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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INTRODUCTION

Rugby union is an intermittent contact invasion game, involving periods of high-intensity activity (i.e. running, collisions, scrumming) 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 (5,853 m) [12]. Positional differences can assist with the facilitation of optimal player training programs and therefore, match-play preparation. 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.

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 ± 5.2 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 ($\text{Vel}_{\text{Max}}^\text{m.s}^{-1}$). 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 within (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$^{-1}$) the PL$_{\text{SLOW}}$ was recorded. The PL$_{\text{SLOW}}$ 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 scrumming) [1] that GPS or video analysis are unable to provide.

The PL$_{\text{SLOW}}$ 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$^{-1}$).

**Results**

Outside Backs (OSB) recorded a higher mean distance (5,880 ± 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$_f$ ($F_{(3,22)} = 5.2; p < 0.0001; d = 0.43$), 2DPL ($F_{(2,20)} = 5.0; p < 0.0001; d = 0.31$) and maximum Velocity ($F_{(2,20)} = 14.4; p < 0.0001; d = 0.52$) than FRF. Inside Backs (ISB) recorded a higher 2DPL than FRF ($F_{(3,23)} = 19.1; p < 0.0001; d = 0.49$). Back Row Forwards (BRF) ($F_{(1,23)} = 11.6; p < 0.0001; d = 0.10$) and OSB ($F_{(2,23)} = 31.9; p < 0.0001; d = 0.43$). Forwards recorded a higher PL$_{\text{SLOW}}$ ($F_{(6,64)} = 2.9; p < 0.0001; d = 0.06$) but had a lower PL$_v$ ($F_{(6,64)} = 6.3; p < 0.0001; d = 0.08$), PL$_s$ ($F_{(6,64)} = 3.0; p < 0.0001; d = 0.08$) and PL$_v$ ($F_{(6,64)} = 6.9; p < 0.0001; d = 0.25$) 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 ±31 b min$^{-1}$) 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$^{-1}$ ($\chi^2 = 7.7; p = 0.0054; z = -2.0; p = 0.0415; d = 0.24$) and 2.5 to 3.5 m s$^{-1}$ 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$^{-1}$ ($\chi^2 = 19.1; p < 0.0001; z = -5.1; p < 0.0001; d = 1.12$) and 7.0 to 8.0 m s$^{-1}$ ($\chi^2 = 9.6; p < 0.0019; z = -3.0; p = 0.0029; d = 0.21$) vector bands when compared with ISB. As a result, forwards recorded a lower distance in the 6.0 to 7.0 m s$^{-1}$ ($\chi^2 = 26.5; p < 0.0001; z = -4.3; p < 0.0001; d = 0.23$) vector 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$^{-1}$; $\chi^2 = 5.6; p = 0.0181; z = -1.3; p = 0.1097; d = 0.02$) and band 5 (2.5 to 3.5 m s$^{-1}$; $\chi^2 = 6.2; p = 0.0127; z = -1.3; p = 0.1894; d = 0.08$) 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 variance using a Shapiro–Wilks 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]; PL2D; PL$_{\text{SLOW}}$; Pl$_f$; PL$_v$; PL$_s$; 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.

The effect size ($d$) was 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.
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 (5,989 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⁻¹) covered more ground per minute than the forwards (55.7 m.min⁻¹) which was similar to U20 [2] rugby union backs (69.1 m.min⁻¹) and forwards (61.5 m.min⁻¹) but less than U19 [29] backs (83.0 m.min⁻¹) and forwards (78.4 m.min⁻¹) and professional [6] rugby union backs (71.1 m.min⁻¹) and forwards (64.6 m.min⁻¹). 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

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.

