter (p<0.05). HIGHER = red, SIMILAR = yellow, and, LOWER = green. Q = quarter.



*Significant differences (P<0.05) are denoted by: * between LOWER and SIMILAR, ^ between LOWER and HIGHER, and, # between SIMILAR and HIGHER.*

4. Discussion

In agreement with our first hypothesis, high-speed activities (HSR, sprint distances and sprint efforts) demonstrated the best fitting models with opponent ranking. Playing higher-ranked opponents resulted in considerably more high-speed activity (Figure 1, Table 1). Conversely, total and low-speed distances were not different. Aside from TD, LSR and decelerations, differences were evident across all locomotor variables between each of LOWER, SIMILAR and HIGHER groups. Opponent ranking therefore modulates locomotor activity across ecologically relevant ranking groups. In contrast to our second hypothesis, FWDs and DEFs experienced the largest increases and reductions in high-speed activities when facing teams in HIGHER or LOWER, respectively, compared with MIDs. In support of our third hypothesis, the largest differences in high-speed activities between HIGHER and LOWER-ranked opponents occurred during Q4.

4.1 Whole match patterns

High-speed activities of the team (volume and intensity of HSR and sprinting), were 12-14% greater against higher-ranked teams (WR #1-8), compared to the grand mean (Table 1). Furthermore, when comparing between ranking groups, high-speed activities were 8-10% lower against SIMILAR teams, compared with the HIGHER teams (Table 1). The largest differences were found between the LOWER and HIGHER groups, whereby high-speed activities reduced by 33-39% against LOWER compared with HIGHER teams. As total playing time did not differ across ranking groups, volume and intensity variables revealed broadly comparable responses. Increased locomotor activity against higher-ranked opponents is broadly supported by previous hockey [7, 14, 15] and soccer [25] research. It is noteworthy that hockey presents similar patterns to other team-sports, despite a different match structure (i.e. four playing quarters and six outfield, 'rolling' substitutions) and a greater playing intensity [26]. However, observing greater locomotor demands from matches against higher-, rather than similarly-ranked opponents, is not universal within hockey [7] nor soccer [16]. When a ranking offset occurs and/or possession is dominated by the higher-ranked opponent, coaches may implement defensive tactical positioning to intentionally limit locomotor activity of their team [16]. Coaches of higher-ranked teams may even intentionally accentuate this effect, by retaining the ball for longer periods against lower-ranked opponents [25]. Conversely, matches against similarly-ranked opponents may provide greater equality of attacking and defending activity [27]. Accordingly, data from the fifth-place team of the Scottish Hockey league, revealed the greatest activity occurred against the third-placed team, with this reducing against the top two sides [7]. It should be acknowledged that White and Macfarlane [7] drew their conclusions from eight matches within a nine-team league, compared with the larger sample of 71 matches analysed in our present study. Furthermore, the range of opponents (WR #1-86) we have included in our analysis may be considered a strength, whereby 24 opponents were faced across a 2-year period of elite international hockey. In summary, our data indicate that players experience the greatest locomotor demands when playing against HIGHER (HSR per min +12%), compared with SIMILAR teams (HSR per min +3%), *vs*. the grand mean (Figure 2).

4.2 Positional differences

In contrast to our second hypothesis, we found the largest differences in the activity of FWDs against different opponents. Against HIGHER, FWD's average speed was 4% greater than the positional mean, but was 6% less against LOWER. Conversely, differences in average speed for MIDs and DEFs were comparable against HIGHER (+2%) and LOWER (-2%) teams. We have previously shown the smallest worthwhile change in average speed to be 3% [3]. The larger differences observed in FWDs' activity contrast with recent data showing the locomotor activity of FWDs to be maintained irrespective of ball possession status [18]. This likely reflects FWDs undertaking 'pressing' activities without ball possession, often covering large distances at high speeds [18] or undertaking considerable locomotor activity to help create attacking opportunities [28]. Our data contrast with those of the New Zealand team from the previous match format, where smaller differences in locomotor activity of FWDs vs. the grand mean, against higher-ranked opposition (up to 8%), than MIDs (up to 10%) or DEFs (up to 18.5%) were observed [15]. It should be noted therefore that changes in the activity of FWDs when facing higher-ranked opponents may vary between teams. Likely contributing factors may include; the structure and frequency of FWDs' rotation schedule [29] and pressing style (e.g. half / full-court press). It is also important to again acknowledge the larger range of opponents within our sample (up to WR #86), compared with previous literature (up to WR# 18 [18], up to WR# [15]) which may include matches with one-sided possession or score-lines, factors that appear to influence locomotor activity in hockey [15] and other team-sports [30].

For all positions, differences were found in high-, rather than low-speed activities. For example, FWDs undertook 13-14% more high-speed activities against HIGHER teams and 18-19% less against LOWER teams (Figure 3, Supplementary Table 3), *vs*. the positional average. There were also notable differences in DEF for high-speed activities *vs*. the DEF mean (+17-20% vs. HIGHER, -15-18% vs. LOWER), whilst differences for MIDs were smaller (+9-10% vs. HIGHER, -13-16% vs. LOWER). We have previously shown the activity of MIDs is similarly maintained across a range of temperatures, a well-established modulator of performance capacity [4]. For DEFs however, large differences have previously been reported against similar- and higher-ranked opposition, compared with lower-ranked hockey teams [15]. A key contributing factor to this pattern may be a coach's tactical approach, such as the individual marking of opposition players increasing running demands, compared with zonal defending [31].

4.3 Patterns across quarters

In accordance with our third hypothesis, we found more sprint activity against HIGHER and less sprint activity against LOWER in Q4. Against HIGHER teams, sprint distance increased by ~9-11% during Q4, compared with Q1-Q3. This may reflect situational factors, such as a losing score-line [15], or a form of pacing, given the match finish is approaching [32]. Whilst an interaction for HSR was observed, the magnitude of difference was modest. Moreover, model fit was only marginally improved by the interaction, in comparison to the differences found for positional comparisons (Supplementary Table 4). Therefore, coaches and sport scientists should note that across playing quarters, the differences between ranking groups, appear smaller than differences observed between positions. LSR displayed consistent reductions across all quarters, with the largest reduction occurring in LOWER between Q1 and Q4. Overall, we found LSR to be most affected by opponent ranking across playing quarters, but the increase in sprint activity during Q4 against HIGHER should be noted when preparing hockey players for high-ranked opponents.

