The Ball in Play Demands of International Rugby Union

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Abstract

Objectives: Rugby union is a high intensity intermittent sport, typically analysed via set time periods or rolling average methods. This study reports the demands of international rugby union via global positioning system (GPS) metrics expressed as mean ball in play (BiP), maximum BiP (max BiP), and whole match outputs.

Design: Single cohort cross sectional study involving 22 international players, categorised as forwards and backs.

Methods: A total of 88 GPS files from eight international test matches were collected during 2016. An Opta sportscode timeline was integrated into the GPS software to split the data into BiP periods. Metres per min ($m \cdot min^{-1}$), high metabolic load per min (HML), accelerations per min (Acc), high speed running per min (HSR), and collisions per min (Coll) were expressed relative to BiP periods and over the whole match (>60min).

Results: Whole match metrics were significantly lower than all BiP metrics ($p < 0.001$). Mean and max BiP HML, ($p < 0.01$) and HSR ($p < 0.05$) were significantly higher for backs versus forwards, whereas Coll were significantly higher for forwards ($p < 0.001$). In plays lasting 61s or greater, max BiP $m \cdot min^{-1}$ were higher for backs. Max BiP $m \cdot min^{-1}$, HML, HSR and Coll were all time dependant ($p < 0.05$) showing that both movement metrics and collision demands differ as length of play continues.

Conclusions: This study uses a novel method of accurately assessing the BiP demands of rugby union. It also reports typical and maximal demands of international rugby union that can be used by practitioners and scientists to target training of worst-case scenario's equivalent to international intensity. Backs covered greater distances at higher speeds and demonstrated higher HML, in general play as well as 'worst case scenarios'; conversely forwards perform a higher number of collisions.

Keywords: GPS analysis, collisions, movement patterns, worst case scenario

Introduction

Rugby union is characterised as a high intensity intermittent collision sport, requiring athletes to perform repeated running actions, collisions, and static efforts of differing work to rest periods. [1] The ability to repeat high intensity efforts is linked to success in rugby union [2,3] and higher match running demands have been reported at international level. [4] Players must be physically prepared for the demands of international competition [4,5], and further research is warranted at this level. [6]

The assessment of in-game demands provides coaches with an understanding of what is required from players [7], and helps establish physical standards to work on or towards. [8] Only two studies have attempted to quantify the physical demands of international rugby using Global Positioning Systems (GPS). [5,8] This method allows the measurement of in game movement patterns and velocities, whilst also monitoring these same metrics during training sessions. This allows the potential to monitor training with the aim of matching or superseding match-play demands, providing a physical and tactical stimulus [7] likely to positively transfer to competition.

The majority of club and international level studies have reported whole match or per half demands of rugby matches. [4,8,9] However, it is noteworthy that whole match averages may not reflect fluctuations in running or playing intensity that occur throughout match-play. [6,10,11] It has been suggested that team sport athletes should be exposed to training at 'worst-case scenario' (WCS) intensities, which align to the highest recorded intensity recorded within match-play. [5,12,13] Previously, studies have analysed small set time periods to view fluctuations in intensity within competition [6,14], however, it may be that the most intense period of play do not fall within these periods, for example, zero to five, or 60 to 70 min into the game . [5] Varley et al. [15] showed that pre-determined blocks under-estimate a peak rolling average method by 25%, and peak rolling average method was also found to best quantify intensities in rugby 7's. [11]

An alternative method is to analyse the actions during the time the ball is in play. [16] This is an important consideration as rugby union is such an intermittent sport. It typically demonstrates a ball in play (BiP) time less than ball out of play time during Rugby World Cups (approximately 44% of overall match time [17]). Recently the longest BiP period in matches (average duration 152-161s) [16], and attacking plays in the opposition 22m zone [13], from the European Rugby Championship and Guinness Pro12 League matches have been investigated. Both studies reported significantly higher metres per min ($m \cdot min^{-1}$) (117 $m \cdot min^{-1}$ and 98.8-115.6 $m \cdot min^{-1}$) than had been previously reported, 68 $m \cdot min^{-1}$ regarding average whole match $m\ min^{-1}$. [14] This analysis was the average of the longest play from each game [16] , or of a specific action by a team [13], therefore neither reports typical demands within a match nor maximum physical demands dependant on movement and/or collision activities (ie. WCS).

