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Research Article

Positional Demands of a Tier 2 International Rugby Union Team using GPS Metrics, Match Performance Indicators and Worst-Case Scenarios

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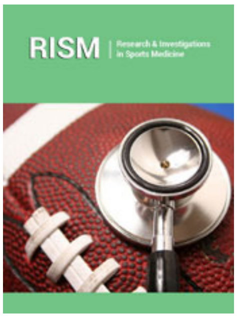

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Abstract

This study aimed to examine the peak, in-game positional demands of a tier-two international rugby team. Data from a Global Positioning System (GPS) and notational analysis from 43 individual players in 19 international games were analysed over two years. Players were categorized as forwards and backs and subsequently into positional groups: front row, second row, back row, half back, centre and back three. GPS variables included distance, total and high-speed running, maximum velocity, accelerations and decelerations greater than 4m•s-2, collisions and sprints. Match Performance Indicator data from notational analysis (MPI) variables included: Ball carries, passes, tackle attempts, ruck involvements, maul involvements and penalties. All dependent variables are expressed relative to playing time. Worst Case Scenario (WCS) data were evaluated using a bespoke analysis application that provided in-game WCS for maximum distance and high-speed running for every GPS file from 60 seconds up to 300 seconds. Significant differences were found between forwards and backs for all variables apart from accelerations, decelerations, sprints, and ball carries. This research confirmed that for this tier-two rugby team, backs cover the highest distance at any speed while forwards have higher involvements in collision-based activities. All positions covered substantially higher distances in the WCS analysis than the reported mean values. Back three had the highest maximum velocities and covered the most total and high-speed running distance of all positional groups across all WCS time epochs. Second rows had the highest number of collisions, maul and ruck involvements, the back row the highest number of tackle attempts and the centers the highest number of ball carries. Back three and half backs had the lowest involvements for these variables. The position-specific information outlined in this study provides practitioners with relevant information to inform the planning of position-specific training protocols and appropriately prepare players for the challenges of elite international rugby union.

Abbreviations: FR: Front Row; SR: Second Row; BR: Back Row; HB: Half Back; C: Centre; B3: Back Three; D: Distance per Minute; HSR: High Speed Running per Minute; MV: Maximum Velocity; AZ4, AZ5 AZ6, DZ4, DZ5, DZ6: Accelerations/Decelerations in Zones 4, 5 and 6; COL: Collisions; SP: Sprints; BC: Total Ball Carries; PASS: Passes; TA: Tackle Attempts; RUCK: Ruck Involvements; MAUL: Maul Involvements; PEN: Penalties; WCSD: Worst Case Scenario Distance; WCSHSR: Worst Case Scenario High-Speed Running

Introduction

Rugby union is a high-intensity intermittent sport, where periods of high-intensity running, and collisions are interspersed with periods of low-intensity work [1]. According to ‘World Rugby’, the global governing body for rugby union, international rugby union is currently played in 105 countries worldwide. These teams are then divided via a tier system.

Tier 1 includes the teams that play in the '6 Nations Championship' in the northern hemisphere, and from the southern hemisphere, those who partake in the 'Rugby Championship'. Tier 2 nations are then defined as those that partake in the Rugby World Cup but are not included in the two competitions above.

The use of Global Positioning Systems (GPS) data is well established in team sports in assessing and quantifying in-game positional demands that help establish standards on which to base training. When planning and implementing training programmes, specific match and peak physical demands for positional groups need to be considered when managing player workloads both in training and in games [2]. There is a multitude of research surrounding the positional movement demands of Tier 1 international rugby through the use of GPS data. The literature suggests that each position has different movement demands depending on the player's speed, size, and skill level [3].

Recent studies have suggested that forwards and backs cover median distances between 5850 to 6545m with relative distances of 64.6m•min-1 to 71.1m•min-1, respectively, and high-speed running distances of 248m per match for forwards and 576m for backs [4]. These position-specific differences can be explained by the roles of the positions within the game [5,6], with forwards experiencing more collisions through tackles, rucks and mauls. Typically, forwards have greater body mass and are more force dominant players to secure possession at set piece and breakdown. Their anthropometry combined with their role on average results in lower overall distances and distances at high speed [5]. Backs have higher open play requirements, where they carry the ball and advance over the gain line, resulting in higher overall distances and high-speed distances being covered due to the increase in the availability of open space [3,7,8]. In addition to these differences between forwards and backs, there are distinct differences within positional groups; e.g., within the forwards, the front row and locks cover significantly lower distances at high speed than the loose forwards, and in the backs, the same can be said for the inside backs in comparison to the outside backs [2,9].

GPS is a powerful tool that provides accurate measures for the running-based demands of the game. However, it cannot track the workload of other game-specific actions that impose a significant amount of stress and transient fatigue on players [10]. This limitation is exemplified in the performance of isometric exertions completed in set pieces, rucks and mauls, as the GPS may track only the initial collision, thus excluding vital information that would help develop a practitioner's understanding of the complete physical demands of the game and the effect of transient fatigue [7,11,12].