4.4 Limitations

The current data are drawn from a single team and therefore, may reflect physical and tactical patterns specific to the Malaysian team. However, this also ensures consistency when comparing against a range of opponents. During the study period, the Malaysia team were ranked world number 11-12, which is above the median for the SIMILAR group (WR range: 9-17). This may incur some bias into our analysis against other similarly ranked teams. However, compared with the other teams contained within SIMILAR, Malaysia achieved fewer Olympic and comparable World Cup qualifications within the preceding two quadrennial cycles to this analysis. Therefore, these predefined ranking groups likely provide the most appropriate ecological context, with a considerable performance gap anecdotally expected *vs.* HIGHER, all of whom participate within the FIH Pro League – a tournament that enables regular matches against other leading nations. Moreover, another performance gap may be considered versus teams contained within LOWER, where in contrast to Malaysia, not all these countries having full-time international programmes. The teams comprising each group were appraised by experienced international coaches, based upon recent performances against the Malaysian team and ongoing scouting analysis of opponents. Furthermore, the performance outcomes against SIMILAR teams (13 wins, 3 draws, 13 losses) support this group composition. Therefore, we believe these classifications accurately characterise the standard of international teams and provide relevant comparisons for coaches. Within our sample, more matches were played against HIGHER teams, although the use of LMM helps to mitigate this effect.

Analysis of contextual factors within team-sports is evidently complex [7, 33] and future research should consider integrating additional contextual factors, such as ball possession, fixture location, environmental conditions, match score-line and result, within planned analyses.

4.5 Practical Applications

The greater demands players experience when competing against higher-ranked opponents occur predominantly in high-, rather than low-intensity activity. For the reference team in this study, going from a test series against a team ranked within LOWER (WR # >18), to attending a tournament predominantly comprising teams from SIMILAR (average +8 WR places), could result in ~20-30% greater high-intensity activities per game. Over a four-match tournament, this equates to an additional match load of cumulative sprinting alone. Therefore, on- and off-field training should prepare players for greater HSR and sprinting demands. For coaches, further considerations to manage these demands include player selection, prior exposure to representative chronic training load and match-day rotation structure. However, such considerations must complement tactical and technical strategies that coaches implement when playing higher-ranked teams, which may also seek to mitigate further increases in physical demands. Such strategies may be especially relevant during Q4 against higher-ranked opponents.

The positional patterns we identified have implications for sport scientists in the management of player loads and recovery practices, both before and during international tournaments. Midfielder demands were consistent throughout the tournament, whereas defenders and forwards appear to experience greater variation. As such, training and recovery programmes should prepare both defenders and forwards based upon data pertaining to HIGHER matches, rather than positional averages. By utilising the models from our analyses, practitioners can estimate a match-loading during critical taper periods, depending on the warm-up game opponent, allowing positional playing time to be managed, or the implementation of additional physical stimuli to be applied/withdrawn where necessary (e.g., additional HSR ‘top-ups’ or reduced HSR load).

5. Conclusion

Within international hockey, high-, but not low-speed activity is modulated by the ranking of the opponent. Matches against higher-ranked opponents demonstrate the highest match average speeds, with matches against lower-ranked opponents the lowest. Forwards and defenders, experience the greatest differences in these variables and therefore players in these positions may require the individualised training and recovery adjustments.

6. Figure Captions:

Figure 1: Panel of scatter plots demonstrating the relationship between opponent world ranking (WR) and volume (panels A-G) and intensity (panels H-L) variables. Data points assigned to HIGHER, SIMILAR and LOWER groups, are shown in red, yellow and green colours, respectively.

Figure 2: Mean volume and intensity of locomotor activity and opponent world ranking (WR), presented by ranking group (HIGHER, SIMILAR, LOWER). Where multiple matches took place against the same opponent, the mean of these is presented. A: Total distance (m), B: HSR distance (m), C: Sprint distance (m), D: Sprint efforts (n), E: Decelerations (n), F: Average speed ($m.min^{-1}$) G: HSR distance ($m.min^{-1}$), H: Sprint distance ($m.min^{-1}$), I: Sprint efforts ($n.min^{-1}$), J: Deceleration efforts ($n.min^{-1}$). Differences (%) between group average and grand mean are annotated beside relevant group data.

Figure 3: Mean volume and intensity of locomotor activity presented by position (DEF, MID and FWD) and opponent world ranking (HIGHER, SIMILAR, LOWER). Panels represent A: Average speed ($m.min^{-1}$), B Sprint distance ($m.min^{-1}$), C: HSR distance ($m.min^{-1}$), D: Sprint efforts ($n.min^{-1}$), E: LSR ($m.min^{-1}$) and F: Deceleration efforts ($n.min^{-1}$).

*Significant differences ($p<0.05$) are denoted by: * between LOWER and SIMILAR, ^ between LOWER and HIGHER, and, # between SIMILAR and HIGHER.*

Figure 4: Mean and SD of intensity of locomotor activity across match quarters (Q1-Q4) and opponent world ranking (WR). Plotted variables all revealed interaction effects between ranking group and playing quarter ($p<0.05$). HIGHER = red, SIMILAR = yellow, and, LOWER = green. Q = quarter.

*Significant differences ($P<0.05$) are denoted by: * between LOWER and SIMILAR, ^ between LOWER and HIGHER, and, # between SIMILAR and HIGHER.*

Supplementary Figure 1: Mean volume and intensity of locomotor activity presented by position (DEF, MID and FWD) and opponent world ranking (HIGHER, SIMILAR, LOWER). Panels represent A: Total distance (m), B: Sprint distance (m), C: HSR distance (m), D: Sprint efforts (n), E: LSR (m), and F: Decelerations (n).

7. Disclosure statement

The authors have no conflicts of interest to report.

8. Author contributions

CJ collected the data. All authors participated in conception of the study and planning the analyses. AD completed the analyses. All authors contributed to drafting the manuscript.