The aims of this study were to report both mean and the max BiP demands of international rugby union alongside whole match demands and differing positional groups. It is hypothesised that BiP demands will differ from whole match demands and that outputs may be higher for the forwards compared to those previously reported. This is due to no movement data from ball out of play time included within the BiP data, therefore disregarding the likely higher repositioning movement of the backs. This will give a greater understanding of the typical physical demands and describe the peak demands of duration specific BiP periods, allowing comparison of WCS in relation to international standards, of which there is a lack of research at present.

Methods

GPS data were collected from eight international matches during 2016, data were included if the player had played $\geq$ 60 min. This was chosen as it has been shown that substitutes have higher outputs than starting players, potentially due to pacing strategies. [18] Given the discrete roles, players were grouped into units of forwards and backs. The average number of files contributed by each player was 4.5 ± 2.6. Every player contributed a minimum of one GPS file, with the maximum collected from any player being eight; there were 35 units used over the course of six months of collection. The GPS data was analysed post game to view locomotor and collision metrics, and data was separated into positional groups and compared. A BiP timeline of all the duration of all plays was generated by Opta

(London, UK), this is the duration which play is ongoing prior to the ball exiting the pitch or the referee stopping play. Matches played were at varying international rugby stadiums.

A total of 22 male international players took part in the study (Table 1). Prior to giving written consent, all players were provided with an outline of the rationale and procedures of the study. Approval was granted from Swansea University ethics committee. All players were healthy and partaking in full training at the time. The data collection was carried out as part of the players' routine monitoring procedures ensuring all players were familiar with wearing GPS units.

****Table 1 about here****

Data was collected between January 2016 and July 2016 over two international competitions. The units were placed in bespoke pockets in the players' match shirts, between their shoulder blades close to their thoracic spine minimising movement artefacts. [19] The 10 Hz GPS units (Viper Pod, STATSports, Belfast, UK) collected data using the four best satellites obtainable, with respect to signal strength. 10 Hz units have been shown previously to be more reliable than 5Hz when assessing team sport movement patterns [20,21], and the manufacturer of these specific units have been utilised for other elite rugby and soccer studies analysing acceleration profiles. [8,22, 23, 24]

The units were turned on approximately four hours prior to kick-off to gain signal and satellites for 30 min in the centre of the pitch. They were turned off to save battery, and switched on again one hour prior to kick off. The data was then downloaded using specific hardware and a consistent version of software (Viper PSA Software, Version 2.6.1.176, STATSports, Belfast, UK); time periods were split manually for the whole match period. GPS data was viewed to identify any files that lost GPS signal for sections of the match, and these files identified were removed from the dataset. An Opta generated timeline of the game (SportsCode, Sportstec, Lower Hutt, New Zealand) was then integrated into the software to automatically split the match data into periods of BiP. Data was then exported into Microsoft Excel (Microsoft Corporation, USA) for further analyses.

Plays less than 30s were not included in the analysis, though ~26% of plays are less than 30s in duration (unpublished research), this helps avoid false representation of intensity due to excessively high calculations of each metric per minute. [13] This procedure will also reduce the potential for compounding errors that are artefacts of the methodology utilised to collect BiP data.

Mean duration of plays in international rugby are 50-55s in duration (unpublished research). Mean and maximum metrics for three periods of 30 to 60s, 61 to 90s and over 90s (~39, 20 and 15% of all plays respectively) were analysed, alongside the mean intensity of all BiP periods over 30s, These periods represent the most frequent BiP time frames occurring in international rugby, whilst also providing information regarding time frames that are pragmatic to technical, tactical, and conditioning drills utilised in game training. [25]