<table>
<thead>
<tr>
<th>FRF</th>
<th>BRF</th>
<th>Forwards</th>
<th>ISB</th>
<th>OSB</th>
<th>Backs</th>
<th>Matches won</th>
<th>Matches lost</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Players (n = )</td>
<td>mean ± SD</td>
<td>mean ± SD</td>
<td>mean ± SD</td>
<td>mean ± SD</td>
<td>mean ± SD</td>
<td>mean ± SD</td>
<td>mean ± SD</td>
<td>mean ± SD</td>
</tr>
<tr>
<td>Match Exposure (hr.)</td>
<td>69.2</td>
<td>69.2</td>
<td>138.3</td>
<td>69.2</td>
<td>51.9</td>
<td>121</td>
<td>179.6</td>
<td>79.8</td>
</tr>
<tr>
<td>Distance (m)</td>
<td>4,060 ± 2,622²</td>
<td>4,410 ± 2,715</td>
<td>4,260 ± 2,673</td>
<td>6,163 ± 2,852</td>
<td>5,880 ± 1,979</td>
<td>5,377 ± 2,579</td>
<td>4,849 ± 2,635</td>
<td>5,188 ± 3,074</td>
</tr>
<tr>
<td>Distance (m.min⁻¹)</td>
<td>50.7 ± 33.5e</td>
<td>60.9 ± 34.4</td>
<td>55.7 ± 34.2</td>
<td>70.3 ± 33.4</td>
<td>66.2 ± 36.1</td>
<td>68.5 ± 34.5</td>
<td>60.6 ± 32.9</td>
<td>64.9 ± 38.4</td>
</tr>
<tr>
<td>PL (au.min⁻¹)</td>
<td>5.5 ± 3.2cd</td>
<td>6.1 ± 3.6ac</td>
<td>5.8 ± 3.4e</td>
<td>7.6 ± 3.4ed</td>
<td>7.1 ± 2.2e</td>
<td>6.9 ± 3.0o</td>
<td>6.4 ± 3.3</td>
<td>6.6 ± 3.6</td>
</tr>
<tr>
<td>2DPL (au.min⁻¹)</td>
<td>3.4 ± 2.0cd</td>
<td>3.7 ± 2.1e</td>
<td>3.6 ± 2.0f</td>
<td>4.6 ± 2.1fd</td>
<td>4.1 ± 1.3ce</td>
<td>4.2 ± 1.8h</td>
<td>3.9 ± 1.9</td>
<td>4.0 ± 2.1</td>
</tr>
<tr>
<td>PLs (au.min⁻¹)</td>
<td>3.1 ± 1.7cd</td>
<td>3.3 ± 1.8ae</td>
<td>3.2 ± 1.7f</td>
<td>3.5 ± 1.5fd</td>
<td>3.3 ± 1.3ce</td>
<td>3.4 ± 1.4g</td>
<td>3.2 ± 1.5f</td>
<td>3.4 ± 1.8e</td>
</tr>
<tr>
<td>PLv (au.min⁻¹)</td>
<td>2.1 ± 1.3cd</td>
<td>2.2 ± 1.3ae</td>
<td>2.2 ± 1.3f</td>
<td>2.8 ± 1.3ef</td>
<td>2.5 ± 0.8ge</td>
<td>2.6 ± 1.1h</td>
<td>2.3 ± 1.2</td>
<td>2.4 ± 1.3</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Band No</th>
<th>Velocity</th>
<th>FRF</th>
<th>BRF</th>
<th>Forwards</th>
<th>ISB</th>
<th>OSB</th>
<th>Backs</th>
<th>Matches won</th>
<th>Matches lost</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band 1</td>
<td>0.0 to 1.5 m.s⁻¹</td>
<td>1,965.9 ± 1,220.8</td>
<td>2,090.1 ± 1,133.3</td>
<td>2,037.0 ± 1,169.4</td>
<td>2,615.3 ± 1,135.4</td>
<td>2,661.5 ± 884.0</td>
<td>2,399.8 ± 1,051.4</td>
<td>2,236.2 ± 1,129.0</td>
<td>2,330.3 ± 1,232.9</td>
<td>2,265.0 ± 1,160.2</td>
</tr>
<tr>
<td>Band 2</td>
<td>1.5 to 2.5 m.s⁻¹</td>
<td>1,026.1 ± 974.2</td>
<td>1,010.1 ± 909.9</td>
<td>1,016.9 ± 934.9</td>
<td>1,343.5 ± 936.5e</td>
<td>1,321.7 ± 752.2e</td>
<td>1,252.3 ± 873.7</td>