The combination of GPS and Match Performance Indicator data from notational analysis (MPI) can provide greater insight into the demands of elite international rugby union, allowing an in-depth understanding of player movement patterns at the tier two standard. This information can feed into the planning and implementation of training programmes of practitioners that elicit physiological adaptations specific to individual playing demands and may enable for improved monitoring of individual and team performance during match play at the tier two level [2].

Within the existing literature assessing the positional demands of rugby union using GPS, most movement demands shown are averages. Whilst understanding averages allow for preparation for the general demands of the game, ultimately, players need to be prepared for the most intense periods of the game, also known as the 'worst case scenarios' [8,13]. By not knowing or understanding these 'in-game' worst case scenarios, players will not have exposure to these peak workloads in training. This lack of exposure may result in under-preparation to tolerate the actual demands of the game, with associated performance limitations and a potentially increased risk of injury during match-play when these acute 'spikes' in workload appear in-game [13].

The existing research primarily assesses the positional demands of the tier 1 nations. However, there is limited research assessing positional movement demands of international rugby union using GPS and MPI data to assess the overall demands of the game at the tier 2 standard. Due to the multifaceted nature of the game, knowing the maximal workload demands while accounting for positional differences in training may allow better transfer to performance in-game. Therefore, this knowledge can ensure that sessions replicate the specific positional demands of elite rugby union by executing relevant skills and decision making while stimulating physical capabilities and capacities.

This research is critical as professional rugby union in Tier 2 nations continues to grow. The United States has seen a continued expansion of the 'Major League Rugby' competition, and the men's international 15s team was recently ranked 12th in the world- their highest ever ranking. To be competitive against higher-level international sides, the combination of GPS, MPI and WCS data will allow for the evaluation and review of training content to ensure that sessions are designed to replicate the specific demands of elite rugby union, as competition demands should underpin programme design [14].

Providing clarity on the necessary training requirements will ensure that players are adequately prepared for the demands of elite international rugby competitions [15], especially as very few players at the tier 2 standards are regularly exposed to the physical demands found in elite international competition, either in their club games or their training environment [16]. Therefore, this study aims to a) explore the locomotor demands of tier 2 international rugby and whether significant differences exist between forwards and backs and between all playing positions, b) to explore the MPI demands of tier 2 international rugby, and whether any significant differences exist between playing positions, and c) examine the peak distances and high-speed running distances for each playing position in tier two international rugby for 60 second time epochs from 60 to 300 seconds and whether differences occur between positions, as the time epochs lengthen, or both.

Methods

Participants

Forty-three elite professional international players (n=43, age 25.8±3.3 years, body mass 107.8±15kg, height 186.3±7.1cm) from a tier 2 international rugby union side participated in this study. All potential participants and the head coach were informed of the data collection procedure and potential research applications before participating in the study. The Cardiff Metropolitan University Ethics Committee approved the study. At the time of data collection, all players were considered to be fit and healthy.

USA Rugby collected the retrospective data provided by participants over two years across multiple international competitions against both 'tier 1' and 'tier 2' teams, with a total of 19 games being played. A total number of 405 GPS files were collected. Each player provided at least one GPS file, with the largest number of files provided by any single player being 18.

Any apparent errors in the data were removed and the data collected during the pre-match warm-up, half-time, and post-match conditioning. The inclusion of these data would potentially result in an over-estimation of both locomotor and collision data. Previous studies have only included the data of subjects that had 60 minutes or more of playing time [1,3,4]. It has previously been shown that substitutes have higher power outputs than starters due to different pacing strategies of starting players. A secondary factor was that the majority of substitutions were made at the 60-minute mark within the game. The inclusion of these cases would result in skewed data as substitutes have been shown to have a greater work rate than starting players due to not having to pace their involvements in the game [17,18]. To explore whether there was a significant difference between playing time and the work rate of an individual and whether the inclusion criteria for the data set should be expanded, individual playing times were grouped at six different time intervals: 19mins<, 20-29mins, 30-39mins, 40-49mins, 50-59mins and >60min playing time, and compared across all variables using a one-way ANOVA or a Kruskal-Wallis one-way ANOVA, depending on assumptions of normality and visual inspection of histograms, boxplots and normal q-q plots. Consistently, across variables, there was no significant difference of means or medians between playing time between 50-59mins and >60mins, so all data with a playing time of 50 minutes or higher were included in the dataset. This procedure removed 141 individual cases, resulting in a data set with a total of 260 total GPS files from 38 participants. Therefore, the statistical analysis was completed on this data set with playing times of 50mins or more.

Procedures

All games took place between June 2018 to October 2019. During data collection, each player wore a GPS unit from 'Stat Sport' in a pocket incorporated into their playing jersey on the upper thoracic spine. The units were turned on before the pre-match warm-up, approximately 30-60min before kick-off. Players wore the same GPS device for each match to avoid inter-unit variation.

