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## Research Article

# Physical Demands of Amateur Senior Domestic Rugby Union Players Over One Round of Competition Matches in New Zealand Assessed Using Heart Rate and Movement Analysis -

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## ABSTRACT

To describe the physical demands of senior domestic amateur rugby union using microtechnology. A cohort descriptive study was conducted to collect data from a senior domestic amateur rugby union team over one round of competition matches ( $n = 13$ ) using heart rate and microtechnology data. Total distance, maximal velocity, Player Load ((PL) accumulated accelerometer-derived load), Two-Dimensional (medio-lateral and anterior-posterior) PL (2DPL), low speed activities ( $<2 \text{ m}\cdot\text{s}^{-1}$ ) ( $\text{PL}_{\text{LOW}}$ ) and individual PL vectors (PL forward ( $\text{PL}_F$ ), PL sideward ( $\text{PL}_S$ ) and PL vertical ( $\text{PL}_V$ )) were examined. Analyses by playing player position, player group were conducted. Outside-backs recorded a higher mean distance ( $5,880 \pm 1,979 \text{ m}$ ) per match than front-row-forwards ( $\chi^2 = 5.1$ ;  $p = 0.0243$ ;  $z = -2.0$ ;  $p = 0.0448$ ;  $d = 0.45$ ). Forwards recorded a higher  $\text{PL}_{\text{LOW}}$  ( $F_{(65,65)} = 2.9$ ;  $p < 0.0001$ ;  $d = 0.06$ ) but had a lower  $\text{PL}_F$  ( $F_{(59,71)} = 6.3$   $p < 0.0001$ ;  $d = 0.08$ ),  $\text{PL}_S$  ( $F_{(66,64)} = 3.0$ ;  $p < 0.0001$ ;  $d = 0.08$ ) and  $\text{PL}_V$  ( $F_{(68,62)} = 6.9$ ;  $p < 0.0001$ ;  $d = 0.25$ ) when compared with backs. Given the similarities in the physical and physiological profile of individual positions, it is likely that players at this level undertake more generalised training regimes that fail to prepare them for higher levels of competition. Further, players may benefit from the incorporation of positional specific training in order to afford each playing position the opportunity to develop game-specific physical qualities.

**Keywords:** Accelerometry; Movement demands; Activity profiles; Physical demands; Match play; Rugby union

## INTRODUCTION

Rugby union is an intermittent contact invasion game, involving periods of high-intensity activity (i.e. running, collisions, scrummaging) and lower-intensity activities including periods of rest [1,2]. The incorporation of microtechnology (Global Positioning System [GPS] and integrated tri-axial accelerometer) devices has enabled researchers and practitioners, to quantify the workloads experienced within team sports such as rugby union [3,4]. The knowledge attained from the incorporation of microtechnology enables detailed sport-specific data positional specific movement profiles [3,4] and is deemed invaluable [5] to coaching staff as it can assist with the facilitation of optimal player training programs and therefore, match-play preparation [6]. Further, the use of microtechnology has been reported to be a reliable approach to the assessment of the physical and physiological demands of team sports [3].

With the advent of professionalism in rugby union, the characteristics of the game have been well documented [6]. Furthermore, the speed and size of players, [7] work to rest ratios, [4] forces in the tackle, [8] the number of tackles and rucks [9] and positional demands [10] have all been documented. Using microtechnology, it has been reported that, on average, rugby union players cover 6,953 m throughout match-play [11]. Total match-play distance is however, dependent upon playing position with back playing positions (6,471 m) covering more distance than forward playing positions (5,853 m) [12]. Positional differences are also reported to exist in relation to the intensity of match-play with back playing positions covering a greater relative distance than forward playing positions (71.9 vs 66.7  $\text{m}\cdot\text{min}^{-1}$ , respectively) [11]. Contradictory literature has, however, been published stating that back playing positions cover slightly less high-speed distance (323m vs 369 m) than forward playing positions [6]. Further, examination of the work:rest ratio by positional groups indicates that backs (1:5.7) and forwards (1:5.8) produce similar work throughout a match [11]. In addition to playing position, both athletic calibre and age have been reported to impact on the distance covered throughout match-play with elite senior [12] and junior [13] rugby union forwards covering 5,853 m and 3,511 m, respectively.

Despite the movement demands of rugby union being fairly well explained, most studies to date have been undertaken at either age-grade elite or the professional level of competitions. As such, there is a paucity of studies reporting on the physical and physiological demands at the amateur senior domestic level of rugby union.

Therefore, the aim of this study was to quantify the movement demands and physiological responses of senior amateur rugby union players by player roles and player positional groups over one round of domestic competition matches within New Zealand.

