Elite international female rugby union physical match demands: A five-year longitudinal analysis by position and opposition quality

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Abstract

Objectives This study aimed to evaluate changes in rugby union physical match characteristics across five seasons of International female competition, according to position and opposition quality. **Design & Methods** Global positional systems and performance analysis data from 78 female rugby union players (minimum of five international appearances) were analysed between 2015 and 2019. Mixed-linear-modelling was used to investigate the effects of season, opposition and position during 969 individual match performances from 53 International matches. **Results** Running demands increased between 2015 and 2017 (World Cup year) and plateaued thereafter, except for sprints among the outside backs, which declined between 2017 and 2019, and accelerations and decelerations >3 $m{\cdot}s^2$ which increased between 2017 and 2019. Collisions were higher in forwards than backs, and highest against stronger opposition. Running demands were greater against weaker opposition, but the 'most intense periods' of running were greater against stronger opposition in 2017. **Conclusions** Match demands increased between 2015 and the 2017 World Cup year, which was underpinned by increased sprinting and greater running during maximum intensity periods against top 5 opposition. The increase in accelerations and decelerations in the latter years, alongside the maintenance of average running demands and collision counts, is consistent with the reported continuous playing style of female rugby, thus placing specific demands on players and requiring tailored training methods. Some positions (Forwards and Scrum-halves) appear to be important for this adopted style, demonstrating concomitantly high relative collision and running intensities.

Key Words: Women, Global positioning systems, collision, Team Sport movement

Introduction

Rugby union is a demanding, intermittent team sport, where frequent bouts of static and dynamic collision-based exertions and high-intensity running are interspersed with periods of lower-intensity activities.[8, 15] While the physical match characteristics of elite male rugby union players has been thoroughly described and incorporated into training practices, much less in known about international female players. Indeed, the only published studies, to date, report on low ranking teams (World ranking of 8 or below according to World Rugby official rankings[31]) and used small sample sizes.[28, 29] This is unfortunate, since within-player variation observed across multiple matches in male rugby union[21] suggests that longitudinal observations and higher sample sizes might be necessary to ensure peak physical match characteristics are reported with greater certainty. Longitudinal variation could be partly explained by quality of the opposition[17, 23] or changes occurring across longer developmental periods, such as the recent transition from amateur to professional rugby among female players. Longitudinal increases in physical match characteristics, such as average speed, high-speed running and collision frequency have also been reported in male rugby league.[12] Thus, the current literature provides limited insight into the imposed demands on International female players during matches and lacks understanding of contextual factors, which has been raised as a current concern in female sport.[6, 11] Based on the above reasoning, the primary aim of the current study was, therefore, to conduct the first extensive, longitudinal analysis of physical match characteristics among elite international female rugby union players. The differences in physical match characteristics were evaluated between: i) positional group ii) matches against teams of high and low ranks (opposition quality), and iii) five consecutive seasons of competitive match performance (2015-2019).

Method

Following institutional ethical approval, a five-year longitudinal analysis of physical match characteristics was conducted between 2015 and 2019, with a total sample of seventy-eight international female rugby union players (age 25 ± 4 years, stature 170.6 ± 6.0 cm, body mass 76.6 ± 9.8 kg) from a single team, ranking in the top 2 nations across the study period (World cup finalists in 2014 and 2017). Each player had a minimum of five international caps (players observed; 2015, n = 40; 2016, n = 38; 2017, n = 47; 2018, n = 39; 2019, n = 39). A total of 967 match files were analysed from 53 matches (19.7 ± 3.0 observations per match, 12.3 ± 9.4 observations per player) over the five seasons. Individual positions were split into six positional groups, comprising: front-row forwards, consisting of props and hookers (FR) (n = 16), locks (L) (n = 10), back-row forwards consisting of flankers and number eights (BR) (n = 15), scrum-halves (SH) (n = 6), inside backs consisting of fly-halves, inside and outside centres (IB) (n = 17) and outside backs consisting of wingers and full-backs (OB) (n = 14). To analyse opposition strength, the 9 opposing teams encountered during the study period were categorised as top or bottom 5, based on current World-ranking at the time of competition (28 and 26 matches against top and bottom 5, respectively).

All matches took place between 12:30 pm and 10:00 pm, across three continents (Europe, America and Australasia), with differences in environmental conditions. To quantify running demands during matches, each player was fitted with a Global Positioning System (GPS) device, integrated with micro-mechanical electrical systems (MEMS). Between 2015 and August 2017, a Viper device was used (STATSports Viper; STATSports, Newry, Northern Ireland). This was changed to the Apex unit in August 2017 until 2019 (STATSports Apex; STATSports, *Newry*, Northern Ireland). Measurement error of these devices is typically < 5% coefficient of variation (CV), with close (< 2% CV) comparisons to sport-specific criterion measurements.[2] The GPS files were gathered from 53 matches and all values were included in the analysis, regardless of time on the pitch (68.5 ± 28.7 min). The files were downloaded using the manufacturer's software, and truncated *post-hoc* to remove half-time periods. Raw speed traces were visually inspected for outliers and removed from the analysis if damaged or incomplete.

All kinematic variables selected for analysis were expressed in absolute and relative to playing time and thresholds were set according to the mean aerobic running and maximum speeds of the cohort, which aligned with previous female reports[29]. These included: total distance (m), and distance at low-speed (< 3 m/s), moderate-speed (3-5.5 m/s) and high-speed (> 5.5 m/s), as well as high-speed zone entries. The number of entries into the following acceleration and deceleration zones were also recorded: moderate zones (2-3 m/s^2), high (3-4 m/s^2) and very-high (> 4m/s^2).[7] Absolute and relative collision values were derived from the GPS-micro-technology devices.[21] To provide an additional metric for collision event, the sum of tackles, carries and scrums were also coded by an expert performance analyst (PA), who was professionally certified and had over five years of experience in elite-level rugby union. All collisions events were recorded as absolute and relative to match playing time (Total collisions (PA) and Collisions/min (PA) respectively). Maximum-intensity periods (MIP) for collision frequency and average speed, were calculated for each player, for a fixed period of 2.75 min in each match. This segment duration was chosen as it represented the average of maximum ball in play periods in international female rugby and aligned with previous reports for 'worst case scenarios' in elite-level male rugby.[24]

Linear mixed-modelling was conducted (SPSS v.22.NY.IBM Corporation) using separate models for each match dependant variable, to evaluate the effects of the following fixed factors: season (2015-2019), position and opposition quality (top 5 and below), which were simultaneously entered into each model. The random effects were individual players for all analyses. Where fixed factors were significant ($p < 0.05$), *post-hoc* Bonferroni comparisons were conducted to determine differences between levels. Significance was accepted as p <

0.05. Finally, the pooled match-to-match variability of each physical match characteristic was calculated, eliciting CV% values between 9 and 34%.