GPS metrics were displayed per minute as a measure of intensity of match play for either BiP or whole match. These were relative total distance covered ($m \cdot min^{-1}$), high metabolic load distance (HML) (defined as distance accelerating over $2.5 m \cdot s^{-2}$ and sprinting over $5.5 m \cdot s^{-1}$), high speed running (HSR) (distance ran over $5 m \cdot s^{-1}$), accelerations (Acc) (over $3 m \cdot s^{-2}$), and collisions (Coll) per min as detected by the GPS unit, recently shown by Hulin et al. [26] to be able to detect 97.6% of collisions in rugby league. Given the importance of frequency of collisions, as dictated by the coaching staff, a pilot study was performed to validate the use of this metric from Statsports units. Results found that 85.3±3.6% of the collisions detected by the gps units were correct when compared to video analysis. This is a slightly lower percentage than reported by Hulin et al., (2016)[26], possibly due to the differing angles of collisions in rugby league compared to other sports [26].

Linear mixed models were used to examine each dependent variable (i.e., the GPS metrics) for the interaction with respect to position (i.e., forwards and backs), with Bonferroni correction used for post hoc analysis and with partial η^2 reported as a measure of effect size. Where sphericity was violated, Greenhouse-Geisser correction was used. All statistical analysis was conducted using SPSS (version 21) with the level of significance set as $p < 0.05$.

RESULTS

Mean Whole Match and BiP

There was a significant difference in mean $m \cdot min^{-1}$ ($F (4, 68) = 432.86$, $p < 0.001$, partial $\eta^2 = 0.962$), HML ($F (4,68) = 223.1$, $p < 0.001$, partial $\eta^2 = 0.929$), Acc ($F (4, 68) = 67.41$, $p < 0.001$, partial $\eta^2 = 0.799$), HSR ($F(4, 68) = 60.81$, $p < 0.001$, partial $\eta^2 = 0.782$), and Coll ($F (4, 68) = 118.79$, $p < 0.001$, partial $\eta^2 = 0.875$) across all periods of play. For mean HML ($F (1,17) = 18.24$, $p < 0.01$ partial $\eta^2 = 0.518$), HSR ($F (1,17) = 33.04$, $p < 0.001$, partial $\eta^2 = 0.660$), and Coll ($F (1,17) = 54.50$, $p < 0.001$, partial $\eta^2 = 0.762$) differences between position were also noted. All differences across position, whole match and BiP duration, as identified by Bonferoni adjusted post hoc analyses, are reported in Table 2.

Max BiP

There was a significant difference for max $m \cdot min^{-1}$ ($F (2,40) = 56.96$, $p < 0.001$, partial $\eta^2 = 0.740$), max HML ($F (2,40) = 106.0$, $p < 0.001$, partial $\eta^2 = 0.840$), max Acc ($F (2,40) = 30.18$, $p < 0.001$, partial $\eta^2 = 0.601$), max HSR, $F(2, 40) = 79.64$, $p < 0.001$, partial $\eta^2 = 0.799$), and max Coll ($F (2,40) = 79.64$, $p < 0.001$, partial $\eta^2 = 0.799$) across all periods of BiP. For max $m \cdot min^{-1}$ ($F(1,20) = 10.06$, $p < 0.01$, partial $\eta^2 = 0.335$), max HML ($F (1,20) = 24.3$, $p < 0.001$, partial $\eta^2 = 0.549$), max HSR ($F (1,20) = 17.69$, $p < 0.001$, partial $\eta^2 = 0.469$), and max Coll ($F (1,20) = 17.69$, $p < 0.001$, partial $\eta^2 = 0.469$), differences between position were also noted. All differences, as identified by Bonferoni adjusted post hoc analyses, regarding position and max BiP duration, are reported in Table 3

****Table 2 and 3** about here****

DISCUSSION

This study reports, for the first time, the mean and maximum demands of BiP periods of international rugby compared to whole match demands. As hypothesised, BiP metrics were significantly higher than whole match averages. Mean BiP metrics significantly differed between forwards and backs, primarily between HML, HSR, and Coll (Table 2). Max BiP metrics mirrored this finding but also included $m \cdot min^{-1}$. Max BiP $m \cdot min^{-1}$, HML, HSR and Coll were all time dependant showing that WCS movement metrics and collision demands decrease in intensity as length of play continues (Table 3). All the above findings offer a novel insight into typical and WCS demands in international rugby match play.