GPS units captured data at a sampling frequency of 10Hz. As well as being more commercially available, the 10Hz units have been proven to be more accurate than 1 & 5Hz devices for quantifying movement patterns in team sports. Due to increased sampling rates, practitioners have confidently depended on the data provided when analyzing and designing training programs and matches [16]. After completing the game, raw data files were exported and processed using 'Stat Sports' by the Head S&C to view locomotor and collision metrics.

Variables

GPS output data were first grouped according to whether the player played in the forwards or backs. Following the initial analysis to ascertain whether there was a significant difference between forwards and backs, data was then grouped into six positional groups for further comparison [13]: Front Row (FR); Second Row (SR); Back Row (BR); Half Back (HB); Centre(C); Back Three(B3). FR, SR and BR all belong to the 'forwards' positional group, while HB, C and B3 belong to the 'backs'.

For each positional group, the following locomotor and collision metrics were collected: distance per minute (D, m•min-1), high-speed running per minute (HSR; m•min-1), maximum velocity (MV; m•s-1), accelerations/decelerations in Zones 4, 5 and 6 (AZ4, AZ5 AZ6, DZ4, DZ5, DZ6; n), collisions (COL, n) and Sprints (SP; n). Retrospective MPI data were provided by USA Rugby that captured the full match involvements for all players. GPS data were separated according to the positional group of the players. Of the data collected, the following variables were incorporated into the analysis: Total ball carries (BC, n), passes (PASS, n), tackle attempts (TA; n), ruck involvements (RUCK; n); maul involvements (MAUL, n) and penalties (PEN; n). To compare the data collected between playing positions, taking into account the variable in-game playing times, all dependent variables are reported relative to playing time per minute, permitting a more appropriate comparison between position.

Worst case scenario data were analysed using a bespoke analysis programme from [13]. This programme provided rolling average epochs every 60s up to 300s for in-game worst-case scenarios for every GPS file for distance covered (WCSD; m) and high-speed running distance, which is the distance covered above 5.5m•s-1 (WCSHSR; m). Rolling averages have been used as it has been confirmed in previous research that the use of fixed time epochs can underestimate between 20-25% of peak HSR distances [13].

Statistical analysis

Data were analysed using SPSS 27.0 (IBM Inc.). All data were checked for normality of distribution using a Kolmogorov-Smirnov as n>50 and visual inspection of histograms, box plots and normal Q-Q plots. Normality of distribution was assumed for HSR, MV, AZ4, DZ4, WCSD60-300 and WCSHSR60-300. Visual inspection of normal q-q plots and box plots verified normality for these dependent variables. One outlier was noted for MV and two for

HRS as assessed by inspection of boxplots. On further inspection, these outliers were included in the data set. These scores were legitimate observations and represented legitimate outputs of players in certain positional groups. Therefore, their exclusion from the dataset would result in a potential underestimation of the positional demands of the game. For all dependent variables that met these assumptions of normality, parametric statistics were uses. Results are presented as means±standard deviations. When data did not meet the assumption of normality, non-parametric statistical analyses were performed, and the medians stated.

To examine differences between forwards and backs for D, HSR, MV, AZ4 and DZ4, an independent samples T-Test was used. A Lavene's test for homogeneity was used to test for equality of variances, with all variables assuming equality of variances (p>.05). Due to multiple independent-samples T-Tests, a Bonferroni correction was applied to account for the inflated risk of a Type one error. Statistical significance was therefore set at p<.01.

A one-way ANOVA was used for D, HSR, MV, AZ4 and DZ4 to determine significant differences between playing positions. A Lavene's test for homogeneity was used to test for equality of variances. All variables except MV and HSR assumed equality of variances, and for these variables, Tukey's post hoc test was used. For the data that did not assume equality of variance, a Welch robust test for equality of variance and a Games-Howell post hoc test was used. Due to multiple one-way ANOVA's, a Bonferroni correction was applied to account for the inflated risk of a type one error. Statistical significance was therefore set at p<.01. The practical significance of observed differences was determined by calculating Cohen's effect size. These were calculated for each position group for all GPS variables. Effect Sizes of 0.2, 0.5 and 0.8 were considered small, medium, and large, respectively.

A Mann-Whitney U test was conducted for AZ5, AZ6, DZ5, DZ6, COL, SP, TC, PASS, TA, RUCK, MAUL and PEN to determine if there was a significant difference between forwards and backs. Distributions of all variables were similar between forwards and backs, as assessed by visual inspection. Due to multiple Mann-Whitney U Tests, a Bonferroni correction was applied to account for the inflated risk of a Type one error. Statistical significance was therefore set at p<.004. To determine whether there was a significant difference between playing positions for these same variables, a Kruskal-Wallis one-way ANOVA were used to examine differences between positional groups. Distributions of all variables were similar between all playing positions. A Bonferroni adjustment was applied to the alpha to account for the inflated risk of a type one error. If a significant difference was revealed between groups, pairwise comparisons were performed using Dunn's (1964) procedure with a Bonferroni correction for multiple comparisons. Statistical significance was accepted at the p<.004 level.