Results

Linear mixed modelling revealed effects of positional group across all variables, with the exception of accelerations and decelerations (3-4 m/s^2). Effects of season were shown for average speed ($p < 0.001$), total distance ($p < 0.001$), average distance <3 m/s ($p < 0.001$), total distance <3 m/s ($p < 0.001$), average distance 3-5.5 m/s ($p < 0.001$), total distance 3-5.5 m/s ($p < 0.001$), average distance >5.5 m/s ($p < 0.001$), total distance >5.5 m/s ($p < 0.001$), sprints/min ($p < 0.001$), total sprints ($p < 0.001$), MIP m/min ($p < 0.001$), accelerations/min >4 m/s^2 ($p < 0.001$), decelerations/min >4 m/s^2 ($p < 0.001$), accelerations/min 2-3 m/s^2 ($p < 0.001$) and decelerations/min 2-3 m/s^2 ($p <0.001$). There were effects ($p < 0.001$) of opposition for average speed, average distance <3 m/s, average distance 3-5.5 m/s, average distance >5.5 m/s and collisions/min. Match playing time was not affected by any factors ($p > 0.001$). Pairwise effects are shown in table 1.

Season x Position interactions showed differences between positions within the same season, and differences between seasons within the same position, for distance >5.5 m/s (m) ($p < 0.05$), sprint/min ($p < 0.05$), total sprints ($p < 0.001$), MIP collisions/min ($p < 0.01$), collisions/min (microtechnological) ($p < 0.05$), accelerations/min >4 m/s^2 ($p < 0.05$), decelerations/min >4 m/s^2 ($p < 0.05$), accelerations/min 3-4 m/s^2 ($p < 0.05$), decelerations/min 3-4 m/s^2 ($p < 0.05$), accelerations/min 2-3 m/s^2 ($p < 0.05$) and decelerations/min 2-3 m/s^2 ($p < 0.05$), Pairwise differences are shown in tables 2 & 3.

Significant interactions were observed between season and opposition for total collisions (PA) and collisions/min (PA), and for MIP m/min ($p < 0.01$). Pairwise comparisons showed that total collisions (PA) and collisions/min (PA) were higher when playing top five opposition compared to bottom five opposition in 2015 and 2017. MIP m/min was higher when playing bottom five opposition compared to top five opposition in 2016, but in 2017, it was higher when playing top five opposition compared to bottom five opposition. MIP m/min in matches against top five opposition was also higher in 2017 compared to all years and higher in 2019 compared to 2015 and 2016. While playing matches against bottom five opposition, 2015 was lower compared to all years.

Table 1: Fixed effect pairwise comparisons for season, position and opposition rank, among elite-level female rugby union players across five seasons.

	Season effect	**Position effect**	**Opposition effect**
Average speed (m/min)	2016,2017,2018,2019>2015; 2017>2016,2019	SH>FR,L,BR,IB, IB,OB>FR,L, BR>FR	Bottom 5 > Top 5
Total distance (km)	2016,2017,2019>2015	BR,IB,OB>FR	-
Average Distance (m/min <3 m/s)	2016,2017,2018,2019>2015	OB>FR,L,BR,SH,IB	Bottom 5 > Top 5
Total distance <3 m/s (m)	2016>2015	L,BR,SH,IB,OB>FR, SH>IB,OB	-
Average Distance (m/min 3-5.5 m/s)	2016,2017,2019>2015	L,BR,SH,IB,OB>FR	Bottom 5 > Top 5
Total distance 3-5.5 m/s (m)	2017>2015,2016,2019	SH>FR,L,BR,IB,OB, BR>FR,OB	-
Average Distance (m/min >5.5 m/s)	2017>2016	OB>FR,L,BR,SH,IB, SH,IB>FR,L,BR	Bottom 5 > Top 5
Total distance >5.5 m/s (m)	2017>2015,2016; 2019>2015	SH, OB>FR,L,BR,SH, OB>IB, BR>FR	-
Sprints/min	2017>2015,2016,2018	SH,IB,OB>FR,L,BR, OB>SH,IB	Bottom 5 > Top 5
Total sprints	2017>2015,2016,2019; 2018>2015	IB,OB>FR,L,BR,SH, BR,SH>FR	-
Collisions/min	-	L,BR>IB,OB, L>SH, FR>OB	-
Total collisions	-	FR,L,BR>SH,IB,OB, L,BR>FR	-
Collisions/min (PA)	-	FR,L,BR>SH,IB,OB	-
Total collisions (PA)	-	-	Top 5 > Bottom 5
MIP (m/min)	2017>2015,2016,2018,2019; 2016,2018,2019>2015; 2019>2016	BR,SH,IB,OB>L, SH,IB,OB>L	-
MIP (collisions/min)	-	L,BR>SH,IB,OB	-
Accelerations/min 2-3 m/s^2	2016,2017,2018,2019>2015; 2017>2016,2019; 2018>2019	SH>IB,OB	-
Accelerations/min 3-4 m/s^2	2018,2019>2015,2016,2017; 2017>2015,2016; 2016>2015	-	-
Accelerations/min >4 m/s^2	2018,2019>2015,2016,2017; 2017>2015	IB>FR,L,OB	-
Decelerations/min 2-3 m/s^2	2016,2017,2018,2019>2015; 2017>2016,2019	SH>IB, FR,L,BR,SH>OB	-
Decelerations/min 3-4 m/s^2	2016,2017,2018>2015; 2017,2018,2019>2016; 2019>2017	-	-
Decelerations/min >4 m/s^2	2018,2019>2015,2016,2017; 2017>2015	L,BR,SH,IB,OB>FR, SH,OB>L	-

– denotes no fixed effect found. FR, L, SH, IB, OB denote Front row, Lock, Scrum half, Inside back, Outside back respectively. PA, collisions derived from performance analysis.