Metres per min did not differ between forwards and backs over whole match or BiP periods. This differs to Reardon et al. [16] who investigated the running demands of the longest play (average duration 152-161s), reporting that both tight five (109 $m \cdot min^{-1}$ CI 104-114 $m \cdot min^{-1}$) and back row (111 $m \cdot min^{-1}$ CI 105-117 $m \cdot min^{-1}$) forwards differed from inside backs (123 $m \cdot min^{-1}$ CI 117-129 $m \cdot min^{-1}$) and outside backs (124 $m \cdot min^{-1}$ CI 117-131 $m \cdot min^{-1}$). These reported $m \cdot min^{-1}$ are slightly higher than our papers mean BiP periods over 90s (105.0 $m \cdot min^{-1}$ and 110.9$m \cdot min^{-1}$ for forwards and backs respectively), however they are much lower than the max BiP data of this study over 90s, 141.9$m \cdot min^{-1}$ and 155.5$m \cdot min^{-1}$ for forwards and backs respectively. This is likely because, although Reardon et al. [17] reports 'WCS' plays, they analysed the average of the longest plays, rather than plays that involved the highest running demands.

Mean BiP $m \cdot min^{-1}$ data did not differ between forwards and backs, however, max BiP $m \cdot min^{-1}$ was significantly higher for backs ($p < 0.05$) for plays 61s or over. Delaney et al. [5] reported similar WCS $m \cdot min^{-1}$ to our paper, with 154-184 $m \cdot min^{-1}$ and 122-147 $m \cdot min^{-1}$ for 1 and 2 min peak rolling averages respectively, and also reported that backs ran significantly further versus tight five. This suggests that typical relative distance may be similar between positions, however, WCS plays demand greater running from the backs due to positional requirements and/or players running capacities.

Both HML and HSR were significantly higher for backs versus forwards across mean whole match (as similarly reported by Cunningham et al. [8]) and mean and max BiP periods. Though there is no significant difference between mean BiP $m \cdot min^{-1}$, the positional difference for both HML and HSR min^{-1} suggests that the backs cover these similar distances at higher speeds than forwards. As Quarrie et al. [4] explains, the role of the backs is typically to utilise the space, whereas the forwards contest for the ball. The average distance for a high intensity running effort is 6-14m [27,28], therefore perhaps the forwards' acceleration capability and capacity is more important than high speed running in respect of their roles. [5] The above point might also explain why the current study found no difference between forwards and backs regarding mean or max BiP Acc. Previous research has shown accelerations to be similar in frequency between forwards and backs [8], and a higher mean acceleration for the forwards (2.46 $m \cdot s^{-2}$) vs backs (2.36 $m \cdot s^{-2}$).[6] This is a very relevant metric to report as acceleration qualities are fundamental [1] and relate to success in rugby. [2,3]

This study supports the notion that collision capability and capacity are also very important for forwards [10, 16], as they are involved in higher Coll than backs over a whole match as well as mean and max BiP periods ($p < 0.01$). This study reports similar Coll over the whole match (0.51 and 0.27 $coll \cdot min^{-1}$ for forwards and backs respectively) using GPS detected collisions, compared to TMA analysis by Lindsay et al. [9] (0.56 and 0.36 $coll \cdot min^{-1}$). Forwards are involved in ~89 static or collision actions throughout a game [3], equating to ~30% of actions [6] and in international rugby there is a ruck every ~12 seconds [17] suggesting multiple players are involved in a collision effort at a high frequency. It is known that collisions and static efforts in rugby are similarly fatiguing to running efforts for players [29], and higher heart rate %, higher rating of perceived exertion, and decrement in sprinting performance has been shown when simulated collisions are added into a running drill. [30] Collisions are therefore an essential metric when reporting holistic physical demands of positional groups alongside movement metrics. [17] This study is the first to report GPS detected collisions within BiP, recently validated by Hulins et al. [26]

Throughout all max BiP periods, GPS metrics decreased over time ($p < 0.05$), with the highest outputs observed in periods lasting 30-60s and the lowest over 90s, a similar trend to movement metrics demonstrated using a peak rolling average by Delaney et al. [5]. This shows the importance of reporting intensity metrics over duration specified periods. If the aim of a rugby or conditioning drill is to align to WCS demands, then there are specific GPS metrics to achieve, dependant on the duration of the drill. The decrease in intensity that occurs as the play duration increases are possibly due to positional or tactical requirements where a player is not involved in a high intensity activity. Conversely, during longer periods of plays, for example >90s, it may not be possible for all players to maintain the intensity of work seen in shorter periods (30-60s) due to limits of their physical capacities.