Finally, for WCSD60-300 and WCSHSR-300, due to the repeated-measure nature of the variables, four separate two-way ANOVA's were completed, exploring whether there were any differences between forwards and backs and whether differences existed between the six playing positions. Preliminary analysis revealed no significant outliers through the use of boxplots, and the data were normally distributed. Homogeneity of variance was assessed using Lavene's test. Homogeneity of covariance, assessed by the Box M Test (p>.001), was violated for WCSHSR60-300. For WCSD60-300, Mauchly's test of sphericity indicated that the assumption of sphericity was met for the two-way interaction. Statistical significance was accepted at the p<.05 level.

Results

The principal aim of the research was to gain an understanding of the differences between forwards and backs and between all positional groups for locomotor metrics (collected through the use of GPS), MPI data (collected from notational analysis) and WCS for maximum total distance and maximum HSR distances collected from raw GPS data. GPS and MPI data shown in Tables 1 & 2 are presented relative to the playing time to allow for easier comparison between groups, while WCS variable data has been presented as absolute values. The initial comparison of combined positions, forwards and backs, across the five variables presented in Table 1 confirmed that the backs covered a significantly greater D and HSR than forwards, as well as having a significantly higher MV (p<.001).

Analysis revealed that D between all three back positions and all forwards positions (p<.01). HSR was significantly higher in B3, and C compared to all other positional groups. There was no difference between HB and BR. HB and BR also had significantly higher HSR than FR and BR. (p<.008). Maximum velocity was significantly higher in B3 than all other positions, whilst BR, HB and C had a significantly higher MV than FR and SR (p<.01). Results for these variables are shown in Table 1. There was no significant difference between forwards and backs for accelerations and decelerations in zones 4 and 5, but backs did present a significantly higher frequency of accelerations and decelerations than forwards in zone 6 (p<.01). Further analysis between playing positions revealed that C had significantly higher frequency of AZ4 and AZ5 than FR, SR and B3 (p<.01), while BR, C and B3 had significantly higher AZ6 entries than FR and SR (p<.004). For DZ4 frequency, SR, BR, HB and C had significantly higher entries than B3 (p<.01), while in DZ5, C had significantly more DZ5 entries than FR, SR, HB and B3 (p<.004). For DZ6, BR, HB, C and B3 had significantly higher entries than FR and SR (p<.004). Interestingly, for most positions, frequency of AZ5 and AZ6 were lower than DZ5 and DZ6. Acceleration and deceleration entries for zone 4 can be found in Table 1 and for zones 5 and 6 in Table 2.

Table 1: Analysis of locomotor demands between forwards and backs and between all playing positions.

	Assessing Differences Between Forwards and Backs for GPS Variables (M±SD)				Assessing Differences Between Playing Positions for GPS Variables (M±SD)						
	Forwards (n=137)	Backs (n=123)	P-value	Effect Size (ETA Squared)	Front Row (n=48)	Second Row (n=34)	Back Row (n=55)	Half Back (n=36)	Centre (n=35)	Back Three (n=52)	Effect Size (ETA Squared)
Distance±Per Minute (m/min-1)	60.91±6.79	69.10±7.65*	<.001	0.266 (Large)	58.40±6.73	60.75±7.15	62.67±5.89	69.39±8.52!@£	67.99±6.16!@£	70.19±7.46!@£	0.304 (Large)
Max Velocity (m/s-1)	7.53±0.81	8.46±0.74*	<.001	0.245 (Large)	6.91±0.50	7.23±0.40	8.20±0.66!@	8.12±0.60!@	8.27±0.52!@	8.88±0.74!@£$%	0.573 (Large)
High Speed Running Per Minute (m/min-1)	2.45±1.66	4.78±1.81*	<.001	0.313 (Large)	1.22±0.79	1.73±1.04	3.83±1.34!@	3.42±1.05!@	4.96±1.48!@£$	5.75±1.76!@£$	0.616 (Large)
Accelerations Z4 (n)	0.35±0.12	0.35±0.14	0.936	0.002 (Large)	0.33±0.11	0.33±0.14	0.39±0.11	0.37±0.14	0.44±0.12!@	0.28±0.11£$%	0.154 (Moderate)
Decelerations Z4 (n)	0.31±0.09	0.29±0.11	0.209	0.006 (Large)	0.28±0.10	0.31±0.08	0.34±0.08	0.33±0.10	0.34±0.09	0.23±0.09@£$%	0.171 (Large)

The mean difference is significant at the 0.01 level. * = Significant difference to Forwards; ! = Significant difference to FR; @ = Significant difference compared to SR; £ = Significant difference compared to BR; $ = Significant difference compared to HB; % = Significant difference to compared C; ^ = Significant difference to compared B3.

Table 2: Analysis of GPS and MPI demands between forwards and backs and between all playing positions.