Table 2: Changes in physical match characteristics between season and position among elite-level female rugby union players. Pairwise comparisons show within and between season differences for position

		FR	L	BR	SH	IB	OB
2015	Average speed (m/min)	59.1 ± 1.3[bd]	50.5 ± 2.2[acdef]	64.2 ± 1.7[b]	67.5 ± 2.4[ab]	64.0 ± 1.6[b]	62.2 ± 1.7[b]
	Total distance (m)	2410 ± 314[c]	2968 ± 498	4115 ± 383[a]	2740 ± 582	4777 ± 378	4605 ± 397
	Average distance (m/min <3 m/s)	42.0 ± 1.0[b]	34.8 ± 1.5[ac]	43.0 ± 1.2[b]	42.9 ± 1.8[b]	43.1 ± 1.1[b]	44.8 ± 1.2[b]
	Total distance <3 m/s (m)	1858 ± 219	2152 ± 348	2484 ± 267	1811 ± 404	3218 ± 263[a]	3341 ± 277[a]
	Average distance (m/min 3-5.5 m/s)	16.0 ± 0.9[d]	15.0 ± 1.4[d]	19.7 ± 1.1[f]	23.8 ± 1.7[abf]	18.1 ± 1.1	14.7 ± 1.1[cd]
	Total distance 3-5.5 m/s (m)	614 ± 104[ce]	770 ± 160	1210 ± 126[a]	874 ± 193	1338 ± 123[a]	1047 ± 129
	Average distance (m/min >5.5 m/s)	0.4 ± 0.3[ded]	0.6 ± 0.4[ef]	0.9 ± 0.3[ef]	2.3 ± 0.5[a]	2.7 ± 0.3[abc]	2.9 ± 0.3[abc]
	Total distance >5.5 m/s (m)	2 ± 2[ef]	35 ± 26[ef]	50 ± 21[ef]	63 ± 33[ef]	196 ± 21[abcd]	185 ± 22[abcd]*
	Sprints/min	0.03 ± 0.01[def]	0.05 ± 0.02[ef]	0.08 ± 0.02[ef]	0.10 ± 0.03[a]	0.20 ± 0.02[abc]	0.21 ± 0.02[abc]*^
	Total Sprints	0.7 ± 1[ef]	2.3 ± 1.6[ef]	4.3 ± 1.3[ef]	4.2 ± 2[e]	12.7 ± 1.3[abcd]	11.3 ± 1.3[abc]#
2016	Average speed (m/min)	62.5 ± 1.5[d]	62.8 ± 2.8	64.2 ± 1.6	72.5 ± 3.0[a]	64.9 ± 1.6	66.6 ± 1.8
	Total distance (m)	3246 ± 355[f]	5078 ± 618	4727 ± 374	4498 ± 683	4703 ± 525	5476 ± 432[a]
	Average distance (m/min <3 m/s)	44.9 ± 1.1	44.0 ± 1.9	44.0 ± 1.1	46.2 ± 2.1	45.0 ± 1.6	46.6 ± 1.3
	Total distance <3 m/s (m)	2401 ± 248	3604 ± 431	3278 ± 261	2986 ± 477	3317 ± 367	3855 ± 301[a]
	Average distance (m/min 3-5.5 m/s)	16.9 ± 1.0[d]	17.8 ± 1.7	18.8 ± 1.1	23.8 ± 1.7[af]	18.1 ± 1.1	14.7 ± 1.1[d]
	Total distance 3-5.5 m/s (m)	811 ± 116[c]	1404 ± 199	1361 ± 122[a]	1418 ± 221	1247 ± 168	1324 ± 140
	Average distance (m/min >5.5 m/s)	0.5 ± 0.3[def]	0.4 ± 0.4[ef]	1.1 ± 0.3[f]	2.2 ± 0.5	2.1 ± 0.4[a]	3.4 ± 0.3[abc]
	Total distance >5.5 m/s (m)	26 ± 20[ef]	31 ± 33[f]	91 ± 20[f]	94 ± 37[f]	127 ± 27[abf]*	255 ± 23[abcde]*
	Sprints/min	0.04 ± 0.02[ef]	0.04 ± 0.02[ef]	0.10 ± 0.02[f]	0.10 ± 0.03[abc]	0.20 ± 0.02	0.21 ± 0.02[abc]*
	Total Sprints	2.1 ± 1.2[cef]	2.5 ± 1.9[f]	7.7 ± 1.1[af]	6.5 ± 2.3[f]	9.5 ± 1.7[a]	15.3 ± 1.4[abcd]#
2017	Average speed (m/min)	64.5 ± 1.0[cd]	65.9 ± 1.5[def]	69.7 ± 1.3[ad]	78.0 ± 2.1[abc]	71.9 ± 1.1[ab]	73.0 ± 1.3[ab]
	Total distance (m)	2960 ± 259[bcef]	4712 ± 352[a]	4981 ± 314[a]	4121 ± 514	4898 ± 284[a]	5472 ± 303[a]
	Average distance (m/min <3 m/s)	44.8 ± 0.8[f]	43.8 ± 1.1[f]	45.8 ± 1.0	44.8 ± 1.6	45.5 ± 0.9	48.5 ± 0.9[ab]
	Total distance <3 m/s (m)	2073 ± 179[bc]	3166 ± 245[a]	3304 ± 218[a]	2338 ± 357[e]	3110 ± 197[a]	3634 ± 211 [ad]
	Average distance (m/min 3-5.5 m/s)	17.8 ± 0.7[cde]	19.8 ± 1.0[d]	21.8 ± 0.9[ad]	30.0 ± 1.5[abf]	21.3 ± 0.8[ad]	19.4 ± 0.9[d]