## METHODS

### Study design

Following a non-intervention descriptive design, the movement demands and physiological responses of senior amateur rugby union players in New Zealand were measured using microtechnology and Heart Rate (HR) during one round of 13 competition matches. The lead researcher's University Ethics Committee (AUTEC 16/35) approved all procedures in the study and all players gave informed written consent prior to participating in the study.

### Participants

A total of 34 senior amateur (premier level) club rugby union players (age:  $23.5 \pm 5.2 \text{ yr.}$ ) participated in the study for 13 competition matches resulting in a match exposure of 259.4 match hr. All players were considered amateur as they received no remuneration for participating in rugby union activities. The matches were played under the rules and regulations of the New Zealand Rugby Union. Players were categorised according to their (1) playing group and (2) positional group [6]. These two groups were: (1a) Forwards (loose-head prop, hooker, tight-head prop, left lock, right lock, blind-side flanker, open-side flanker, and number eight) and (1b) Backs (scrum half, fly half, left wing, inside centre, outside centre, right wing, and full back); and (2a) Front Row Forwards (FRF) (loose-head prop, tight-head prop; left lock, right lock); (2b) Back Row Forwards (BRF) (hooker; blind-side flanker, open-side flanker, number eight); (2c) In-Side Backs (ISB) (scrum half; fly half, inside centre, outside centre) and (2d) Out-Side Backs (OSB) (left wing, right wing, full back). The hooker was included in the BRF group due to their roving style of play [14]. This would most accurately reflect the positions with similar match demands and enable comparisons to be undertaken.

### Data collection procedures

Player movements were monitored using microtechnology devices (OptimEye S5 device; Catapult Innovations, Melbourne, Australia) worn in a custom designed pocket within a vest supplied by the device manufacturer, between the shoulder blades. These devices produce a 10 Hz GPS sampling rate through the in-built GPS-chip. Additionally, the devices contain a tri-axial accelerometer, gyroscope and magnetometer sampling at 100 Hz (firmware v.5.27). As such, the

device can continuously monitor linear and rotational accelerations, direction and orientation of the player during match-play. Player HR were continuously measured during match-play using a portable monitor (Team Heart Rate System, Polar, Kempele, Finland). The OptimEye S5 has been previously reported to have valid and reliable distance and speed measurements, have very strong correlation ( $r = 0.94$ ) with distance covered and acceptable within- and between-device reliability for the measurement of acceleration forces [15,16].

Mean and peak HR for each match were calculated for each player. During each match the following time and GPS-based variables were analysed: match time (min), total distance (m) and maximum Velocity ( $(Vel_{Max})$  m.s<sup>-1</sup>). Additionally, accumulated accelerometer-derived loads, known as PlayerLoad (PL), were calculated by the sum of accelerations in the mediolateral [x], anteroposterior [y] and vertical [z] directions to provide a measure of the total stress upon an athlete as a result of accelerations, decelerations, and changes of direction [16,17].

PlayerLoad is expressed as the square root of the sum of the squared instantaneous rate of change in each of the three vectors. The application of this variable as a marker of training load has been established against both internal [18] and external load [19] measures. PL has previously been shown to be reliable both between (1.02% Coefficient of Variation (CV)) and within devices (1.05% CV) for dynamic movements [20]. Further, within a team sport circuit, the reliability of PL was reported as 4.9% CV. Additionally, PL demonstrates high inter-unit reliability within Australian Rules Football (1.94% CV) [20]. There is a strong relationship between PL and total distance [21] and as such, the vertical vector of the PL equation can be removed, thereby providing a measure of acceleration in the medio-lateral and anterior-posterior planes only (Two-Dimensional Player Load (2DPL)) [22]. Such 2D measures have recently been shown [23] to be more sensitive to collision load within contact based team sports such as rugby league. To report only low-speed activities ( $<2$  m.s<sup>-1</sup>) the  $PL_{SLOW}$  was recorded. The  $PL_{SLOW}$  is accumulated through accelerations that are recorded in the three vectors of movement and is a proxy measure for the frequency and magnitude of low-speed exertions in rugby union (e.g., rucking and scrummaging) [1] that GPS or video analysis are unable to provide. The  $PL_{SLOW}$  is related ( $r^2 = 0.62$ ) to collisions that occur during rugby union match-play [24]. The PL and 2DPL were recorded as well as the PL in each of the individual axes i.e. PL forward ( $PL_F$ ), PL sideward ( $PL_S$ ) and PL vertical ( $PL_V$ ). Each PL variable were normalised for all match times (minutes) and reported in arbitrary units (au.min<sup>-1</sup>).

## Procedures

All players were allocated an individual S5 device which they wore during all recorded matches. Heart rate was continuously monitored during match participation to establish mean and peak HR. Post-match all data were downloaded and trimmed (to include in-match-play only) using proprietary software (Openfield, Catapult Innovations, Melbourne, Australia). The use of GPS technology has been utilised for research in several sporting codes including soccer, rugby league, Australian football league [3] and rugby union [25] and has been reported to be acceptable [26] and ecologically [27] valid when assessing contact-based team sports.