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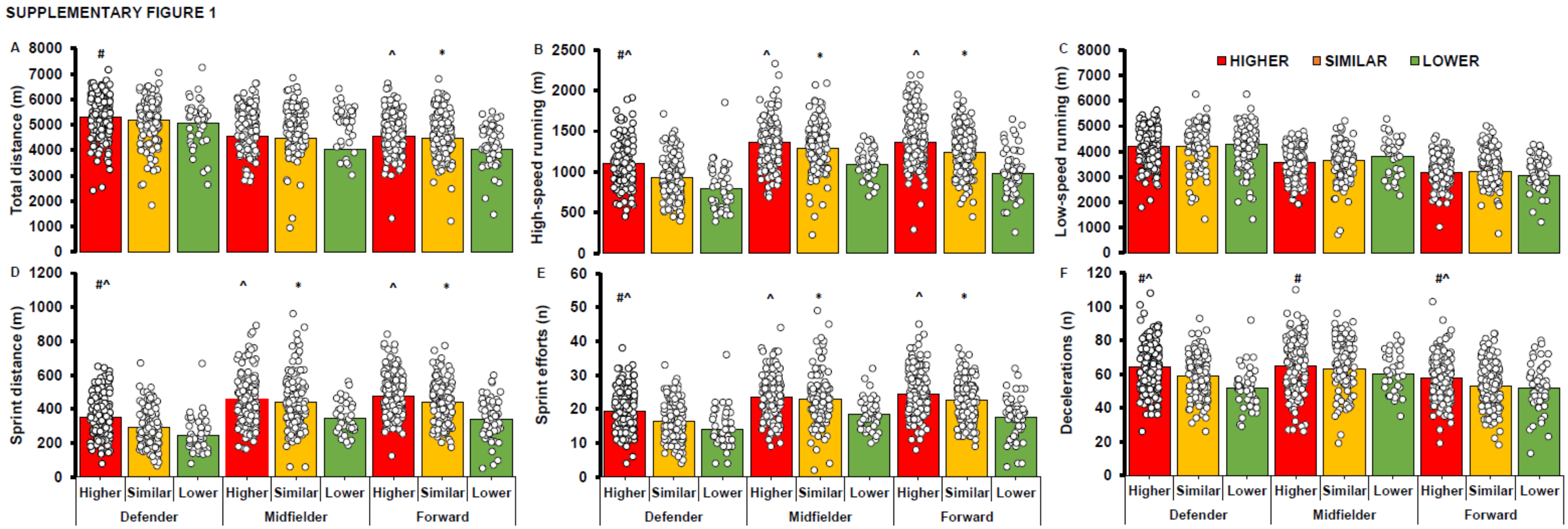
Supplementary Figure 1

Mean volume and intensity of locomotor activity presented by position (DEF, MID and FWD) and opponent world ranking (HIGHER, SIMILAR, LOWER).

Panels represent A: Total distance (m), B: Sprint distance (m), C: HSR distance (m), D: Sprint efforts (n), E: LSR (m), and F: Decelerations (n).



Supplementary Table 1

Linear mixed-model summaries for predicting locomotor activity, utilising opponent ranking as continuous variable, with both the tournament and player entered as random effects (M1). * represents the removal of tournament as a random effect in order to improve model fit.

Metric	β (standard error, 95% confidence interval)	t ratio	P value	Conditional R^2 Marginal R^2
Playing time (min)	0.01 (0.02, [-0.02, 0.05])	0.66	0.511	0.611 0.000
Total distance (m)	-6.11 (2.05, [-10.15, -2.05])	-2.98	0.003	0.433 0.007
High-speed running (m)	-4.87 (0.72, [-6.28, -3.45])	-6.78	<0.0001	0.520 0.035
Low-speed running (m)	-0.94 (1.64, [-4.16, 2.30])	-0.57	0.570	0.55 0.00
Sprinting distance (m)	-2.41 (0.34, [-3.07, -1.75])	-7.18	<0.0001	0.49 0.04
Sprinting efforts (n)	-0.1 (0.02, [-0.13, -0.07])	-6.06	<0.0001	0.420 0.034
Decelerations (n) *	-0.06 (0.01, [-0.08, -0.04])	-5.03	<0.0001	0.437 0.015
Average speed (m.min)	-0.19 (0.02, [-0.23, -0.15])	-8.88	<0.0001	0.79 0.03
High-speed running (m.min)	-0.14 (0.02, [-0.18, -0.11])	-8.32	<0.0001	0.76 0.03
Low-speed running (m.min)	-0.05 (0.01, [-0.07, -0.02])	-3.53	<0.0001	0.670 0.007
Sprinting distance (m.min)	-0.07 (0.01, [-0.09, -0.05])	-7.62	<0.0001	0.656 0.032
Sprinting efforts (n.min)	-0.003 (0, [-0.004, -0.002])	-6.83	<0.0001	0.620 0.028
Decelerations (n.min)	-0.001 (0, [-0.002, -0.001])	-4.00	<0.0001	0.407 0.013

Marginal R^2 represents the variance explained only by fixed effects. Conditional R^2 represents the variance explained by the entire model (i.e., both fixed effects and random effects) (Nakagawa and Schielzeth 2013).

Supplementary Table 2

Estimated marginal means contrasts and effect sizes for linear-mixed models utilising opponent ranking as a categorical variable and both tournament and individual player as random effects (M2). * represents the removal of tournament as a random effect in order to improve model fit.