	Total distance 3-5.5 m/s (m)	788 ± 88[bcdef]	1385 ± 116[a]	1529 ± 104[a]	1614 ± 171[a]	1458 ± 95[a]	1403 ± 100[a]
	Average distance (m/min >5.5 m/s)	0.5 ± 0.2[def]	0.8 ± 0.3[def]	1.2 ± 0.2[ef]	2.6 ± 0.4[abf]	3.2 ± 0.2[abcf]	4.3 ± 0.2[abcde]
	Total distance >5.5 m/s (m)	18 ±16[cdef]	63 ± 19.9[ef]	93.3 ± 17.9[aef]	132.3 ± 30[af]	224.1 ± 17[abcf]¥	326.8 ± 17[abcde]#¥$
	Sprints/min	0.05 ± 0.1[def]	0.07 ± 0.2[ef]	0.11 ± 0.01[ef]	0.20 ± 0.02[af]	0.21 ± 0.01[abc]^$	0.31 ± 0.1[abcd]#¥$
	Total Sprints	1.9 ± 1.0[cdef]	5.5 ± 1.2[ef]	6.7 ± 1.1[aef]	8.3 ± 1.8[af]	14.5 ± 1.0[abcf]	19.4 ± 1.1[abcde]#¥$
2018	Average speed (m/min)	59.1 ± 2.0[df]	61.5 ± 2.6	63.4 ± 2.3	73.2 ± 4.2[a]	64.3 ± 2.2	68.3 ± 2.3[a]
	Total distance (m)	2817 ± 447[ef]	3703 ± 586	4742 ± 512	4429 ± 943	5090 ± 502[a]	4993 ± 519[a]
	Average distance (m/min <3 m/s)	41.7 ± 1.4	42.6 ± 1.8	43.6 ± 1.5	44.4 ± 2.8	44.8 ± 1.5	47.3 ± 1.6
	Total distance <3 m/s (m)	2110 ± 314	2694 ± 410	3330 ± 358	2725 ± 661	3529 ± 351[a]	3512 ± 362
	Average distance (m/min 3-5.5 m/s)	16.8 ± 1.3[a]	18.5 ± 1.6	19.1 ± 1.4	44.4 ± 2.8[af]	44.8 ± 1.5	47.3 ± 1.6
	Total distance 3-5.5 m/s (m)	689 ± 143[ce]	974 ± 186	1358 ± 162[a]	1528 ± 298	1406 ± 160[a]	1213 ± 166
	Average distance (m/min >5.5 m/s)	0.4 ± 0.3[def]	0.5 ± 0.4[ef]	0.7 ± 0.3[ef]	2.5 ± 0.6[a]	2.3 ± 0.4[abc]	3.3 ± 0.4[abc]
	Total distance >5.5 m/s (m)	16.2 ± 23.5[ef]	33.9 ± 30[ef]	63.5 ± 26.1[ef]	132.0 ± 47.8	188.5 ± 26[abc]	240.2 ± 27.2[abc]
	Sprints/min	0.03 ±0.02[def]	0.04 ± 0.02[def]	0.06 ± 0.02[def]	0.18 ± 0.04[abc]	0.14 ± 0.02[abcf]*	0.23 ± 0.2[abce]#
	Total Sprints	1.6 ± 1.4[def]	2.7 ± 1.8[ef]	4.6 ± 1.6[ef]	11.6 ± 3.0[a]	11.8 ± 1.6[abc]	16.5 ± 1.7[abc]
2019	Average speed (m/min)	62.1 ± 1.2[d]	63.6 ± 1.7[df]	64.0 ± 1.3[df]	72.9 ± 2.1[abc]	67.1 ± 1.4	70.9 ± 1.4[abc]
	Total distance (m)	3240 ± 287[ef]	4287 ± 397	4429 ± 942	3468 ± 496[f]	5158 ± 328[a]	5283 ± 320[ad]
	Average distance (m/min <3 m/s)	44.9 ± 0.9	44.7 ± 1.2	43.4 ± 0.9[f]	43.1 ± 1.5	45.2 ± 1.0	47.9 ± 1.0[c]
	Total distance <3 m/s (m)	2349 ± 199	3034 ± 276	2932 ± 215	2087 ± 344[ef]	3469 ± 228[ad]	3636 ± 223 [ad]
	Average distance (m/min 3-5.5 m/s)	16.8 ± 0.8[d]	18.9 ± 1.1[d]	19.9 ± 0.9[d]	26.0 ± 1.4 [abcef]	19.1 ± 1.0[d]	18.2 ± 1.0[d]
	Total distance 3-5.5 m/s (m)	875 ± 95	1235 ±130	1334 ± 102	1193 ± 165	1479 ± 108	1303 ± 105
	Average distance (m/min >5.5 m/s)	0.3 ± 0.2[def]	0.6 ± 0.3[def]	1.1 ± 0.2[def]	2.6 ± 0.4[abc]	2.6 ± 0.3[abcf]	3.8 ± 0.2[abce]
	Total distance >5.5 m/s (m)	14.5 ± 16.7[bcdef]	48.4 ± 21.8[ef]	83.8 ± 17.3[aef]	118.4 ± 18.6[af]	25.0 ± 18.7[abcf]	281 ± 17.6[abcde]*
	Sprints/min	0.03 ± 0.01[def]	0.04 ± 00.2[def]	0.07 ± 0.01[ef]	0.14 ± 0.02[ab]	0.16 ± 0.02[abc]*	0.22 ± 0.01[abc]*
	Total Sprints	1.1 ± 1.0[cef]	3.3 ± 1.3[ef]	5.4 ± 1.1[aef]	6.5 ± 1.8[ef]	12.9 ± 1.1[abcd]	15.7 ± 1.1[abcd]#