## Statistical analysis

All data collected were analysed with SPSS (V25.0 Armonk, NY: IBM Corp). Data were checked for normality and homogeneity of

variance using a Shapiro-Wilk's test of normality. If tolerances were not met, the equivalent non-parametric tests were utilised. Comparison of the physical demands (i.e. Player Load [PL];  $PL_{2D}$ ;  $PL_{SLOW}$ ;  $PL_F$ ;  $PL_S$ ;  $PL_V$ ; MaxVel;) among player positions and participation levels were compared using a 1-way Analysis of Variance (ANOVA) with a Tukey post-hoc test to determine the source of differences. Data that were shown to be non-parametric (Distance; Max HR; Mean HR and Velocity band distance) were analysed with a Friedman repeated measures ANOVA on ranks. If any notable differences were observed, a Wilcoxon signed-rank post-hoc test was conducted with a Bonferroni correction applied. Cohen's effect size ( $d$ ) were utilised to calculate practically meaningful differences between playing positions, matches and for different levels of participation. Effect sizes of  $<0.19$ ,  $0.20$ - $0.60$ ,  $0.61$ - $1.20$  and  $>1.20$  were considered trivial, small, moderate, and large, respectively [28]. The level of significance was set at  $p \leq 0.05$ , and all data are expressed as means and standard deviations.

## RESULTS

Outside Backs (OSB) recorded a higher mean distance ( $5,880 \pm 1,979$  m) per match than Front Row Forwards (FRF) ( $\chi^2 = 5.1$ ;  $p = 0.0243$ ;  $z = -2.0$ ;  $p = 0.0448$ ;  $d = 0.45$ ) (see table 1). As a result, OSB recorded a higher PL ( $F_{(30,26)} = 5.2$ ;  $p < 0.0001$ ;  $d = 0.43$ ), 2DPL ( $F_{(28,28)} = 5.0$ ;  $p < 0.0001$ ;  $d = 0.31$ ) and maximum velocity ( $F_{(28,28)} = 14.4$ ;  $p < 0.0001$ ;  $d = 0.52$ ) than FRF. Inside Backs (ISB) recorded a higher 2DPL than FRF ( $F_{(34,35)} = 19.1$ ;  $p < 0.0001$ ;  $d = 0.49$ ), Back Row Forwards (BRF) ( $F_{(34,32)} = 11.6$ ;  $p < 0.0001$ ;  $d = 0.10$ ) and OSB ( $F_{(20,36)} = 31.9$ ;  $p < 0.0001$ ;  $d = 0.43$ ). Forwards recorded a higher  $PL_{SLOW}$  ( $F_{(65,65)} = 2.9$ ;  $p < 0.0001$ ;  $d = 0.06$ ) but had a lower  $PL_F$  ( $F_{(59,71)} = 6.3$ ;  $p < 0.0001$ ;  $d = 0.08$ ),  $PL_S$  ( $F_{(66,64)} = 3.0$ ;  $p < 0.0001$ ;  $d = 0.08$ ) and  $PL_V$  ( $F_{(68,62)} = 6.9$ ;  $p < 0.0001$ ;  $d = 0.25$ ) when compared with backs. Forwards recorded a higher mean HR than backs ( $\chi^2 = 4.2$ ;  $p = 0.0397$ ;  $z = -2.6$ ;  $p = 0.0086$ ;  $d = 0.23$ ) per match. Players recorded a higher mean HR in matches lost ( $145 \pm 31$  b.min<sup>-1</sup>) when compared with matches won ( $\chi^2 = 5.6$ ;  $p = 0.0181$ ;  $z = -2.3$ ;  $p = 0.0187$ ;  $d = 0.13$ ).