<td>1,142.8 ± 897.9</td>
<td>1,131.7 ± 980.8</td>
<td>1,139.4 ± 923.4</td>
</tr>
<tr>
<td>Band 3</td>
<td>2.5 to 3.5 m.s⁻¹</td>
<td>477.9 ± 347.7</td>
<td>480.7 ± 344.4</td>
<td>479.5 ± 344.7</td>
<td>740.3 ± 434.0e</td>
<td>699.7 ± 305.0e</td>
<td>633.6 ± 393.3</td>
<td>566.6 ± 386.2</td>
<td>591.6 ± 376.9</td>
<td>574.2 ± 382.8</td>
</tr>
<tr>
<td>Band 4</td>
<td>3.5 to 6.0 m.s⁻¹</td>
<td>416.8 ± 383.1</td>
<td>504.6 ± 493.1</td>
<td>467.1 ± 490.2</td>
<td>641.0 ± 611.0o</td>
<td>755.2 ± 356.2o</td>
<td>685.0 ± 536.9</td>
<td>596.2 ± 525.3</td>
<td>606.2 ± 485.6</td>
<td>599.2 ± 512.5</td>
</tr>
<tr>
<td>Band 5</td>
<td>6.0 to 7.0 m.s⁻¹</td>
<td>45.1 ± 60.1e</td>
<td>68.8 ± 72.3</td>
<td>58.6 ± 68.2</td>
<td>160.9 ± 121.6o</td>
<td>161.2 ± 70.5e</td>
<td>114.9 ± 106.5o</td>
<td>100.4 ± 101.0</td>
<td>92.4 ± 92.3</td>
<td>97.9 ± 98.3</td>
</tr>
<tr>
<td>Band 6</td>
<td>7.0 to 8.0 m.s⁻¹</td>
<td>9.5 ± 21.6e</td>
<td>20.1 ± 23.4e</td>
<td>15.1 ± 22.9</td>
<td>45.5 ± 60.0o</td>
<td>65.5 ± 53.9e</td>
<td>55.8 ± 57.0e</td>
<td>34.8 ± 49.7</td>
<td>24.1 ± 31.2</td>
<td>31.5 ± 45.1</td>
</tr>
<tr>
<td>Band 7</td>
<td>8.0 to 9.0 m.s⁻¹</td>
<td>1.6 ± 9.5e</td>
<td>1.2 ± 5.6e</td>
<td>1.4 ± 7.5e</td>
<td>1.5 ± 6.0o</td>
<td>15.8 ± 22.5e</td>
<td>3.9 ± 15.5e</td>
<td>3.3 ± 11.5</td>
<td>3.4 ± 11.7</td>
<td>3.3 ± 11.5</td>
</tr>
<tr>
<td>Band 8</td>
<td>9.0 to 10.0 m.s⁻¹</td>
<td>0.0 ± 0.0</td>
<td>0.0 ± 0.0</td>
<td>0.0 ± 0.0</td>
<td>0.0 ± 0.0</td>
<td>0.7 ± 2.4</td>
<td>0.1 ± 1.4</td>
<td>0.1 ± 0.8</td>
<td>0.2 ± 1.1</td>
<td>0.1 ± 0.9</td>
</tr>
</tbody>
</table>

FRF: Front-Row Forwards; BRF: Back-Row Forwards; ISB: Inside Backs; OSB: Outside Backs; SD: Standard Deviation; m: metres; au.min⁻¹: arbitrary units per minute; PL: Player Load; 2DPL: 2-Dimension (frontal & sagittal) Player Load; PLvol: player load < 2 m.s⁻¹ (metres per second); PLv: player load in frontal plane; PLs: PlayerLoad in sagittal plane; PLu: PlayerLoad in transverse plane; MaxVel (m.s⁻¹): Maximum Velocity (metres per second); HR: Heart Rate; b.min⁻¹: 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.
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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 require 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

13. Hartwig TB, Naughton G, Searl J. Motion analyses of adolescent rugby union

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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