FR = front row, L = lock, BR = back row, SH = scrum half, IB =inside back, OB = outside back. [a], [b], [c], [d], [e], [f] = significantly different to front row, lock, back row, scrum half, inside back, outside back respectively, within the tabulated year. #, ¥, *, ^, $ = significantly different to 2015, 2016, 2017, 2018, 2019 respectively, within the tabulated position.

Table 3: Changes in physical match characteristics between season and position among elite-level female rugby union players. Pairwise comparisons show within and between season differences for position

		FR	L	BR	SH	IB	OB
2015	Collisions/min	0.38 ± 0.3^{f}	0.41 ± 0.06$^{f}_{¥*}$	0.40 ± 0.04^{f}	0.40 ± 0.06^{f}	0.21 ± 0.04	0.14 ± 0.04^{abcd}
	Total collisions	17.7 ± 2.7	22.3 ± 4.5	25.1 ± 3.3	19.9 ± 5.0	17.1 ± 3.3	10.3 ± 3.6
	Collisions/min (PA)	0.47 ± 0.02	0.50 ± 0.04	0.47 ± 0.03	0.27 ± 0.04	0.22 ± 0.03	0.11 ± 0.03
	Total collisions (PA)	21.1 ± 1.8	30.7 ± 2.9	33.1 ± 2.2	10.0 ± 3.3	15.3 ± 2.2	9.1 ± 2.4
	MIP (m/min)	97.0 ± 2.3	98.4 ± 3.6	107.0 ± 2.8	107.5 ± 4.3	109.2 ± 2.8	106.3 ± 3.0
	MIP (collisions/min)	1.2 ± 0.07$_{¥*}$	1.3 ± 1.1	1.4 ± 0.1^{e}	1.4 ± 0.13$_{\$}$	0.9 ± 0.09^{c}	1.0 ± 0.09
	Accelerations/min 2-3 m/s^2	0.73 ± 0.5$_{*\$}$	0.67 ± 0.3$_{*\wedge\$}$	0.62 ± 0.3$_{*\$}$	0.62 ± 0.4$_{*\wedge\$}$	0.68 ± 0.3$_{*\$}$	0.61 ± 0.3$_{\$}$
	Accelerations/min 3-4 m/s^2	0.17 ± 0.1$_{*}$	0.13 ± 0.1$_{\wedge}$	0.17 ± 0.2$_{*\wedge}$	0.16 ± 0.2	0.17 ± 0.1$_{*\wedge}$	0.14 ± 0.1$_{\wedge}$
	Accelerations/min >4 m/s^2	0.03 ± 0.03$_{\$}$	0.04 ± 0.04$_{\wedge\$}$	0.02 ± 0.01$_{\$}$	0.02 ± 0.02$_{\$}$	0.03 ± 0.03$_{*\wedge\$}$	0.01 ± 0.02$_{\$}$
	Decelerations/min 2-3 m/s^2	0.72 ± 0.5$_{*}$	0.67 ± 0.2$_{*\wedge}$	0.61 ± 0.3$_{¥*\wedge\$}$	0.56 ± 0.3$_{*\wedge\$}$	0.61 ± 0.3$_{*}$	0.52 ± 0.4
	Decelerations/min 3-4 m/s^2	0.21 ± 0.1$_{*\wedge\$}$	0.19 ± 0.1$_{\wedge\$}$	0.21 ± 0.1$_{*\wedge\$}$	0.14 ± 0.1$_{*\wedge\$}$	0.17 ± 0.1$_{*\wedge\$}$	0.18 ± 0.1
	Decelerations/min >4 m/s^2	0.06 ± 0.07$_{\$}$	0.04 ± 0.04$_{\$}$	0.05 ± 0.05$_{*\wedge\$}$	0.04 ± 0.04$_{\$}$	0.08 ± 0.06$_{*\wedge\$}$	0.06 ± 0.06$_{*\wedge\$}$
2016	Collisions/min	0.31 ± 0.04	0.48 ± 0.07$^{f}_{\#\$}$	0.44 ± 0.04^{f}	0.19 ± 0.08	0.23 ± 0.4	0.14 ± 0.04^{bc}
	Total collisions	15.6 ± 3.2	37.4 ± 5.6	33.7 ± 3.3	10.7 ± 6.6	26.7 ± 4.8	17.8 ± 3.8
	Collisions/min (PA)	0.42 ± 0.03	0.41 ± 0.05	0.53 ± 0.03	0.16 ± 0.06	0.22 ± 0.04	0.11 ± 0.3
	Total collisions (PA)	22.8 ± 2.1	34.1 ± 3.4	37.2 ± 2.2	10.9 ± 4.0	14.3 ± 3.1	8.6 ± 2.5
	MIP (m/min)	103.2 ± 2.5	101.1 ± 3.9	113.7 ± 2.5	118.9 ± 4.6	108.2 ± 3.6	116.2 ± 3.0
	MIP (collisions/min)	1.01 ± 0.08^{c}	1.41 ± 0.13$_{\#}$	1.43 ± 0.08^{af}	1.17 ± 0.16	1.07 ± 0.12	1.02 ± 0.1^{c}
	Accelerations/min 2-3 m/s^2	0.86 ± 0.4$_{\$}$	0.88 ± 0.3$_{*}$	0.94 ± 0.5	0.94 ± 0.4$_{*}$	0.74 ± 0.4$_{*}$	0.79 ± 0.38
	Accelerations/min 3-4 m/s^2	0.21 ± 0.2	0.21 ± 0.1$_{\$}$	0.24 ± 0.2$_{*¥\$}$	0.19 ± 0.1$_{\$}$	0.22 ± 0.1$_{*¥\$}$	0.23 ± 0.1$_{\#}$
	Accelerations/min >4 m/s^2	0.03 ± 0.03	0.03 ± 0.03$_{\wedge}$	0.05 ± 0.03	0.03 ± 0.03$_{\$}$	0.08 ± 0.07$_{*\wedge\$}$	0.04 ± 0.03
	Decelerations/min 2-3 m/s^2	0.85 ± 0.4	0.87 ± 0.3	0.9 ± 0.4$_{\#}$	0.92 ± 0.3	0.72 ± 0.3	0.71 ± 0.4
	Decelerations/min 3-4 m/s^2	0.32 ± 0.2	0.23 ± 0.1	0.28 ± 0.2$_{\$}$	0.23 ± 0.1$_{\$}$	0.21 ± 0.1$_{*\wedge\$}$	0.26 ± 0.1
	Decelerations/min >4 m/s^2	0.06 ± 0.06$_{\$}$	0.07 ± 0.06$_{\$}$	0.12 ± 0.08$_{\wedge\$}$	0.09 ± 0.06$_{\$}$	0.08 ± 0.06$_{*\wedge\$}$	0.11 ± 0.06$_{\wedge\$}$
2017	Collisions/min	0.32 ± 0.03^{f}	0.43 ± 0.04$^{f}_{¥\$}$	0.43 ± 0.04^{f}	0.26 ± 0.03^{f}	0.26 ± 0.03	0.21 ± 0.03^{abcd}
	Total collisions	14.3 ± 2.1	28.0 ± 3.0	33.1 ± 2.6	11.2 ± 4.3	17.1 ± 2.3	15.8 ± 2.6
	Collisions/min (PA)	0.45 ± 0.02	0.46 ± 0.05	0.51 ± 0.02	0.21 ± 0.04	0.22 ± 0.02	0.18 ± 0.02
	Total collisions (PA)	19.9 ± 1.4	29.9 ± 2.0	35.2 ± 1.8	7.7 ± 2.9	12.8 ± 1.6	10.7 ± 1.7
	MIP (m/min)	110.9 ± 1.8	113.0 ± 2.4	117.4 ± 2.1	131.0 ± 3.5	122.4 ± 1.9	120.1 ± 2.1