Metric	Groups	β (standard error, 95% confidence interval)	t ratio	P value	Effect size [95% confidence interval]
Total Distance (m)	L-S	-160 (78, [-347, 7.71])	-2.05	0.124	-0.23 [-0.46, 0]
	L-H	-287 (86.6, [-496, -78.53])	-3.31	0.003	-0.42 [-0.67, -0.16]
	S-H	-128 (54.7, [-259, 3.76])	-2.33	0.060	-0.19 [-0.35, -0.02]
High-speed running (m)	L-S	-145.5 (26.7, [-209, -81.6])	-5.46	<0.0001	-0.63 [-0.87, -0.40]
	L-H	-236.7 (30.3, [-309, -164.1])	-7.81	<0.0001	-1.03 [-1.30, -0.76]
	S-H	-91.2 (18.7, [-136, -46.3])	-4.87	<0.0001	-0.34 [-0.56, -0.23]
Low-speed running (m)	L-S	4.96 (62.2, [-144, 154.2])	0.08	1.000	0.009 [-0.22, -0.24]
	L-H	-37.13 (69.6, [-204, 130.2])	-0.53	1.000	-0.07 [-1.32, -0.19]
	S-H	-42.09 (43.6, [-147, 62.5])	-0.97	1.000	-0.08 [-0.24, -0.09]
Sprinting distance (m)	L-S	-74.4 (12.46, [-104.2, -44.5])	-5.97	<0.0001	-0.69 [-0.93, -0.45]
	L-H	-112.3 (14.18, [-146.3, -78.3])	-7.92	<0.0001	-1.05 [-1.32, -0.77]
	S-H	-37.9 (8.75, [-58.9, -16.9])	-4.33	<0.0001	-0.35 [-0.52, -0.19]
Sprinting efforts (n)	L-S	-3.41 (0.62, [-4.9, -1.92])	-5.49	<0.0001	-0.63 [-0.87, -0.34]
	L-H	-5.1 (0.70, [-6.79, -3.41])	-7.25	<0.0001	-0.95 [-1.22, -0.69]
	S-H	-1.69 (0.44, [-2.74, -0.65])	-3.89	0.0003	-0.36 [-0.48, -0.15]
Decelerations (n) *	L-S	-0.75 (0.42, [-1.76, 0.27])	-1.77	0.2300	-0.18 [-0.39, -0.04]
	L-H	-2.26 (0.40, [-3.23, -1.29])	-5.58	<0.0001	-0.54 [-0.76, -0.31]
	S-H	-1.51 (0.30, [-2.23, -0.80])	-5.09	0.0003	-0.36 [-0.51, -0.20]
Average speed (m.min)	L-S	-4.77 (0.79, [-6.66, -2.88])	-6.05	<0.0001	-0.71 [-0.94, -0.47]
	L-H	-8.85 (0.90, [-11.01, -6.69])	-9.84	<0.0001	-1.31 [-1.58, -1.03]
	S-H	-4.08 (0.55, [-5.41, -2.75])	-7.37	<0.0001	-0.60 [-0.77, -0.44]
High-speed running (m.min)	L-S	-4.56 (0.62, [-6.08, -3.04])	-7.20	<0.0001	-0.84 [-1.08, -0.60]
	L-H	-6.76 (0.70, [-8.49, -5.03])	-9.36	<0.0001	-1.24 [-1.52, -0.97]
	S-H	-2.20 (0.44, [-3.27, -1.13])	-4.94	<0.0001	-0.41 [-0.57, -0.23]
Low-speed running (m.min)	L-S	-0.19 (0.45, [-1.39, 1.00])	-0.39	1.0000	-0.05 [-0.28, -0.19]
	L-H	-2.10 (0.57, [-3.47, -0.73])	-3.68	0.0007	-0.49 [-0.76, -0.22]
	S-H	-1.91 (0.35, [-2.75, -1.06])	-5.43	<0.0001	-0.45 [-0.61, -0.28]
Sprinting distance (m.min)	L-S	-2.24 (0.33, [-3.04, -1.45])	-6.74	<0.0001	-0.79 [-1.02, -0.55]
	L-H	-3.13 (0.34, [-4.04, -2.24])	-8.28	<0.0001	-1.10 [-1.37, -0.83]
	S-H	-0.89 (0.23, [-1.45, -0.33])	-3.83	0.0004	-0.31 [-0.48, -0.15]
Sprinting efforts (n.min)	L-S	-0.10 (0.02, [-0.14, -0.07])	-0.07	<0.0001	-0.76 [-1.00, -0.53]
	L-H	-0.14 (0.02, [-0.18, -0.10])	-0.10	<0.0001	-1.07 [-1.35, -0.81]
	S-H	-0.04 (0.01, [-0.07, -0.02])	-0.02	0.0004	-0.31 [-0.48, -0.15]
Decelerations (n.min)	L-S	-0.01 (0.01, [-6.08, -3.04])	-0.02	1.000	-0.11 [-0.33, 0.12]
	L-H	-0.06 (0.01, [-8.49, -5.03])	-0.03	0.0001	-0.51 [-0.75, -0.27]
	S-H	-0.05 (0.01, [-3.27, -1.13])	-0.03	<0.0001	-0.40 [-0.56, -0.25]

Footnote: L = 'LOWER' ranked teams (world rankings 18-66), S = 'SIMILAR' ranked teams (world rankings 9-17) and H = 'HIGHER' ranked teams (world rankings 1-8).

Supplementary Table 3

Within positional Contrasts using Estimated Marginal Means. Models generated with ranking group and playing position as fixed effects and both tournament and individual player as random effects (M3). * represents the removal of tournament as a random effect in order to improve model fit.