	Assessing Differences Between Forwards and Backs for GPS and MPI Variables (M±SD)				Assessing Differences Between Playing Positions for GPS and MPI Variables (M±SD)							
	Forwards (n=137)	Backs (n-123)	P-value	Effect Size (ETA Squared)	Front Row (n=48)	Second Row (n=34)	Back Row (n=55)	Half-Back (n=36)	Centre (n=35)	Back three (n=52)	P-value	Effect Size (ETA Squared)
Acceleration Zone5 (n)	0.12	0.13	0.949	0.004 (Small)	0.08	0.08	0.170[!@]	0.120[£]	0.160[!@]	0.100[£%]	<0.001	0.169 (Large)
Acceleration Zone6 (n)	0.02	0.0.30*	0.002	0.189 (Large)	0	0.01	0.040[! @]	0.025[!]	0.040[!@]	0.040[!@]	<0.001	0.220 (Large)
Decelerations Z5 (n)	0.12	0.13	0.138	0.092 (Moderate)	0.09	0.12	0.140[!]	0.12	0.160[!@$]	0.12%	<0.001	0.154 (Large)
Decelerations Z6 (n)	0.05	0.080*	<0.001	0.389 (Large)	0.04	0.05	0.070[! @]	0.070[!@]	0.110[!@]	0.080[!@]	<0.001	0.291 (Large)
Sprints (n)	0.08	0.09	0.034	0.131 (Moderate)	0.05	0.045	0.110[! @]	0.07	0.090[!]	0.105[!@]	<0.001	0.157 (Large)
Collisions (n)	0.35	0.200*	<0.001	0.583 (Large)	0.33	0.385	0.370[! @]	0.190[!@£$%]	0.28	0.170[!@£%]	<0.001	0.484 (Large)
Ball Carries (n)	0.07	0.06	0.14	0.092 (Moderate)	0.07	0.07	0.08	0.050[£]	0.100[$]	0.050[£%]	<0.001	0.115 (Moderate)
Mauls (n)	0.08	0.000*	,0.001	0.831 (Large)	0.075	0.090[!]	0.06	0.000[!@£]	0.000[!@£]	0.000[!@£]	<0.001	0.724 (Large)
Passes (n)	0.05	0.070*	<0.001	0.233 (Large)	0.02	0.06	0.060[!]	0.390[!@£]	0.050[!$]	0.040[$]	<0.001	0.420 (Large)
Penalties (n)	0	0.000*	<0.001	0.338 (large)	0.02	0.005	0	0	0.000[!£]	0	<0.001	0.130 (Moderate)
Rucks (n)	0.22	0.235*	<0.001	0.787 (Large)	0.235	0.24	0.2	0.030[!@£]	0.100[!@£$]	0.065[!@£]	<0.001	0.736 (Large)
Tackle Attempt (n)	0.15	0.130*	<0.001	0.460 (Large)	0.13	0.15	0.16	0.080[£]	0.11	0.045[!@£$%]	<0.001	0.359 (Large)

The mean difference is significant at the 0.004 level. * = Significant difference to Forwards; ! = Significant difference to FR; @ = Significant difference compared to SR; £ = Significant difference compared to BR; $ = Significant difference compared to HB; % = Significant difference to compared C; ^ = Significant difference to compared B3.

For all other variables, there were no significant difference between forwards and backs for sprints completed per minute (Table 2). Forwards had a significantly higher frequency of COL than backs. For sprint frequency, the BR and B3 groups had significantly higher SP entries than FR and SR (p<.001). C also completed a significantly more sprints per minute than FR (p<.001). For collisions, FR, SR, BR and C had a significantly higher number of collisions per minute than their counterparts in HB and B3 (p<.001). Results for SP and COL between forwards and backs and between playing positions can be found in Table 2.

Analysis between forwards and backs revealed forwards had a significantly higher frequency of MAUL, RUCK, TA and PEN per minute, than their counterparts in the backs (p<.001), while the backs had a higher number of passes per minute than the forwards ($p<.001$). There was no significant difference between backs and forwards for the number of BC per minute.

Further analysis between playing positions revealed that FR, SR and BR had significantly higher RUCK and MAUL involvements than HB, C and B3 ($p<.001$). C also had a significantly higher amount of RUCK involvements than HB ($p<.001$). TA per minute were significantly lower in B3 than all other playing positions ($p<.001$), and the number of tackles attempted by HB were significantly lower than BR ($p<.001$). Although there was no significant difference between forwards and backs for the frequency of BC completed per minute between playing positions, BR and C had a significantly higher frequency of Ball Carries than HB and B3 ($p<.001$; $p=.002$ against BR). The number of passes completed per minute were significantly higher in HB than all other playing positions ($p<.001$) and were significantly higher in BR and SR than FR ($p<.001$). Penalties conceded were significantly higher in FR and BR than C ($p<.001$). Penalties committed by SR were also significantly higher than B3 ($p<.001$). All results for the tests completed on MPI data variables can be found in Table 2.