ISB recorded a higher mean distance in the  $1.5$  to  $2.5$  m.s<sup>-1</sup> ( $\chi^2 = 7.7$ ;  $p = 0.0054$ ;  $z = -2.0$ ;  $p = 0.0415$ ;  $d = 0.24$ ) and  $2.5$  to  $3.5$  m.s<sup>-1</sup> velocity band ( $\chi^2 = 6.3$ ;  $p = 0.0118$ ;  $z = -2.3$ ;  $p = 0.0197$ ;  $d = 0.36$ ) when compared with OSB (see table 2). Front-Row forwards recorded a lower mean distance in the  $6.0$  to  $7.0$  m.s<sup>-1</sup> ( $\chi^2 = 19.1$ ;  $p < 0.0001$ ;  $z = -5.1$ ;  $p < 0.0001$ ;  $d = 1.12$ ) and  $7.0$  to  $8.0$  m.s<sup>-1</sup> ( $\chi^2 = 9.6$ ;  $p = 0.0019$ ;  $z = -3.0$ ;  $p = 0.0029$ ;  $d = 0.21$ ) velocity bands when compared with ISB. As a result, forwards recorded a lower distance in the  $6.0$  to  $7.0$  m.s<sup>-1</sup> ( $\chi^2 = 28.6$ ;  $p < 0.0001$ ;  $z = -5.7$ ;  $p < 0.0001$ ;  $d = 0.86$ ) and  $7.0$  to  $8.0$  m.s<sup>-1</sup> ( $\chi^2 = 26.5$ ;  $p < 0.0001$ ;  $z = -4.3$ ;  $p < 0.0001$ ;  $d = 0.23$ ) velocity bands than backs. Interestingly matches that were won recorded higher mean distances when compared with games lost in band 4 ( $2.5$  to  $3.5$  m.s<sup>-1</sup>;  $\chi^2 = 5.6$ ;  $p = 0.0181$ ;  $z = -1.3$ ;  $p = 0.1697$ ;  $d = 0.02$ ) and band 5 ( $2.5$  to  $3.5$  m.s<sup>-1</sup>;  $\chi^2 = 6.2$ ;  $p = 0.0127$ ;  $z = -1.3$ ;  $p = 0.1894$ ;  $d = 0.08$ ) velocities, although these were not significant.

## DISCUSSION

This study reports the physical demands of amateur domestic senior rugby union players over a round of competition matches by player position and roles in New Zealand. The results identify the physical and physiological profile of individual positional groups in rugby union throughout match participation. Given the limited availability of both GPS- and accelerometer-based variables in amateur senior rugby union, this study highlights the importance of



**Table 1:** Summary of movement demands and physiological responses of senior amateur domestic rugby union players in New Zealand over a round (13 matches) of competition matches by player positional groups, player roles, matches won, matches lost and total players.

	FRF	BRF	Forwards	ISB	OSB	Backs	Matches won	Matches lost	Total
	mean ± SD	mean ± SD	mean ± SD	mean ± SD	mean ± SD	mean ± SD	mean ± SD	mean ± SD	mean ± SD
Players (n = )	4	4	8	4	3	7	15	15	15
Match Exposure (hr.)	69.2	69.2	138.3	69.2	51.9	121	179.6	79.8	259.4
Distance (m)	4,060 ± 2,622 <sup>d</sup>	4,410 ± 2,715	4,260 ± 2,673	6,163 ± 2,852	5,880 ± 1,979 <sup>a</sup>	5,377 ± 2,579	4,849 ± 2,635	5,188 ± 3,074	4,953 ± 2,775
Distance (m·min <sup>-1</sup> )	50.7 ± 33.5 <sup>d</sup>	60.9 ± 34.4	55.7 ± 34.2	70.3 ± 33.4	66.2 ± 36.1 <sup>a</sup>	68.5 ± 34.5	60.6 ± 32.9	64.9 ± 38.4	62.0 ± 34.9
PL (au·min <sup>-1</sup> )	5.5 ± 3.2 <sup>bcd</sup>	6.1 ± 3.6 <sup>acd</sup>	5.8 ± 3.4 <sup>f</sup>	7.6 ± 3.4 <sup>abd</sup>	7.1 ± 2.2 <sup>abc</sup>	6.9 ± 3.0 <sup>e</sup>	6.4 ± 3.3	6.6 ± 3.6	6.4 ± 3.4
2DPL (au·min <sup>-1</sup> )	3.4 ± 2.0 <sup>bcd</sup>	3.7 ± 2.1 <sup>acd</sup>	3.6 ± 2.0 <sup>f</sup>	4.6 ± 2.1 <sup>abd</sup>	4.1 ± 1.3 <sup>abc</sup>	4.2 ± 1.8 <sup>e</sup>	3.9 ± 1.9	4.0 ± 2.1	3.9 ± 2.0
PL <sub>Slow</sub> (au·min <sup>-1</sup> )	3.1 ± 1.7 <sup>bcd</sup>	3.3 ± 1.8 <sup>acd</sup>	3.2 ± 1.7 <sup>f</sup>	3.5 ± 1.5 <sup>abd</sup>	3.3 ± 1.3 <sup>abc</sup>	3.4 ± 1.4 <sup>e</sup>	3.2 ± 1.5 <sup>h</sup>	3.4 ± 1.8 <sup>g</sup>	3.3 ± 1.6
PL <sub>F</sub> (au·min <sup>-1</sup> )	2.1 ± 1.3 <sup>bcd</sup>	2.2 ± 1.3 <sup>acd</sup>	2.2 ± 1.3 <sup>f</sup>	2.8 ± 1.3 <sup>abd</sup>	2.5 ± 0.8 <sup>abc</sup>	2.6 ± 1.1 <sup>e</sup>	2.3 ± 1.2	2.4 ± 1.3	2.4 ± 1.2
PL <sub>S</sub> (au·min <sup>-1</sup> )	2.3 ± 1.3 <sup>bcd</sup>	2.4 ± 1.3 <sup>acd</sup>	2.3 ± 1.3 <sup>f</sup>	3.0 ± 1.3 <sup>abd</sup>	2.7 ± 0.9 <sup>abc</sup>	2.7 ± 1.2 <sup>e</sup>	2.5 ± 1.3	2.6 ± 1.4	2.6 ± 1.3
PL <sub>T</sub> (au·min <sup>-1</sup> )	3.7 ± 2.2 <sup>bcd</sup>	4.2 ± 2.5 <sup>acd</sup>	4.0 ± 2.4 <sup>f</sup>	5.4 ± 2.4 <sup>abd</sup>	5.0 ± 1.6 <sup>abc</sup>	4.8 ± 2.1 <sup>e</sup>	4.4 ± 2.3	4.5 ± 2.5	4.5 ± 2.4
MaxVel (m·s <sup>-1</sup> )	6.5 ± 1.3 <sup>bcd</sup>	6.9 ± 1.4 <sup>ac</sup>	6.7 ± 1.4	7.5 ± 1.1 <sup>abd</sup>	8.6 ± 1.3 <sup>ac</sup>	7.3 ± 1.2	7.2 ± 1.5	7.0 ± 1.3	7.1 ± 1.4
Max HR (b·min <sup>-1</sup> )	195 ± 39	194 ± 41	195 ± 40	199 ± 38	201 ± 22	199 ± 33	196 ± 37	198 ± 38	197 ± 37
Mean HR (b·min <sup>-1</sup> )	138 ± 33	143 ± 31 <sup>c</sup>	141 ± 32 <sup>f</sup>	143 ± 33 <sup>b</sup>	146 ± 12	144 ± 28 <sup>e</sup>	141 ± 30 <sup>h</sup>	145 ± 31 <sup>g</sup>	142 ± 30