Metric	Position	Groups	β (standard error, 95% confidence interval)	t ratio	P value	Effect size [95% confidence interval]
Total distance (m)	DEF	L-S	-58.4(123.6, [-355, 238.04])	-0.473	1.0000	-0.0839(0.18, [-0.437, 0.269])
		L-H	-291.8(125.5, [-593, 9.25])	-2.326	0.0609	-0.4237(0.183, [-0.782, -0.065])
		S-H	-233.4(86.6, [-441, -25.72])	-2.695	0.0215	-0.3398(0.126, [-0.587, -0.0922])
	MID	L-S	23.3(122.1, [-269, 316.12])	0.191	1.0000	0.0359(0.178, [-0.313, 0.3843])
		L-H	-27.4(126.2, [-330, 275.51])	-0.217	1.0000	-0.0389(0.184, [-0.399, 0.3215])
		S-H	-50.7(84.7, [-254, 152.38])	-0.599	1.0000	-0.0747(0.123, [-0.316, 0.167])
	FWD	L-S	-405(117.5, [-687, -123.16])	-3.446	0.0018	-0.5875(0.171, [-0.924, -0.2512])
		L-H	-513.5(120.5, [-803, -224.46])	-4.263	0.0001	-0.7473(0.176, [-1.093, -0.4018])
		S-H	-108.6(84.3, [-311, 93.55])	-1.288	0.5941	-0.1598(0.123, [-0.4, 0.0808])
High-speed running (m)	DEF	L-S	-70.7(41.5, [-170, 28.88])	-1.702	0.2671	-0.309(0.182, [-0.666, 0.0475])
		L-H	-221.6(42.7, [-324, -119.24])	-5.19	<.0001	-0.97(0.188, [-1.339, -0.6011])
		S-H	-151(29.1, [-221, -81.18])	-5.187	<.0001	-0.661(0.128, [-0.912, -0.4093])
	MID	L-S	-123.7(41.1, [-222, -25.13])	-3.009	0.008	-0.541(0.18, [-0.895, -0.1876])
		L-H	-184(43.1, [-287, -80.75])	-4.274	0.0001	-0.805(0.189, [-1.177, -0.434])
		S-H	-60.3(28.5, [-129, 8.01])	-2.117	0.1036	-0.264(0.125, [-0.509, -0.019])
	FWD	L-S	-228.6(39.5, [-323, -133.96])	-5.793	<.0001	-1(0.174, [-1.342, -0.659])
		L-H	-292.4(41, [-391, -194.16])	-7.136	<.0001	-1.28(0.181, [-1.636, -0.9239])
		S-H	-63.9(28.3, [-132, 4.11])	-2.253	0.0734	-0.279(0.124, [-0.523, -0.0358])
Sprinting distance (m)	DEF	L-S	-36(19.4, [-82.7, 10.56])	-1.854	0.1919	-0.337(0.182, [-0.694, 0.0199])
		L-H	-93.1(20, [-141, -45.1])	-4.652	<.0001	-0.87(0.188, [-1.239, -0.5014])
		S-H	-57(13.6, [-89.7, -24.35])	-4.185	0.0001	-0.533(0.128, [-0.784, -0.2822])
	MID	L-S	-78.1(19.2, [-124.2, -31.98])	-4.06	0.0002	-0.731(0.181, [-1.085, -0.3762])
		L-H	-106.7(20.2, [-155, -58.33])	-5.291	<.0001	-0.998(0.19, [-1.37, -0.6253])
		S-H	-28.6(13.3, [-60.6, 3.42])	-2.141	0.0974	-0.267(0.125, [-0.512, -0.0221])
	FWD	L-S	-104.2(18.5, [-148.5, -59.92])	-5.642	<.0001	-0.975(0.174, [-1.316, -0.6332])
		L-H	-132.6(19.2, [-178.6, -86.54])	-6.907	<.0001	-1.24(0.181, [-1.596, -0.8837])
		S-H	-28.3(13.3, [-60.2, 3.47])	-2.136	0.0987	-0.265(0.124, [-0.509, -0.0213])
Sprinting efforts (n)	DEF	L-S	-1.591(0.971, [-3.92, 0.7379])	-1.638	0.3052	-0.297(0.182, [-0.654, 0.0591])
		L-H	-4.34(0.997, [-6.73, -1.9484])	-4.352	<.0001	-0.811(0.187, [-1.178, -0.4438])
		S-H	-2.749(0.681, [-4.38, -1.1174])	-4.039	0.0002	-0.514(0.128, [-0.764, -0.2633])
	MID	L-S	-3.793(0.961, [-6.1, -1.489])	-3.947	0.0003	-0.709(0.18, [-1.062, -0.3552])
		L-H	-4.631(1.005, [-7.04, -2.2209])	-4.608	<.0001	-0.865(0.189, [-1.236, -0.4951])
		S-H	-0.838(0.666, [-2.44, 0.7596])	-1.258	0.6265	-0.157(0.125, [-0.401, 0.0878])
	FWD	L-S	-4.619(0.923, [-6.83, -2.4057])	-5.005	<.0001	-0.863(0.173, [-1.204, -0.5228])
		L-H	-6.168(0.957, [-8.46, -3.8733])	-6.446	<.0001	-1.153(0.181, [-1.507, -0.7985])
		S-H	-1.549(0.663, [-3.14, 0.0399])	-2.338	0.0588	-0.289(0.124, [-0.533, -0.0462])

Decelerations (n) *	DEF	L-S	-1.7441(0.752, [-3.55, 0.0592])	-2.319	0.0617	-0.3887(0.171, [-0.724, -0.0534])
		L-H	-3.4534(0.712, [-5.16, -1.7471])	-4.853	<.0001	-0.8049(0.163, [-1.124, -0.4857])
		S-H	-1.7093(0.527, [-2.97, -0.4464])	-3.245	0.0036	-0.4161(0.12, [-0.651, -0.1815])
	MID	L-S	0.0856(0.732, [-1.67, 1.8412])	0.117	1.0000	-0.0166(0.165, [-0.341, 0.3075])
		L-H	-1.5346(0.712, [-3.24, 0.1719])	-2.156	0.0939	-0.3838(0.161, [-0.699, -0.0686])
		S-H	-1.6202(0.517, [-2.86, -0.3803])	-3.133	0.0053	-0.3672(0.117, [-0.597, -0.1371])
	FWD	L-S	-0.6155(0.714, [-2.33, 1.0958])	-0.862	1.0000	-0.1034(0.163, [-0.423, 0.216])
		L-H	-1.8423(0.684, [-3.48, -0.2027])	-2.694	0.0215	-0.4014(0.156, [-0.708, -0.0946])
		S-H	-1.2268(0.506, [-2.44, -0.0147])	-2.427	0.0462	-0.298(0.114, [-0.523, -0.0734])
Low-speed running (m)	DEF	L-S	29.3(97.9, [-205.4, 264.1])	0.299	1.0000	0.054(0.18, [-0.3, 0.408])
		L-H	-56(99.7, [-295.3, 183.3])	-0.561	1.0000	-0.1032(0.184, [-0.464, 0.2576])
		S-H	-85.3(68.6, [-249.8, 79.1])	-1.244	0.6414	-0.1572(0.126, [-0.4053, 0.0909])
	MID	L-S	166.8(96.7, [-65.2, 398.8])	1.724	0.2548	0.3074(0.178, [-0.0426, 0.6574])
		L-H	174.4(100.4, [-66.5, 415.3])	1.737	0.2482	0.3214(0.185, [-0.042, 0.6848])
		S-H	7.6(67.1, [-153.3, 168.5])	0.113	11.0000	0.014(0.124, [-0.2286, 0.2566])
	FWD	L-S	-156.4(93, [-379.5, 66.7])	-1.681	0.2791	-0.2883(0.172, [-0.6249, 0.0484])
		L-H	-208.6(95.8, [-438.3, 21.2])	-2.178	0.0891	-0.3843(0.177, [-0.7311, -0.0376])
		S-H	-52.1(66.8, [-212.2, 107.9])	-0.781	1.0000	-0.0961(0.123, [-0.3375, 0.1454])
Average speed (m.min)	DEF	L-S	-1.51(1.221, [-4.44, 1.42])	-1.238	0.6481	-0.225(0.182, [-0.583, 0.132])
		L-H	-6(1.258, [-9.02, -2.98])	-4.769	<.0001	-0.895(0.189, [-1.265, -0.525])
		S-H	-4.49(0.856, [-6.54, -2.44])	-5.242	<.0001	-0.669(0.128, [-0.921, -0.417])
	MID	L-S	-4.56(1.208, [-7.46, -1.66])	-3.776	0.0005	-0.68(0.181, [-1.035, -0.326])
		L-H	-8.74(1.269, [-11.78, -5.7])	-6.886	<.0001	-1.303(0.191, [-1.678, -0.928])
		S-H	-4.18(0.839, [-6.19, -2.16])	-4.977	<.0001	-0.623(0.126, [-0.869, -0.376])
	FWD	L-S	-7.84(1.16, [-10.62, -5.05])	-6.755	<.0001	-1.168(0.175, [-1.511, -0.825])
		L-H	-11.29(1.208, [-14.19, -8.4])	-9.35	<.0001	-1.684(0.184, [-2.044, -1.323])
		S-H	-3.46(0.834, [-5.46, -1.46])	-4.144	0.0001	-0.515(0.125, [-0.76, -0.27])
High-speed running (m.min)	DEF	L-S	-2.2(0.985, [-4.56, 0.163])	-2.232	0.0774	-0.406(0.182, [-0.764, -0.0488])
		L-H	-4.86(1.014, [-7.29, -2.425])	-4.788	<.0001	-0.898(0.188, [-1.268, -0.5279])
		S-H	-2.66(0.691, [-4.31, -1.003])	-3.851	0.0004	-0.491(0.128, [-0.743, -0.2402])
	MID	L-S	-6.49(0.936, [-8.74, -4.249])	-4.875	<.0001	-0.878(0.181, [-1.234, -0.5228])
		L-H	-8.07(0.974, [-10.4, -5.733])	-6.896	<.0001	-1.304(0.191, [-1.679, -0.9288])
		S-H	-1.58(0.673, [-3.19, 0.037])	-3.405	0.0021	-0.426(0.125, [-0.672, -0.1797])
	FWD	L-S	-7.84(1.16, [-10.62, -5.05])	-6.939	<.0001	-1.2(0.175, [-1.543, -0.8569])
		L-H	-11.29(1.208, [-14.19, -8.4])	-8.286	<.0001	-1.491(0.183, [-1.85, -1.1326])
		S-H	-3.46(0.834, [-5.46, -1.46])	-2.343	0.058	-0.291(0.124, [-0.536, -0.047])
Sprinting distance (m.min)	DEF	L-S	-1.114(0.517, [-2.35, 0.125])	-2.156	0.0939	-0.392(0.182, [-0.75, -0.03492])
		L-H	-2.138(0.532, [-3.41, -0.862])	-4.017	0.0002	-0.753(0.188, [-1.122, -0.38371])
		S-H	-1.024(0.362, [-1.89, -0.155])	-2.826	0.0144	-0.36(0.128, [-0.611, -0.10968])
	MID	L-S	-2.464(0.512, [-3.69, -1.238])	-4.817	<.0001	-0.867(0.181, [-1.223, -0.51223])
		L-H	-3.385(0.537, [-4.67, -2.099])	-6.308	<.0001	-1.192(0.191, [-1.566, -0.81759])
		S-H	-0.921(0.355, [-1.77, -0.07])	-2.595	0.0288	-0.324(0.125, [-0.57, -0.07868])