Analysis between forwards and backs for WCSD revealed a statistically significant interaction between forwards and backs and time for distance covered during each WCS time epoch ($p<.001$, partial eta squared=.096). Time also had a main effect on peak running distance as distance covered by players significantly increased as the WCS epoch length increased ($p<.001$, partial eta squared=.976). Position had a significant main effect on the distance covered in a WCS epoch as distance covered was significantly greater in the backs than forwards across all time epochs ($p<.001$, partial eta squared=.260).

Between playing positions, there was a statistically significant interaction between playing position and time epoch on the distance covered during each WCS epoch ($p<.001$, partial eta squared=.124). WCS epoch length significantly influenced the distance covered by players, as distance covered by players significantly increased as the WCS epoch length increased ($p<.001$, partial eta squared=.976). Position also had a significant main effect on the distance covered in a WCS epoch as distance covered was significantly greater in the B3, C and HB group than the FR, SR and BR groups across all time epochs ($p<.001$, partial eta squared=.342). FR also covered significantly less distance than their counterparts in BR and SR($p<.001$). All results for WCSD can be found in Table 3.

Table 3: Analysis of maximum distance covered for worst case scenario time epochs 60 to 300s between forwards and backs and between all playing positions.

	Assessing Differences Between Forwards and Backs for Peak Distances Covered Across Multiple Time Epochs (M±SD)		Assessing Differences Between Positions for Peak Distances Covered Across Multiple Time Epochs (M±SD)					
Time Epoch (s)	Forwards (n = 137)	Backs (n = 123)	Front Row (n = 48)	Second Row (n = 34)	Back Row (n = 55)	Half Back (n = 36)	Centre (n = 35)	Back Three (n = 52)
60	160.13±16.00	180.18±17.40*	151.58±16.63	163.78±14.56$^{!}$	164.89±13.690$^{!}$	178.92±17.19$^{! @£}$	177.86±17.47$^{! @£}$	183.09±16.66$^{! @£}$
120	256.58±26.06	284.78±26.47*	243.24±24.35	261.57±25.81$^{!}$	263.83±22.88$^{!}$	282.18±26.06$^{! @£}$	281.13±22.02$^{! @£}$	290.41±2827$^{! @£}$
180	345.59±39.33	383.63±39.23*	327.05±36.81	353.41±40.73$^{!}$	354.17±35.27$^{!}$	384.19±40.30$^{! @£}$	379.90±35.85$^{! @£}$	388.67±38.63$^{! @£}$
240	421.00±43.14	469.81±45.54*	399.04±40.37	428.64±46.05$^{!}$	433.13±35.42$^{!}$	467.68±46.03$^{! @£}$	464.71±39.27$^{! @£}$	477.10±47.69$^{! @£}$
300	499.22±54.13	556.12±55.02*	474.14±5115	510.44±56.06$^{!}$	512.29±47.1$^{!}$	556.66±59.79$^{! @£}$	550.95±45.10$^{! @£}$	562.16±57.47$^{! @£}$

The mean difference is significant at the 0.05 level. * = Significant difference to Forwards; ! = Significant difference to FR; @ = Significant difference compared to SR; £ = Significant difference compared to BR; $ = Significant difference compared to HB; % = Significant difference to compared C; ^ = Significant difference to compared B3.

For WCSHSR there was a statistically significant interaction between position and WCS time epoch on HSR distance covered (p<.001, partial eta squared=.094). WCS epoch length significantly influenced the HSR distance covered, as HSR distance significantly increased as the WCS epoch length increased (p<.001, partial eta squared=.681). Position also had a significant main effect on the HSR distance covered in a WCS epoch as HSR distance covered was significantly greater in the backs than forwards, across all time epochs (p<.001, partial eta squared=.296).

Further analysis revealed a statistically significant interaction between playing position and time on HSR distance covered during each time epoch (p<.001, partial eta squared=.199). Playing position had a significant main effect on the HSR distance covered in a WCS epoch, as demonstrated in the increase in HSR distance covered at every position from FR to B3 as WCSHSR time epoch increased (p<.001, partial eta squared=.533). WCSHSR epoch length had a significant main effect as HSR distance covered by players significantly increased as the WCS epoch length increased (p<.001, partial eta squared=.693). Post hoc analysis revealed that HSR Distance covered in WCSHSR60 was significantly greater in the B3 and C group than the FR, SR, BR groups, and the B3 group additionally covered significantly more distance at high speed than HB (p<.05). BR covered significantly more distance than their counterparts in FR and SR (p<.05).

In WCSHSR120 and 300 HSR, the distance covered was significantly greater in the B3 and C group than FR, SR, BR and HB. BR covered significantly more HSR distance than FR (p<.05). In WCSHSR180 HSR, the distance covered was only significantly greater in B3 than the FR, SR, BR and HB. FR also covered significantly less distance than their counterparts in BR (p<.05). Additionally, in WCSHSR300, FR also covered significantly less distance than their counterparts in BR, SR and HB (p<.05).