It is also worth noting that this analysis was performed using commercially available software that can output any GPS metric available. Other analysis of peak demands of play such as peak rolling average, is appropriate for only certain metrics, and is not as yet readily commercially available or usable.

Conclusion

This study is the first to report whole match, mean and max BiP demands of international rugby union. BiP analysis allows an accurate portrayal of the movement and collision demands to further the understanding of international rugby union. BiP metrics were higher than whole match averages. During both mean and max BiP, backs perform greater HML and HSR, and forwards perform a higher number of collisions.

Practical Implications

- The challenge within rugby union is to attempt to improve various aspects of technical, tactical and physical qualities of performance simultaneously. With knowledge of typical, but perhaps more so, the maximum demands of duration specific movement and collision outputs in international rugby, training can be aimed to match or supersede these metrics whilst monitored by GPS for feedback.
- WCS training drills or conditioning drills should align to positional differences encompassing that backs cover greater HML and HSR, and forwards must have the capacity to repeat accelerations and collisions.
- By aligning WCS playing demands to training drills there is likely greater transfer to performance in match play via executing skills and decision making, alongside stimulating physical capabilities and capacities.

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Table 1. Anthropometric data for each positional group and presented as an average for the team.

Positional Group	BW (kg)	Age (years)	Height (cm)
Forwards (F) n = 12	116.8 ± 7.7	27.4 ± 3.0	191 ± 6
Back (B) n = 10	91.9 ± 5.7	26.6 ± 2.8	182 ± 5
Team n = 22	106.1 ± 14.1	27.0 ± 2.9	187 ± 7

Data is presented as means ± standard deviation

Table 2. Average outputs for GPS metrics across a whole match (>60min), and various passages of BiP, separated by position (Forwards vs. Backs).

		Mean Whole Match	Mean BiP	Mean for Plays 30-60s	Mean for Plays 61-90s	Mean for Plays >90s
M Min^{-1} per Position	**Forwards**	65.7 ± 3.8[a]	106.0 ± 5.6	106.9 ± 5.6	104.6 ± 6.1	105.0 ± 8.5
	Backs	69.7 ± 5.0[a]	111.4 ± 10.5	109.6 ± 11.4	115.1 ± 11.4*[b]	110.9 ± 9.5
	Average	67.6 ± 4.8[a]	108.6 ± 8.5	108.2 ± 8.7	109.6 ± 10.2	107.8 ± 9.2
HML per min per Position	**Forwards**	7.9 ± 1.5[a]	21.8 ± 4.3	23.7 ± 4.2[e]	19.8 ± 4.8	19.2 ± 4.7[c]
	Backs	11.2 ± 1.6*[a]	29.5 ± 4.4*	29.8 ± 5.4 [e]*	30.3 ± 4.8*	27.5 ± 2.9[c]*
	Average	9.5 ± 2.3[a]	25.4 ± 5.8	26.6 ± 5.6[e]	24.8 ± 7.1	23.1 ± 5.7[c]
Acc >3m s^{-3} per min per Position	**Forwards**	0.3 ± 0.1[a]	0.8 ± 0.2[e]	0.8 ± 0.2	0.8 ± 0.2	0.7 ± 0.2[b]
	Backs	0.4 ± 0.1[a]	0.9 ± 0.1[e]	0.9 ± 0.2[e]	0.8 ± 0.2	0.7 ± 0.1[bc]
	Average	0.3 ± 0.1[a]	0.8 ± 0.2[e]	0.8 ± 0.2	0.8 ± 0.2	0.7 ± 0.2[b]
Coll per min per Position	**Forwards**	0.5 ± 0.1^[a]	1.1 ± 0.2^	1.1 ± 0.2^	1.2 ± 0.2^	1.1 ± 0.2^
	Backs	0.3 ± 0.1[a]	0.5 ± 0.1	0.5 ± 0.1	0.7 ± 0.2	0.6 ± 0.1
	Average	0.4 ± 0.2[a]	0.8 ± 0.3[cd]	0.8 ± 0.3[bd]	0.9 ± 0.3[bc]	0.8 ± 0.3
HSR per min per Position	**Forwards**	3.3 ± 1.5[a]	8.9 ± 4.0[ce]	10.9 ± 4.7	7.0 ± 4.1[b]	5.8 ± 2.7[b]
	Backs	7.8 ± 1.9*[a]	19.0 ± 4.5*[ce]	20.3 ± 5.7*	18.9 ± 5.1*[b]	15.6 ± 3.4*[b]
	Average	5.5 ± 2.8[a]	13.7 ± 6.6 [ce]	15.4 ± 7.0[e]	12.6 ± 7.6[b]	10.4 ± 5.8[bc]