	MIP (collisions/min)	1.12 ± 0.05$^{ab}_{\#}$	1.41 ± 0.07^{adef}	1.53 ± 0.6^{adef}	1.01 ± 0.11^{bc}	1.17 ± 0.06^{bc}	0.95 ± 0.06^{bc}
	Accelerations/min 2-3 m/s^2	0.98 ± 0.4$_{\#\$}$	1.10 ± 0.4$_{\#¥\$}$	1.10 ± 0.2$_{\#}$	1.44 ± 0.3$^{f}_{\#¥\$}$	1.12 ± 0.3$_{\#¥}$	0.81 ± 0.3^{d}
	Accelerations/min 3-4 m/s^2	0.31 ± 0.2$_{\#}$	0.26 ± 0.1	0.34 ± 0.1$_{\#¥}$	0.29 ± 0.1	0.36 ± 0.1$^{abdf}_{\#¥}$	0.25 ± 0.2$^{e}_{*}$
	Accelerations/min >4 m/s^2	0.05 ± 0.05$^{e}_{\$}$	0.03 ± 0.03$^{e}_{\wedge\$}$	0.05 ± 0.03	0.03 ± 0.03$^{e}_{\$}$	0.08 ± 0.07$_{\#¥\$}$	0.04 ± 0.03$^{e}_{\$}$
	Decelerations/min 2-3 m/s^2	0.99 ± 0.4$^{f}_{\#\wedge\$}$	0.95 ± 0.4$^{f}_{\#}$	1.01 ± 0.2$^{f}_{\#}$	1.21 ± 0.3$^{f}_{\#}$	0.92 ± 0.2$^{d}_{\#\$}$	0.72 ± 0.4^{abcd}
	Decelerations/min 3-4 m/s^2	0.28 ± 0.1$_{\#}$	0.28 ± 0.1	0.33 ± 0.1$_{\#}$	0.31 ± 0.1$_{\#\$}$	0.35 ± 0.1$_{\#¥}$	0.27 ± 0.1
	Decelerations/min >4 m/s^2	0.08 ± 0.06$^{cef}_{\$}$	0.07 ± 0.06$^{e}_{\$}$	0.13 ± 0.06$^{a}_{\#\wedge\$}$	0.09 ± 0.07$_{\$}$	0.15 ± 0.08$^{ab}_{\#¥}$	0.13 ± 0.08$^{a}_{\#\wedge\$}$
2018	Collisions/min	0.38 ± 0.03	0.53 ± 0.07^{f}	0.41 ± 0.06	0.22 ± 0.12	0.32 ± 0.06	0.24 ±0.06^{b}
	Total collisions	17.8 ± 4.2	27.2 ± 5.5	31.5 ± 4.8	11.4 ± 9.2	24.1 ± 4.7	17.3 ± 4.8
	Collisions/min (PA)	0.37 ± 0.04	0.38 ± 0.05	0.48 ± 0.04	0.12 ± 0.08	0.17 ± 0.05	0.18 ± 0.04
	Total collisions (PA)	18.3 ± 2.7	23.4 ± 3.5	34.2 ± 3.1	8.4 ± 5.6	13.5 ± 3.3	10.9 ± 3.1
	MIP (m/min)	104.2 ± 3.1	105.1 ± 4.1	111.0 ± 3.6	125.0 ± 6.6	112.9 ± 3.5	118.2 ± 3.6
	MIP (collisions/min)	1.11 ± 0.1	1.41 ± 0.14	1.32 ± 0.12	0.95 ± 0.22	1.08 ± 0.1	0.91 ± 0.12
	Accelerations/min 2-3 m/s^2	0.84 ± 0.2^{d}	1.02 ± 0.2$_{\#}$	1.02 ± 0.2	1.33 ± 0.3$^{a}_{\#}$	1.01 ± 0.2	0.92 ± 0.2
	Accelerations/min 3-4 m/s^2	0.31 ± 0.1	0.34 ± 0.1$_{\#}$	0.42 ± 0.1$_{\#¥}$	0.41 ± 0.2	0.42 ± 0.1$_{\#¥}$	0.35 ± 0.1$_{\#¥*}$
	Accelerations/min >4 m/s^2	0.05 ± 0.04^{e}	0.07 ± 0.05$_{\#¥*}$	0.12 ± 0.1	0.08 ± 0.07	0.13 ± 0.07$^{a}_{\#¥}$	0.07 ± 0.04
	Decelerations/min 2-3 m/s^2	0.79 ± 0.2$_{*}$	0.91 ± 0.3$_{\#}$	0.81 ± 0.2$_{\#}$	1.12 ± 0.3$_{\#}$	0.82 ± 0.2	0.63 ± 0.1
	Decelerations/min 3-4 m/s^2	0.27 ± 0.1$_{\#}$	0.34 ± 0.1$_{\#}$	0.37 ± 0.1$_{\#}$	0.42 ± 0.2$_{\#}$	0.39 ± 0.1$_{\#¥}$	0.28 ± 0.1
	Decelerations/min >4 m/s^2	0.12 ± 0.1$^{cef}_{\$}$	0.12 ± 0.08^{c}	0.21 ± 0.12$^{ab}_{\#¥*}$	0.16 ± 0.08	0.19 ± 0.08$^{a}_{\#¥}$	0.22 ± 0.06$^{a}_{\#¥*}$
2019	Collisions/min	0.33 ± 0.03^{f}	0.35 ± 0.04$^{f}_{¥*}$	0.34 ± 0.03^{f}	0.24 ± 0.05	0.24 ± 0.04	0.17 ± 0.04^{abc}
	Total collisions	17.1 ± 2.4	23.1 ± 3.4	28.4 ± 2.7	11.4 ± 4.2	20.5 ± 2.8	15.3 ± 2.8
	Collisions/min (PA)	0.48 ± 0.02	0.48 ± 0.03	0.53 ± 0.02	0.15 ± 0.04	0.15 ± 0.02	0.14 ±0.03
	Total collisions (PA)	23.1 ± 1.6	32.9 ± 2.3	32.0 ± 1.8	7.5 ± 2.9	11.1 ± 1.9	11.1 ± 1.9
	MIP (m/min)	106.8 ± 2.0	112.1 ± 2.7	113.1 ± 2.1	121.4 ± 3.4	121.0 ± 2.3	120.5 ± 2.2
	MIP (collisions/min)	1.22 ± 0.06^{c}	1.28 ± 0.09^{df}	1.43 ± 0.07^{bc}	0.91 ± 0.1$^{c}_{\#}$	1.07 ± 0.07	0.94 ± 0.07^{bc}
	Accelerations/min 2-3 m/s^2	0.78 ± 0.3$^{d}_{¥\$}$	0.86 ± 0.3$_{*}$	0.92 ± 0.3	1.34 ± 0.4$^{af}_{*\#}$	0.82 ± 0.3	0.74 ± 0.2^{d}
	Accelerations/min 3-4 m/s^2	0.31 ± 0.1d$^{d}_{\#}$	0.32 ± 0.2$^{d}_{\#¥}$	0.36 ± 0.1$_{\#¥}$	0.51 ± 0.2$^{abf}_{\#¥*}$	0.33 ± 0.1$_{\#¥}$	0.31 ± 0.1$^{d}_{\#}$
	Accelerations/min >4 m/s^2	0.06 ± 0.06$^{de}_{\#*}$	0.09 ± 0.04$^{e}_{\#*}$	0.06 ± 0.04$^{de}_{\#}$	0.10 ± 0.07$^{ac}_{\#¥*}$	0.13 ± 0.07$^{abcf}_{\#¥*}$	0.08 ± 0.05$^{e}_{\#*}$
	Decelerations/min 2-3 m/s^2	0.79 ± 0.2d$^{d}_{*}$	0.84 ± 0.2^{f}	0.81 ± 0.2$^{df}_{\#}$	1.15 ± 0.2$^{acef}_{\#}$	0.71 ± 0.2$^{df}_{*}$	0.61 ± 0.2^{bcde}
	Decelerations/min 3-4 m/s^2	0.34 ± 0.2$^{d}_{\#}$	0.34 ± 0.2$^{d}_{\#}$	0.41 ± 0.2$^{f}_{\#¥}$	0.51 ± 0.3$^{abef}_{\#¥*}$	0.34 ± 0.2$^{d}_{\#¥}$	0.28 ± 0.1^{cd}
	Decelerations/min >4 m/s^2	0.17 ± 0.11$_{\#¥*\wedge}$	0.16 ± 0.13$_{\#¥*}$	0.19 ± 0.1$_{\#¥*}$	0.24 ± 0.11$_{\#¥*}$	0.17 ± 0.07$_{\#¥}$	0.20 ± 0.08$_{\#¥*}$