FRF: Front-Row Forwards; BRF: Back-Row Forwards; ISB: Inside Backs; OSB: Outside Backs; SD: Standard Deviation; min: Minutes; m: metres; au·min<sup>-1</sup>: arbitrary units per minute; PL: Player Load; 2DPL: 2-Dimension (frontal & sagittal) Player Load; PL<sub>Slow</sub>: player load < 2 m·s<sup>-1</sup> (metres per second); PL<sub>Fwd</sub>: player load in frontal plane; PL<sub>Side</sub>: PlayerLoad in sagittal plane; PL<sub>Up</sub>: PlayerLoad in transverse plane; MaxVel (m·s<sup>-1</sup>): Maximum Velocity (metres per second); HR: Heart Rate; b·min<sup>-1</sup>: beats per minute; Significant difference ( $p < 0.05$ ) than (a): FRF; (b): BRF; (c): ISB; (d): OSB; (e): Forwards; (f): Backs (g); matches won; (h): matches lost.

**Table 2:** Summary of velocity and distances covered for senior amateur domestic rugby players over a round (13 matches) of competition matches in New Zealand by player positional groups, player roles and total players.

		FRF	BRF	Forwards	ISB	OSB	Backs	Matches won	Matches lost	Total
Band No	Velocity	mean ± SD	mean ± SD	mean ± SD	mean ± SD	mean ± SD	mean ± SD	mean ± SD	mean ± SD	mean ± SD
Band 1	0.0 to 1.5 (m·s <sup>-1</sup> )	1,965.9 ± 1,220.8	2,090.1 ± 1,133.3	2,037.0 ± 1,169.4	2,615.3 ± 1,135.4	2,661.5 ± 884.0	2,399.8 ± 1,051.4	2,236.2 ± 1,129.0	2,330.3 ± 1,232.9	2,265.0 ± 1,160.2
Band 2	1.5 to 2.5 (m·s <sup>-1</sup> )	1,026.1 ± 974.2	1,010.1 ± 909.9	1,016.9 ± 934.9	1,343.5 ± 936.5 <sup>d</sup>	1,321.7 ± 752.2 <sup>c</sup>	1,252.3 ± 873.7	1,142.8 ± 899.7	1,131.7 ± 980.8	1,139.4 ± 923.4
Band 3	2.5 to 3.5 (m·s <sup>-1</sup> )	477.9 ± 347.7 <sup>c</sup>	480.7 ± 344.4	479.5 ± 344.7	740.3 ± 434.0 <sup>ad</sup>	699.7 ± 305.0 <sup>c</sup>	633.6 ± 393.3	566.6 ± 386.2	591.6 ± 376.9	574.2 ± 382.8
Band 4	3.5 to 6.0 (m·s <sup>-1</sup> )	416.8 ± 383.1 <sup>c</sup>	504.6 ± 493.1	467.1 ± 450.2 <sup>f</sup>	841.0 ± 611.0 <sup>ad</sup>	755.2 ± 356.2 <sup>c</sup>	685.0 ± 536.9 <sup>e</sup>	596.2 ± 525.3	606.2 ± 485.6	599.2 ± 512.5
Band 5	6.0 to 7.0 (m·s <sup>-1</sup> )	45.1 ± 60.1 <sup>cd</sup>	68.8 ± 72.3	58.6 ± 68.2 <sup>f</sup>	160.9 ± 121.7 <sup>ab</sup>	161.2 ± 70.5 <sup>a</sup>	114.9 ± 106.5 <sup>e</sup>	100.4 ± 101.0	92.4 ± 92.3	97.9 ± 98.3
Band 6	7.0 to 8.0 (m·s <sup>-1</sup> )	9.5 ± 21.1 <sup>cd</sup>	20.1 ± 23.4 <sup>d</sup>	15.1 ± 22.9	45.5 ± 60.0 <sup>a</sup>	65.5 ± 53.9 <sup>bc</sup>	55.8 ± 57.0 <sup>e</sup>	34.8 ± 49.7	24.1 ± 31.2	31.5 ± 45.1
Band 7	8.0 to 9.0 (m·s <sup>-1</sup> )	1.6 ± 9.5 <sup>cd</sup>	1.2 ± 5.6 <sup>d</sup>	1.4 ± 7.5 <sup>f</sup>	1.5 ± 6.0 <sup>ad</sup>	15.8 ± 22.5 <sup>abc</sup>	3.9 ± 15.5 <sup>e</sup>	3.3 ± 11.5	3.4 ± 11.7	3.3 ± 11.5
Band 8	9.0 to 10.0 (m·s <sup>-1</sup> )	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.7 ± 2.4	0.1 ± 1.4	0.1 ± 0.8	0.2 ± 1.1	0.1 ± 0.9

FRF: Front-Row Forwards; BRF: Back-Row Forwards; ISB: Inside Backs; OSB: Outside Backs; SD: Standard Deviation; m·s<sup>-1</sup>: metres per second; Significant difference ( $p < 0.05$ ) than (a): FRF; (b): BRF; (c): ISB; (d): OSB; (e): Forwards; (f): Backs.

integrating microtechnology into the routine monitoring of amateur sports such as rugby union.