Data is presented as means ± standard deviation

*^ = significantly different to backs, * = significantly different to forwards, a = significantly different to all BiP periods, b = significantly different than mean BiP, c = significantly different than mean BiP periods 30-60s, d = significantly different than mean BiP periods 61-90s, e = significantly different than mean BiP periods over 90s.*

Table 3. Maximum outputs for GPS metrics across a whole match (>60min), and various passages of BiP, separated by position (Forwards vs. Backs).

		Max for Plays 30-60s	Max for Plays 61-90s	Max for Plays >90s
Metres per Min per Position	**Forwards**	184.1 ± 16.9^{gh}	143.3 ± 14.0^{f}	141.9 ± 13.9^{f}
	Backs	196.8 ± 18.2^{gh}	164.8 ± 19.9*^{f}	155.5 ± 15.6*^{f}
	Average	189.9 ± 18.3^{gh}	153.0 ± 19.8^{f}	148.1 ± 15.9^{f}
HML per min per Position	**Forwards**	80.8 ± 10.5^{gh}	44. 3 ± 12.2^{fh}	36.4 ± 10.1^{fg}
	Backs	95.4 ± 14.9*^{gh}	66.0 ± 16.2 *^{fh}	56.9 ± 7.1*^{fg}
	Average	87.5 ± 14.5^{gh}	54.1 ± 17.7^{fh}	45.7 ± 13.7^{fg}
Accels >3m s^{-3} per min per Position	**Forwards**	4.7 ± 1.2^{gh}	3.2 ± 0.9^{fh}	2.2 ± 0.6^{fg}
	Backs	4.7 ± 2.2^{gh}	2.9 ± 1.1^{fh}	2.2 ± 0.6^{fg}
	Average	4.7 ± 1.7^{gh}	3.1 ± 1.0^{fh}	2.2 ± 0.5^{fg}
Collisions per min per Position	**Forwards**	3.8 ± 1.1^^{gh}	2.9 ± 0.7^^{f}	2.6 ± 0.7^^{f}
	Backs	3.5 ± 1.0^{gh}	1.9 ± 0.5^{fh}	1.5 ± 0.4^{fg}
	Average	3.7 ± 1.0^{gh}	2.4 ± 0.8^{fh}	2.1 ± 0.8^{fg}
HSR per Min per Position	**Forwards**	85.5 ± 25.7^{h}	35.0 ± 17.9^{h}	24.2 ± 7.9^{fg}
	Backs	106.0 ± 19.3^{gh}	62.8 ± 22.9*^{fh}	45.3 ± 10.3*^{fg}
	Average	94.6 ± 25.5^{gh}	47.6 ± 24.4^{fh}	33.7 ± 13.9^{fg}

Data is presented as means ± standard deviation

*^ = significantly different to backs, * = significantly different to forwards, f = significantly different than max BiP periods 30-60s, g = significantly different than max BiP periods 61-90s, h = significantly different than max BiP periods over 90s.*