In WCSHSR240 HSR, the distance covered was significantly greater in the B3 and C than the FR, SR, BR groups (p<.05). Additionally, there was a significant difference in HSR distance covered between HB for B3. FR also covered significantly less distance than their counterparts in BR, SR and HB (p<.05). All results for WCSHSR can be found in Table 4.

Table 4: Analysis of maximum high-speed running distance covered for worst case scenario time epochs 60 to 300s between forwards and backs and between all playing positions.

	Assessing Differences Between Forwards and Backs for Peak HSR Distances Covered Across Multiple Time Epochs (M±SD)		Assessing Differences Between Positions for Peak HSR Covered Across Multiple Time Epochs (M±SD)					
Time Epoch (s)	Forwards (n = 137)	Backs (n = 123)	Front Row (n = 48)	Second Row (n = 34)	Back Row (n = 55)	Half Back (n = 36)	Centre (n = 35)	Back Three (n = 52)
60	45.89±18.27	68.76±16.62*	32.50±13.54	42.15±13.42!	58.89±14.80!@	62.20±14.24!@	68.42±18.01!@£	74.59±14.23!@£$
120	52.98±24.09	81.86±22.85*	37.29±19.02	47.31±16.98	68.71±21.14!@	69.16±15.35!@	82.00±22.74!@£	92.10±27.55!@£$
180	61.93±27.30	92.64±25.48*	43.32±21.55	55.73±19.91	79.94±21.14!@	81.28±24.85!@	93.78±24.47!@£	101.96±22.30!@£$
240	28.99±29.82	105.47±27.97*	46.89±22.70	62.86±18.11!	89.64±21.14!@	94.11±25.06!@	108.14±29.62!@£	114.10±24.57!@£$
300	75.56±34.31	115.74±30.89*	50.69±22.7	67.64±21.12	99.21±21.14!@	100.81±25.87!@	118.51±28.45!@£	127.32±30.22!@£$

The mean difference is significant at the 0.05 level. * = Significant difference to Forwards; ! = Significant difference to FR; @ = Significant difference compared to SR; £ = Significant difference compared to BR; $ = Significant difference compared to HB; % = Significant difference to compared C; ^ = Significant difference to compared B3.

Discussion

This study is the first paper to provide an insight into the positional demands of tier-two international rugby union matches using a combination of locomotor metrics from GPS data and MPI data recorded through notational analysis. Combining these two measures provides a comprehensive overview of the demands of the game at the tier-two standard. This research is also the first to combine these metrics to provide an accurate assessment of in-game worst-case scenarios while accounting for differences between positions. The information provided in this study for overall workload and maximal demands for the work rate of international tier-two rugby union players can potentially be used to develop training protocols that facilitate a greater transfer to in-game performance improvements. This may be achieved by concurrently executing relevant rugby drills inclusive of specific skills and decision-making activities while also stressing the appropriate physical capabilities and capacities. Also, by understanding the demand placed on players during 'in-game' worst-case scenarios, training protocols that replicate the appropriate intensities, activity durations, and rest periods could be developed. Frequently exposing players to training protocols designed to replicate the specific positional demands of elite rugby union, including stimuli that match or surpass the demands faced during games, may be beneficial for performance while mitigating the injury risks associated with spikes in in-game workload.

As previously discussed, the physical demands of rugby union are primarily governed by the positional roles' players undertake within the game. While there are some exceptions, these roles are typically associated with anthropometry, physical attributes, and the specific skillset of players. Lindsay et al. (2015) suggest that forwards have a substantially larger collision load than their counterparts in the backs due to their repeated involvements in collisions, tackles, breakdowns, and set piece to retain possession [3]. Forwards are, therefore, often physically bigger and more force-dominant players in comparison to backs. There is an increased open-play requirement for backs, where their ability to carry the ball and advance over the gain line are critical markers of success [5]. Whilst not consistently accurate, this means that backs tend to be physically smaller, quicker and more agile players, with superior ball skills that help them attain these critical indicators of success. These physical attributes and the increased availability of open space often result in higher overall distances and distance at high speed being covered by backs [3,7,8].

The current research reinforces the findings of numerous studies that demonstrate that movement demands, and stresses placed on players are specific to individual playing positions. However, a more in-depth analysis has further evaluated the specific positional differences and increased our understanding of the demands of tier-two international rugby union and could underpin the planning and design of individual, position-specific programmes improving both preparation for and recovery from on-field performance.

The analysis revealed that backs covered significantly more D and HSR and had a significantly higher MV than their counterparts in the forwards. For D, backs covered substantially more distance (69.1±7.65m•min-1) than forwards (60.91±6.79m•min-1). Our results are very similar to the relative distances covered by elite international u20 rugby players for backs and forwards respectively (69.1±7.6m•min-1 and 61.5±8.0m•min-1) [17], and slightly higher than values from four European cup rugby games (67.8m•min-1 and 60.4 m•min-1) [5]. However, distance per minute is slightly lower than reported for a tier-one southern hemisphere professional club side (84.7±10.4m•min-1 and 77.3±20.5m•min-1) [3] and by elite senior international rugby players from a tier-one team (73.3±8.1m•min-1 and 66.8±7.0m•min-1) [12]. Further analysis revealed that D was significantly higher in HB, C, and B3 than FR, SR, and BR (Table 1). These trends are similar to those presented in previous studies [4,6,7,12,17,19,20].