The mean total distance covered over the duration of the study (4,953 m) is higher than that reported for Under 18 [13] (4,000 m) rugby union players but less than the mean total distances covered in professional rugby union [11] (6,953 m). When compared by player groups, the findings were similar to previous studies, [6,29] with the backs covering a greater mean distance (5,377 m) per match when compared with the forwards (4,260 m). The mean distances covered were similar to U19 [29] backs (5,998 m) and forwards (5,892 m) but lower than those reported in an English premiership [6] (Backs: 6,545 m; Forwards: 6,427 m) and Celtic nations [11] (Backs: 7,227

m; Forwards: 6,680 m) professional rugby competitions. In relative terms the backs (68.5 m·min<sup>-1</sup>) covered more ground per minute than the forwards (55.7 m·min<sup>-1</sup>) which was similar to U20 [2] rugby union backs (69.1 m·min<sup>-1</sup>) and forwards (61.5 m·min<sup>-1</sup>) but less than U19 [29] backs (83.0 m·min<sup>-1</sup>) and forwards (78.4 m·min<sup>-1</sup>) and professional [6] rugby union backs (71.1 m·min<sup>-1</sup>) and forwards (64.6 m·min<sup>-1</sup>). These differences may be related to the differences in the levels of fitness seen between sub-elite and professional players when compared with amateur domestic senior rugby union players. The current cohort of amateur senior domestic rugby union players were required to train as a team twice a week before matches, undertook their own individual training in-between academic studies and working full time as well as some players were parents of young



children. As a result, the fitness levels of the domestic amateur senior players would be lower when compared with professional players.

Throughout matches back playing positions travelled greater total distances, including distances above  $6.0 \text{ m}\cdot\text{s}^{-1}$  and accumulated PL and  $\text{PL}_v$  values than forward playing positions. Such a finding is perhaps not surprising given that during running and jogging type movements, the vertical component of this accelerometer-based metric accounts for between 50 and 60% of the overall three-dimensional load [16]. Similarly, back playing positions also accumulated greater 2DPL throughout match-play. Whilst such a finding is contrary to previous work within contact based team-sports, [30] it is likely that increased 2DPL values of the backs is attributable to both short burst of changes of direction and being tackled. On the other hand, the PL and  $\text{PL}_v$  for forwards is likely comprised predominantly of collision and tackle events. Although significant differences are apparent between positions for a number of metrics (PL,  $\text{PL}_v$  and 2DPL) the variance between positions is somewhat trivial from a practical perspective, suggesting that minimal differences are apparent in the physical demands of match-play at this level of competition. Further, such findings highlight the importance of incorporating a variety of external load metrics into the routine monitoring of collision-based sports such as rugby union, in order to adequately quantify the workload across different playing positions.