	FWD	L-S	-3.043(0.491, [-4.22, -1.865])	-6.196	<.0001	-1.071(0.174, [-1.413, -0.72886])
		L-H	-3.732(0.511, [-4.96, -2.507])	-7.307	<.0001	-1.314(0.182, [-1.671, -0.95658])
		S-H	-0.689(0.353, [-1.54, 0.157])	-1.953	0.1533	-0.243(0.124, [-0.487, 0.00136])
Sprinting efforts (n.min)	DEF	L-S	-0.0519(0.0246, [-0.111, 0.00713])	-2.108	0.1057	-0.383(0.182, [-0.74, -0.0262])
		L-H	-0.0984(0.0253, [-0.1592, -0.03767])	-3.884	0.0003	-0.726(0.188, [-1.094, -0.3581])
		S-H	-0.0465(0.0173, [-0.0879, -0.00508])	-2.692	0.0217	-0.343(0.128, [-0.593, -0.0925])
	MID	L-S	-0.1195(0.0244, [-0.178, -0.06109])	-4.904	<.0001	-0.882(0.181, [-1.237, -0.5272])
		L-H	-0.1548(0.0255, [-0.216, -0.09353])	-6.06	<.0001	-1.142(0.19, [-1.515, -0.7691])
		S-H	-0.0352(0.0169, [-0.0758, 0.00531])	-2.084	0.1123	-0.26(0.125, [-0.505, -0.0149])
	FWD	L-S	-0.1354(0.0234, [-0.1915, -0.07927])	-5.784	<.0001	-0.999(0.174, [-1.34, -0.6575])
		L-H	-0.1797(0.0243, [-0.238, -0.1214])	-7.39	<.0001	-1.326(0.182, [-1.682, -0.9695])
		S-H	-0.0443(0.0168, [-0.0846, -0.00398])	-2.635	0.0256	-0.327(0.124, [-0.571, -0.083])
Decelerations (n.min)	DEF	L-S	-0.03884(0.0214, [-0.0901, 0.012401])	-1.818	0.2082	-0.2865(0.179, [-0.638, 0.06457])
		L-H	-0.08293(0.0215, [-0.1346, -0.031263])	-3.855	0.0004	-0.6712(0.179, [-1.024, -0.3185])
		S-H	-0.04409(0.015, [-0.08, -0.008183])	-2.945	0.0099	-0.3847(0.125, [-0.631, -0.1386])
	MID	L-S	-0.0143(0.0211, [-0.0648, 0.036233])	-0.679	1.0000	-0.1217(0.175, [-0.465, 0.22198])
		L-H	-0.06363(0.0216, [-0.1155, -0.01172])	-2.945	0.0102	-0.5295(0.179, [-0.881, -0.17806])
		S-H	-0.04933(0.0146, [-0.0844, -0.014243])	-3.372	0.0023	-0.4077(0.123, [-0.649, -0.16687])
	FWD	L-S	-0.00163(0.0203, [-0.0503, 0.047086])	-0.08	1.0000	0.0632(0.171, [-0.273, 0.39919])
		L-H	-0.04882(0.0207, [-0.0985, 0.000813])	-2.362	0.0556	-0.3472(0.173, [-0.687, -0.00718])
		S-H	-0.04719(0.0146, [-0.0821, -0.01225])	-3.239	0.0037	-0.4104(0.122, [-0.65, -0.17111])
Low-speed running (m.min)	DEF	L-S	0.698(0.778, [-1.17, 2.564])	0.896	1.0000	0.1633(0.182, [-0.194, 0.5207])
		L-H	-1.138(0.803, [-3.06, 0.786])	-1.418	0.4693	-0.2663(0.188, [-0.635, 0.1023])
		S-H	-1.836(0.546, [-3.14, -0.527])	-3.363	0.0024	-0.4296(0.128, [-0.681, -0.1783])
	MID	L-S	0.196(0.77, [-1.65, 2.043])	0.254	1.0000	0.0458(0.18, [-0.308, 0.3995])
		L-H	-1.68(0.809, [-3.62, 0.261])	-2.075	0.1146	-0.3931(0.19, [-0.765, -0.0211])
		S-H	-1.875(0.535, [-3.16, -0.593])	-3.506	0.0014	-0.4388(0.126, [-0.685, -0.1926])
	FWD	L-S	-1.32(0.74, [-3.09, 0.453])	-1.785	0.2235	-0.3089(0.173, [-0.649, 0.0308])
		L-H	-3.261(0.77, [-5.11, -1.414])	-4.233	0.0001	-0.763(0.181, [-1.118, -0.4079])
		S-H	-1.94(0.532, [-3.22, -0.665])	-3.649	0.0008	-0.454(0.125, [-0.699, -0.2091])