FR = front row, L = lock, BR = back row, SH = scrum half, IB =inside back, OB = outside back. [a], [b], [c], [d], [e], [f] = significantly different to front row, lock, back row, scrum half, inside back, outside back respectively, within the tabulated year. $_{\#}$, $_{¥}$, $_{*}$, $_{\wedge}$, $_{\$}$ = significantly different to 2015, 2016, 2017, 2018, 2019 respectively, within the tabulated position.

Discussion

The current study is the first to report physical match characteristics of female rugby players from an international team ranked in the top 2 nations between 2015-2019. This is also the first study to demonstrate an increase in average running demands, sprints and high-intensity accelerating and decelerating, among female rugby union players across a five-year period, spanning the transition from amateur to professional status. Furthermore, we provide evidence that match-running demands and collisions of this high-ranking international team are affected by their field position and the quality of their playing opposition.

The average speed reported in the current study (65.9 m/min) was similar to that reported in female rugby (68.3 m/min)[29] and comparable to the lower values found in male rugby,[4, 7] yet below the highest reported therein (~ 81 m/min).[1, 19] Despite this parity with previous female reports,[29] the same study found that ~ 1.2% of total distance was spent at high speeds (>5.5 m/s) and sprint frequency was reported as 0.02/min and 0.1/min (for forwards and backs, respectively). This was markedly lower than the 2.7 % high-speed running and sprint frequency of 0.18 /min and 0.54 /min reported in the current study. We also show slightly higher average speed during MIP in the same season (115.8 ± 13.5 *vs.* 111.4 ± 10.4 m/min), than those reported by Sheppy et al. (2019) using a similar duration of rolling epochs. However, during 2017 World Cup Year, the average speed during MIP in the current team (118.4 ± 12.9 m/min) was higher, particularly when playing top 5 opposition (120.5 ± 12.8 m/min). Although factors such as team playing style, sample size differences, and the elapsed time between these reports might have affected the differences between studies,[9] our findings suggest that previous reports may not fully account for the higher range of running demands in elite-level female matches.

Differences in physical match characteristics between forwards and backs have been reported in bottom 5 ranked international female teams,[28, 29] and we confirm this for top 5 ranked teams. Our findings also agree with those of Sheppy et al. (2019), in that FR covered the least total distance in matches but are similar to SH. Front row and SH typically played fewer minutes (53 ± 26 min and 54 ± 28 min, respectively) than other positions, indicating that typical substitution strategies, rather than lower average match demands, account for this pattern. Front row and L had the lowest average running outputs, particularly in higher speed zones, while backrow players were generally comparable with IB but performed less high-speed efforts, and SH run at the highest average speed. Scrum-halves produced the greatest and OB the least number of average accelerations and decelerations 2-3 m/s^2 (1.2 ± 0.5 and 0.8 ± 0.5, respectively). These findings may reflect the constant running demand of SH at moderate intensities and frequent match involvements,[8] and the relatively low running activity of OB in 2-3 m/s running zones.[29] Average speed during MIP was similar to those of Sheppy et al. (2019) for forwards but higher for backs during similar duration match segments in the same season. Although these differences may be due to the slightly lower epoch in our study (3 min *vs.* 2 min 45 s), we speculate that greater technical skill and physical ability amongst our elite-level cohort could have caused these observations. Whilst our data also agree with reports that FR have the lowest average speed during MIP, [24] we found no differences between L and FR during similar duration segments. This is a discrepancy that we speculate is a result of the higher-level front five forwards in our cohort being specialised for their critical role in intensive collisions and static exertion.[14, 23, 27]