Although differences were noted between positional groups in regard to  $\text{PL}_{\text{SLOW}}$ , from a practical perspective it appears that both forward and back playing positions accumulate similar loads from low velocity activities such as physical collisions and tackles. This is dissimilar to previous work reporting that forwards attain a greater  $\text{PL}_{\text{SLOW}}$  than their back playing counterparts [31]. Such discrepancies may however, be attributed to altered physical capacities and game play strategies between the examined cohorts.

These results suggest that the physical and physiological profile of individual playing positions at the amateur domestic level of rugby union are quite similar and is perhaps suggestive of generalised rather than specialised training regimes that fail to prepare players for higher levels of competition. Indeed, this cohort may benefit from the incorporation of positional specific training which would provide forward playing positions with the opportunity to develop collision and contact abilities, whilst simultaneously allowing backs a greater opportunity to train their high intensity running capacity.

The current study followed a senior domestic premier rugby union team during one round of competition matches. Therefore, the results reported in this study should be interpreted with caution and may not be transferable to other levels of rugby union participation.

## CONCLUSION

The physical and physiological profile of positional groups at the amateur domestic level of rugby union suggest that players at this level are quite evenly matched. This may be due to their training regimes being more generalised rather than specialised. Given the limited availability of microtechnology data at this level of competition, the study highlights the importance of integrating a variety of external load metrics into the routine monitoring of collision-based sports such as rugby union.

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## PRACTICAL APPLICATIONS

The findings of this study can be utilised to assist with training and tactical strategies that are used in match environments. The present findings suggest that there are specialized playing positions within rugby union that have unique movement and physiological demands. Backs are required to undertake large loads, travel long distances and requires a higher aerobic capacity. Training for these roles should focus on the development of the aerobic capacity for both attack and defending roles. Forwards undertake lower distances and have a lower aerobic capacity. Training for these positions should focus more on skill development and the development of anaerobic capacities.

## REFERENCES

1. Roberts S, Trewartha G, Higgitt RJ, El-Abd J, Stokes KA. The physical demands of elite English rugby union. *J Sports Sci.* 2008; 26: 825-833. <https://goo.gl/SGc1PY>
2. Cunningham D, Shearer D, Drawer S, Eager R, Taylor N, Cook CJ, et al. Movement demands of elite Under-20s and senior international rugby union players. *PLoS One.* 2016; 11: e0153275. <https://goo.gl/nDmuBn>
3. Cummins C, Orr R, O'Connor H, West C. Global Positioning Systems (GPS) and microtechnology sensors in team sports: A systematic review. *Sports Med.* 2013; 43:1025-1042. <https://goo.gl/ms5FxF>
4. Austin D, Gabbett T, Jenkins D. The physical demands of Super 14 rugby union. *J Sci Med Sport.* 2011; 14: 259-263. <https://goo.gl/8KBQMF>
5. Gabbett T. GPS analysis of elite women's field hockey training and competition. *J Strength Cond Res.* 2010; 24: 1321-1324. <https://goo.gl/eZx8VY>
6. Cahill N, Lamb K, Worsfold P, Headey R, Murray S. The movement characteristics of english premiership rugby union players. *J Sports Sci.* 2013; 31: 229-237. <https://goo.gl/3dSuHE>
7. Fuller CW, Taylor AE, Brooks JH, Kemp SP. Changes in the stature, body mass and age of english professional rugby players: A 10-year review. *J Sports Sci.* 2013; 31: 795-802. <https://goo.gl/cPqfCY>
8. Usman J, McIntosh AS, Fréchéde B. An investigation of shoulder forces in active shoulder tackles in rugby union football. *J Sci Med Sport.* 2011; 14: 547-552. <https://goo.gl/RhRAia>
9. Quarrie K, Hopkins W. Changes in characteristics and match activities in Bledisloe Cup rugby union from 1972 to 2004. *J Sports Sci* 2007; 25: 895-903. <https://goo.gl/Tyg6Ce>
10. Lindsay A, Draper N, Lewis J, Gieseg SP, Gill N. Positional demands of professional rugby. *Eur J Sport Sci.* 2015; 15: 480-487. <https://goo.gl/K3mBU>
11. Cunniffe B, Proctor W, Baker JS, Davies B. An evaluation of the physiological demands of elite rugby union using global positioning system tracking software. *J Strength Cond Res.* 2009; 23: 1195-1203. <https://goo.gl/gzXVNu>
12. Suárez-Arrones L, Portillo L, González-Ravé J, Muñoz V, Sanchez F. Match running performance in Spanish elite male rugby union using global positioning system. *Isokinetic Exer Sci.* 2012; 20: 77-83. <https://goo.gl/zGGjQ>
13. Hartwig TB, Naughton G, Searl J. Motion analyses of adolescent rugby union