Footnote: L = 'LOWER' ranked teams (world rankings 18-66), S = 'SIMILAR' ranked teams (world rankings 9-17) and H = 'HIGHER' ranked teams (world rankings 1-8).

DEF = Defenders, MID = midfielders, FWD = forwards.

Supplementary Table 4

Contrasts displaying between-quarter differences where linear mixed-model interaction term was significant. Models generated with ranking group and playing quarter as fixed effects and both tournament and individual player as random effects (M4).

Metric	Playing Quarter	Groups	β (standard error, 95% confidence interval)	t ratio	P value	Effect size [95% confidence interval]
Sprinting distance (m)	Q1	L-S	-19.86(4.68, [-31.1, -8.656])	-4.245	0.0001	-0.428(0.101, [-0.626, -0.2302])
		L-U	-25.08(4.77, [-36.5, -13.655])	-5.258	<.0001	-0.541(0.103, [-0.743, -0.3387])
		S-U	-5.21(3.27, [-13, 2.624])	-1.593	0.3337	-0.112(0.0706, [-0.251, 0.026])
	Q2	L-S	-23.58(4.67, [-34.8, -12.39])	-5.047	<.0001	-0.508(0.1009, [-0.706, -0.3106])
		L-U	-32.79(4.76, [-44.2, -21.384])	-6.887	<.0001	-0.707(0.1029, [-0.909, -0.5051])
		S-U	-9.21(3.28, [-17.1, -1.358])	-2.809	0.015	-0.198(0.0707, [-0.337, -0.0599])
	Q3	L-S	-7.74(4.7, [-19, 3.511])	-1.647	0.2986	-0.167(0.1013, [-0.365, 0.0317])
		L-U	-15.2(4.78, [-26.7, -3.741])	-3.177	0.0045	-0.328(0.1032, [-0.53, -0.1253])
		S-U	-7.46(3.28, [-15.3, 0.403])	-2.272	0.0694	-0.161(0.0708, [-0.3, -0.022])
	Q4	L-S	-22.9(4.69, [-34.1, -11.672])	-4.884	<.0001	-0.494(0.1012, [-0.692, -0.2953])
		L-U	-35.48(4.78, [-46.9, -24.041])	-7.43	<.0001	-0.765(0.1033, [-0.967, -0.5624])
		S-U	-12.58(3.28, [-20.4, -4.72])	-3.834	0.0004	-0.271(0.0708, [-0.41, -0.1324])
Sprinting efforts (n)	Q1	L-S	-0.881(0.228, [-1.428, -0.3334])	-3.854	0.0004	-0.389(0.1009, [-0.586, -0.19074])
		L-U	-1.135(0.233, [-1.692, -0.5783])	-4.882	<.0001	-0.501(0.1028, [-0.702, -0.29947])
		S-U	-0.255(0.16, [-0.637, 0.1278])	-1.594	0.3327	-0.112(0.0705, [-0.251, 0.02582])
	Q2	L-S	-0.945(0.228, [-1.492, -0.3992])	-4.145	0.0001	-0.417(0.1007, [-0.615, -0.21969])
		L-U	-1.436(0.232, [-1.992, -0.8801])	-6.186	<.0001	-0.634(0.1027, [-0.835, -0.43241])
		S-U	-0.491(0.16, [-0.874, -0.1075])	-3.067	0.0065	-0.216(0.0706, [-0.355, -0.07804])
	Q3	L-S	-0.372(0.229, [-0.921, 0.1772])	-1.622	0.3145	-0.164(0.1012, [-0.363, 0.03426])
		L-U	-0.693(0.233, [-1.252, -0.1341])	-2.97	0.009	-0.306(0.103, [-0.508, -0.10381])
		S-U	-0.321(0.16, [-0.705, 0.0629])	-2.002	0.1359	-0.142(0.0707, [-0.28, -0.00293])
	Q4	L-S	-1.184(0.229, [-1.732, -0.6356])	-5.172	<.0001	-0.522(0.1012, [-0.721, -0.32405])
		L-U	-1.633(0.233, [-2.19, -1.075])	-7.011	<.0001	-0.72(0.103, [-0.922, -0.5184])
		S-U	-0.449(0.16, [-0.832, -0.0653])	-2.803	0.0153	-0.198(0.0707, [-0.337, -0.05945])
High-speed running (m.min)	Q1	L-S	-6.49(0.876, [-8.59, -4.3966])	-7.416	<.0001	-0.749(0.1013, [-0.947, -0.5502])
		L-U	-8.05(0.893, [-10.18, -5.9066])	-9.009	<.0001	-0.928(0.1035, [-1.131, -0.7249])
		S-U	-1.55(0.612, [-3.02, -0.0856])	-2.535	0.0339	-0.179(0.0706, [-0.317, -0.0405])
	Q2	L-S	-5.05(0.874, [-7.14, -2.953])	-5.773	<.0001	-0.582(0.101, [-0.78, -0.3839])
		L-U	-7.84(0.892, [-9.98, -5.7096])	-8.799	<.0001	-0.905(0.1033, [-1.107, -0.7022])
		S-U	-2.8(0.613, [-4.27, -1.3298])	-4.563	<.0001	-0.323(0.0708, [-0.462, -0.1839])
	Q3	L-S	-2.36(0.879, [-4.46, -0.2522])	-2.682	0.022	-0.272(0.1014, [-0.471, -0.073])
		L-U	-4.76(0.896, [-6.91, -2.6147])	-5.314	<.0001	-0.549(0.1035, [-0.752, -0.3461])
		S-U	-2.4(0.614, [-3.87, -0.9322])	-3.912	0.0003	-0.277(0.0709, [-0.416, -0.1382])
	Q4	L-S	-5.16(0.877, [-7.27, -3.0629])	-5.886	<.0001	-0.595(0.1014, [-0.794, -0.3968])
		L-U	-7.22(0.894, [-9.36, -5.0756])	-8.071	<.0001	-0.832(0.1035, [-1.035, -0.6293])
		S-U	-2.05(0.614, [-3.52, -0.5833])	-3.345	0.0025	-0.237(0.0708, [-0.376, -0.0979])
Sprinting distance (m.min)	Q1	L-S	-2.63(0.513, [-3.86, -1.4004])	-5.123	<.0001	-0.5172(0.1011, [-0.715, -0.319])
		L-U	-3.023(0.523, [-4.28, -1.7696])	-5.776	<.0001	-0.5945(0.1031, [-0.797, -0.3924])
		S-U	-0.393(0.359, [-1.25, 0.4666])	-1.095	0.8207	-0.0774(0.0706, [-0.216, 0.061])
	Q2	L-S	-2.674(0.513, [-3.9, -1.4461])	-5.216	<.0001	-0.5257(0.1009, [-0.724, -0.3279])