For the first time, we report collision outputs during International female rugby. For micro-technologically-derived collisions, we show similar demand between forward positions. Outside backs were lower than all forward positions, IB were lower than L and BR, and SH were lower than only L. These findings contrast reports utilising the same technology,[20] which show greater average collision demand for forwards positions compared to backs in an elite male cohort, with half-backs also lower than centres. Average collision values by position were similar, albeit slightly lower than previous reports,[20] but the demand for SH was higher (0.25 ± 0.2 and 0.18 ± 0.1 collisions/min, respectively). Collisions/min (PA) were similar among SH and other backline positions, which is also not in agreement with studies in male rugby, where centres were found to be higher than SH.[24, 26] This might be a by-product of the more ‘open and continuous’ style of play associated with the female game,[15] demanding greater tackling frequency among SH. However, position by season interactions showed average collisions during MIP to diminish among SH between 2015 and 2019. We therefore acknowledge that although the collision demands of SH appear higher in female rugby, this may be changing to align more closely with the corresponding demand of SH in male rugby. Average collisions during MIP were higher than those reported in a professional male cohort [24] (range 0.97 ± 0.3 to 1.46 ± 0.5 and mean 0.3 to 0.9, respectively), and albeit with different analytical methods (microtechnological *vs.* performance analysis derived, respectively). This may have important implications for specific training methods and safety interventions amongst female rugby players, given the increasing awareness of head injury management in rugby union.[7]

Analysis by season showed that sprints/min, average speed, average distance at 3-5 m/s, accelerations and decelerations 2-3 m/s^2 /min and average speed during MIP were lowest in 2015, peaked during the 2017 World Cup year and declined in 2019. The current team, and many other higher ranked nations, were professional or trained more regularly during 2017 compared to previous years, thereafter losing their professional status in 2018 and regaining it in 2019. This may account for the observed pattern, assuming professional status facilitated developments in physical fitness and skill of players.[12, 25] The current data support this notion, as average speed during MIP was greater against top 5 opposition in 2017 compared to all other years. However, when playing bottom 5 opposition, MIP m/min was only higher in 2017 compared to 2015, suggesting that the match demands against top 5 teams increased in 2017. However, the 2019 decline in average running values was mirrored only by corresponding absolute values for sprints amongst the backs and average speed during MIP, whilst other variables plateaued after 2017. Lower total sprint demands of IB and OB, therefore, most likely accounts for the overall decline in average running output, and suggests these positions were utilised frequently to deliver a more intermittent, high-intensity game format during 2017. Indeed, intensive running is a typical differentiation between higher and lower levels in male rugby[1, 13, 24] and is, therefore, consistent with a more effective playing style. In contrast, however, we show acceleration and deceleration frequency in 3-4 m/s^2 and >4 m/s^2 zones to increase between 2017 and 2018 and plateau in 2019, suggesting that the intensity of movement over short distances has increased in the latter seasons. Increasing endurance fitness levels across time could have led to more frequent high-intensity efforts[13], which is a favourable characteristic of successful teams in other rugby codes [18] and could possibly explain this trend in our elite cohort.

In matches against top 5 opposition, average collisions were higher, but average speed was higher in matches against bottom 5 opposition. Both findings agree with evidence from other rugby codes[17, 23] and are, presumably, due to more clean breaks and tries when playing poorer teams, as well as more effective defences when playing better teams.[3,13, 15] However, in contrast, our finding that average speed during MIP, was higher against top 5 opposition in 2017, despite the higher collisions, demonstrates the capacity to maintain an expansive running game, irrespective of the negative effect of collisions on running.[17, 22] Thus, coaches should be aware of the need for players to endure similar or higher running intensities during the most demanding match scenarios, whilst tolerating the same frequency of collisions.

In most cases, the magnitude of difference in physical match characteristics found during pairwise comparisons of position, season or opposition strength was greater than the pooled match-match variability. However, for variables such as collisions and average speed during

MIP, the magnitude of change was lower and often less than the typical between-match variation, thus reducing the certainty of the finding. The higher variation in collisions and MIP average speed could be explained by the changing playing style of the opponents and reactive tactical variation of the current team. Indeed, playing styles have been shown to influence match running and contact demands.[18] Our interpretation is that variables, such as collisions and average MIP speed, are less predictable and can range in their magnitude, irrespective of player's position or opponents, and have been this way for five seasons. Therefore, players should be physically and tactically prepared to react to these more variable demands of international rugby. Finally, it is a possible limitation that the current analysis included only one team.[9] Extrapolating the current findings to the wider elite-level female rugby population should be viewed with some caution, as changes may have been specific to one team and their tactical preferences.

Conclusion

In conclusion, we provide evidence of a general increase in match demands across the study period, with most physical match characteristics lowest in the two earliest years of the study, prior to professionalization of the sport. Average running demands generally peaked during the 2017 World cup year, and were underpinned by increases in sprinting efforts among IB and OB, as well as greater running demands during maximum intensity periods when competing against top 5 opposition. Therefore, matches played in the most competitive year of women's rugby, against the most competitive teams, generally demanded the greatest peak physical match activities. During briefer match periods, the SH position had the greatest relative high-speed and sprinting demands, which were maintained alongside high relative collision counts. Thus, these data characterise the particular physical and tactical requirements of players in the SH position, and their potential importance during the most competitive matches. Players in the forward positions performed a high frequency of collisions in matches, which was generally equivalent to that reported in the rugby literature but, importantly among the highest recorded in the literature during the MIPs of any rugby matches. The increases in high-intensity accelerations and decelerations in the latter years of the current study, alongside the maintenance of average running demands and collision counts, is consistent with the previously reported continuous and 'open' playing style of female rugby, which could place different demands on these elite players, particularly among positions that require frequent ball involvement for tactical purposes. Our findings suggest that training methods designed for elite-level female rugby players should account for the full variation in physical match characteristics highlighted in this study, with focus on preparing players for high-speed demands, frequent acceleration, deceleration and collision events to support the chosen playing style. In preparation for lower-ranking teams, high running demands should be expected but, in the most competitive matches, coaches should anticipate the greatest peak in these physical demands.

Practical Implications

- Practitioners working with elite-level female players should develop physical capabilities which underpin intermittent high-speed running, acceleration and deceleration capacity, particularly among backline players.
- Training strategies based on maximum intensity periods in matches should be aligned to collision and running demands against high ranked teams, but average running speed in training should be aligned to demands against lower ranked opposition.
- Collision demand during maximum intensity periods may be higher in female rugby and, therefore, could represent a greater risk of contact injury than in the male game, which should be considered in physical and technical preparations.

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