- players: a comparison of training and game demands. *J Strength Cond Res.* 2011; 25: 966-972. <https://goo.gl/TyDoJb>
14. Deutsch M, Maw G, Jenkins D, Reaburn P. Heart rate, blood lactate and kinematic data of elite colts (under 19) rugby union players during competition. *J Sports Sci.* 1998; 16: 561-570. <https://goo.gl/X8F751>
15. Malone JJ, Lovell R, Varley MC, Coutts AJ. Unpacking the black box: applications and considerations for using GPS devices in sport. *Int J Sports Psychol Perform.* 2017; 12: S218-S226. <https://goo.gl/rWZEGN>
16. Barrett S, Midgley A, Lovell R. PlayerLoad™: reliability, convergent validity, and Influence of unit position during treadmill running. *Int J Sports Physiol Perform.* 2014; 9: 945-952. <https://goo.gl/WkWKCL>
17. Waldron M, Twist C, Highton J, Worsfold P, Daniels M. Movement and physiological match demands of elite rugby league using portable global positioning systems. *J Sports Sci.* 2011; 29: 1223-1230. <https://goo.gl/5b7V1y>
18. Casamichana D, Castellano J, Calleja-Gonzalez J, San Román J, Castagna C. Relationship between indicators of training load in soccer players. *J Strength Cond Ass.* 2013; 27: 369-374. <https://goo.gl/GZCwEi>
19. Scott TJ, Black CR, Quinn J, Coutts AJ. Validity and reliability of the session-RPE method for quantifying training in Australian Football: a comparison of the CR10 and CR100 scales. *J Strength Cond Ass.* 2013; 27: 270-276. <https://goo.gl/VY1vsq>
20. Davidson A, Trewartha G. Understanding the physical demands of netball: a time-motion investigation. *Int J Perform Anal Sport.* 2008; 8: 1-17. <https://goo.gl/HHCJRY>
21. Boyd L, Gallaher E, Ball K, Stepto N, Aughey R, Varley M. Practical application of accelerometers in Australian football. *J Sci Med Sport.* 2010; 13: e14-e15. <https://goo.gl/GD6tws>
22. Johnston RD, Gabbett TJ, Jenkins DG. Influence of number of contact efforts on running performance during game-based activities. *Int J Sports Physiol Perform.* 2015; 10: 740-745. <https://goo.gl/jj3Erk>
23. McLean BD, Cummins C, Conlan G, Duthie G, Coutts AJ. The fit matters: influence of accelerometer fitting and training drill demands on load measures in rugby league players. *Int J Sports Physiol Perform.* 2018; 13: 1083-1089. <https://goo.gl/3nGbQi>
24. Roe G, Halkier M, Beggs C, Till K, Jones B. The use of accelerometers to quantify collisions and running demands of rugby union match-play. *Int J Perform Anal Sport.* 2016; 16: 590-601. <https://goo.gl/4wUabt>
25. Owen SM, Venter RE, du Toit S, Kraak WJ. Acceleratory match-play demands of a Super Rugby team over a competitive season. *J Sports Sci.* 2015; 33: 2061-2269. <https://goo.gl/7U1Lwk>
26. Read DB, Jones B, Pibbs PJ, Roe GAB, Darrall-Jones J, Weakley JJS, et al. The physical characteristics of match-play in English schoolboy and academy rugby union. *J Sports Sci.* 2018; 36: 645-650. <https://goo.gl/DjhPc9>
27. Gastin PB, McLean O, Spittle M, Breed RV. Quantification of tackling demands in professional Australian football using integrated wearable athlete tracking technology. *J Sci Med Sport.* 2013; 16:589-593. <https://goo.gl/ab8Nx3>
28. Hopkins W, Marshall S, Batterham A, Hanin J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc.* 2009; 41: 3-13. <https://goo.gl/sgn1iD>
29. Portillo J, Abián P, Navia JA, Sánchez M, Abian-Vicen J. Movement patterns in under-19 rugby union players: evaluation of physical demands by playing position. *Int J Perform Anal Sport.* 2014; 14: 934-945. <https://goo.gl/WdtGq8>
30. Cummins C, McLean B, Halaki M, Orr R. Positional differences in external on-field load during specific drill classifications over a professional rugby league preseason. *Int J Sports Physiol Perform.* 2017; 12: 764-776. <https://goo.gl/yHPgdw>
31. Read DB, Jones B, Pibbs PJ, Roe GAB, Darrall-Jones JD, Weakley JJS, et al. Physical demands of representative match-play in adolescent rugby union. *J Strength Cond Res.* 2017; 31: 1290-1296. <https://goo.gl/YsQf6r>