		L-U	-3.703(0.523, [-4.95, -2.4514])	-7.086	<.0001	-0.7281(0.103, [-0.93, -0.5262])
		S-U	-1.029(0.36, [-1.89, -0.1681])	-2.862	0.0127	-0.2024(0.0707, [-0.341, -0.0638])
	Q3	L-S	-1.21(0.515, [-2.44, 0.0242])	-2.348	0.0568	-0.238(0.1013, [-0.437, -0.0393])
		L-U	-1.998(0.525, [-3.26, -0.7406])	-3.805	0.0004	-0.393(0.1033, [-0.596, -0.1905])
		S-U	-0.788(0.36, [-1.65, 0.0744])	-2.188	0.0861	-0.155(0.0708, [-0.294, -0.0162])
	Q4	L-S	-2.605(0.514, [-3.84, -1.3726])	-5.063	<.0001	-0.5122(0.1013, [-0.711, -0.3136])
		L-U	-4.087(0.524, [-5.34, -2.8318])	-7.798	<.0001	-0.8037(0.1034, [-1.006, -0.601])
		S-U	-1.482(0.36, [-2.34, -0.6205])	-4.119	0.0001	-0.2915(0.0708, [-0.43, -0.1526])
Sprinting efforts (n.min)	Q1	L-S	-0.1147(0.0241, [-0.1725, -0.05688])	-4.752	<.0001	-0.479(0.101, [-0.677, -0.2813])
		L-U	-0.1419(0.0246, [-0.2007, -0.08297])	-5.769	<.0001	-0.593(0.103, [-0.795, -0.3911])
		S-U	-0.0272(0.0169, [-0.0676, 0.01324])	-1.61	0.3221	-0.114(0.0705, [-0.252, 0.0247])
	Q2	L-S	-0.1168(0.0241, [-0.1745, -0.0591])	-4.848	<.0001	-0.488(0.1008, [-0.686, -0.2905])
		L-U	-0.1692(0.0245, [-0.228, -0.11045])	-6.894	<.0001	-0.707(0.1029, [-0.909, -0.5057])
		S-U	-0.0524(0.0169, [-0.0929, -0.01196])	-3.103	0.0058	-0.219(0.0707, [-0.358, -0.0806])
	Q3	L-S	-0.0513(0.0242, [-0.1093, 0.00671])	-2.118	0.1027	-0.214(0.1013, [-0.413, -0.0159])
		L-U	-0.089(0.0247, [-0.1481, -0.02996])	-3.609	0.0009	-0.372(0.1032, [-0.574, -0.1699])
		S-U	-0.0377(0.0169, [-0.0783, 0.00282])	-2.229	0.0777	-0.158(0.0708, [-0.296, -0.0189])
	Q4	L-S	-0.1409(0.0242, [-0.1988, -0.08297])	-5.826	<.0001	-0.589(0.1013, [-0.787, -0.3904])
		L-U	-0.1924(0.0246, [-0.2514, -0.13344])	-7.815	<.0001	-0.804(0.1033, [-1.007, -0.6018])
		S-U	-0.0515(0.0169, [-0.092, -0.01101])	-3.046	0.007	-0.215(0.0707, [-0.354, -0.0767])
Low-speed running (m.min)	Q1	L-S	1.125(0.728, [-0.618, 2.8672])	1.546	0.3667	0.1561(0.101, [-0.0419, 0.3541])
		L-U	-0.569(0.742, [-2.347, 1.2086])	-0.767	1.0000	-0.079(0.103, [-0.281, 0.123])
		S-U	-1.694(0.509, [-2.913, -0.4754])	-3.329	0.0026	-0.2351(0.0707, [-0.3737, -0.0966])
	Q2	L-S	-0.401(0.726, [-2.14, 1.3387])	-0.552	1.0000	-0.0556(0.1008, [-0.2533, 0.142])
		L-U	-1.689(0.741, [-3.464, 0.086])	-2.279	0.0682	-0.2344(0.1029, [-0.4362, -0.0327])
		S-U	-1.288(0.51, [-2.509, -0.0675])	-2.527	0.0346	-0.1788(0.0708, [-0.3175, -0.04])
	Q3	L-S	-0.314(0.73, [-2.063, 1.4353])	-0.429	1.0000	-0.0435(0.1014, [-0.2422, 0.1552])
		L-U	-2.874(0.745, [-4.657, -1.0902])	-3.859	0.0003	-0.3989(0.1034, [-0.6017, -0.196])
		S-U	-2.56(0.51, [-3.783, -1.3374])	-5.015	<.0001	-0.3553(0.071, [-0.4944, -0.2162])
	Q4	L-S	-1.518(0.729, [-3.264, 0.2278])	-2.082	0.1121	-0.2107(0.1012, [-0.4092, -0.0123])
		L-U	-3.285(0.743, [-5.065, -1.5045])	-4.419	<.0001	-0.4559(0.1033, [-0.6584, -0.2534])
		S-U	-1.767(0.51, [-2.988, -0.545])	-3.463	0.0016	-0.2452(0.0708, [-0.3841, -0.1063])

Footnote: L = 'LOWER' ranked teams (world rankings 18-66), S = 'SIMILAR' ranked teams (world rankings 9-17) and H = 'HIGHER' ranked teams (world rankings 1-8).

Q1 = first playing quarter, Q2 = second playing quarter, Q3 = third playing quarter, Q4 = fourth playing quarter.