The significant difference between relative HSR distance covered by backs and forwards (4.78±1.81 and 2.45±1.66m•min-1) highlights how playing position affect players' locomotor demands. As presented in Table 1, HSR was significantly higher in B3 and C than all other positional groups. There was no difference between HB and BR. These playing positions had significantly higher HSR than FR and BR (Table 1). This trend in high-speed running distance supports the findings of previous literature [4,3,6,7,12,17,19,20] as the higher amount of HSR experienced by B3 and C originates from their roles in the backline and suggests that the further away players are from the ruck area the more space there is available for these playing positions to use their higher maximum velocity to attack the gain line. For HB and BR, their lower HSR but higher D could originate from running support lines in attack and the increased requirement to be at each breakdown across the field to retain possession and distribute the ball to their teammates, while defensive roles and responsibilities will also contribute to these differences. The higher levels of HSR experienced by B3 and C have been shown to increase eccentric loading through intense stretch-shortening cycle activity and thus an increase in markers of muscle damage up to 60 hours post-game [21]. This data suggest that appropriate recovery protocols should be used to assist with the return to training following games for players that experience high levels of HSR during games, especially during the most intense periods of competition, were, for example, there may only be four days between games, as seen in the Rugby World Cup in 2019.

Although trends may be similar to previous studies, the reported D and HSR covered by players were much lower in our study when compared to other senior tier-one professional rugby union players at both an international and club level across all playing positions. Data reported by the current study were similar to the data presented for u20 international rugby and Australian premier grade level rugby [17,22]. These lower values, especially for HSR, may attest to differences in technical or tactical styles of play, the demands of the game, standard of the opposition, result of the game, and even environmental factors. Quarrie et al. [2], Siriotic et al. [23] and Beard et al. [6] have previously reported that HSR distance is a distinguishing factor between playing levels in both rugby union and rugby league and that distances covered at high speed are greater in professionals playing at an international standard than professionals playing at club standard [2,6,23]. Therefore, for tier two sides to continue to be competitive at an international level against higher-level opponents, repeated speed training should be emphasized for these positions that experience high HSR demands in-game, namely C and B3. This training would aim to build a tolerance to the more considerable HSR demands placed upon them against higher caliber international sides [6].

The average in-game MV achieved for backs was higher for both forwards and backs in comparison to what has been shown in previous studies for a tier one international side (8.44 for backs, 7.31 for forwards) [4], and for a tier two senior club side (8.34 for backs and 7.42 for forwards) [24]. This difference may be accounted for by differences in the tactical approach, emphasizing a kicking game being used by this tier-two team, resulting in a higher amount of kick chases that provide all players with the opportunity and the space necessary to achieve higher speeds. According to Pollard et al. [25], backs may have a higher in-game MV than the forwards because they are presented with more space in-game and more opportunities to express this quality in-game to exploit gaps in the opponent's defense. Proximity to other players and higher frequency of collisions result in lower HSR and MV for forwards [25], potentially highlighting that acceleration capability and repeatability may be of greater importance for forwards than their ability to cover ground at high-speed, as the ability to achieve high rates of acceleration is fundamental to dominating collisions in the limited space available to them.

The data in Table 1 demonstrate that MV was significantly higher in B3 than in all other positions. Furthermore, BR, HB, and C had a significantly higher MV than FR and SR, providing practitioners with vital information regarding the variance in stimulus needed for positional groups in training programmes. FR and SR require more focus on acceleration and speed off the mark, which is underpinned by rate of force development, strength, and power. Backs and back-rowers also need regular exposure to maximum velocity running at or above 95% of max velocity to improve performance and tolerance to the higher speeds experienced in-game [26].

When assessing SP frequency relative to time, there was no significant difference between forwards and backs, and when assessing positional differences, FR and SR had significantly lower SP entries than both BR and B3. BR attained the highest number of SP relative to playing time out of all positions. Table 1 shows that relative SP frequency is lower than seen in previous studies [12] and suggests yet again that to improve performance, a focus should be placed on repeated speed in training to build a tolerance to the higher sprint frequency associated with tier-one international rugby union. The SP frequency differs from previous results where B3 completed the highest number of sprints relative to playing time, followed by all other positions in the backs and then BR across both international and professional club teams [6,24]. When comparing where BR places against other playing positions in SP frequency versus BR's volume of HSR distance covered per minute in our study, a question is raised regarding thresholds for HSR. In this study, an absolute threshold of >5.5m•s-1 was set to measure player's HSR to allow for comparison to previous studies. However, Reardon et al. suggest that the use of an individualized threshold of 60% of MS for HSR may be more accurate in determining HSR volume, especially as the absolute threshold of >5.5m•s-1 may underestimate the amount of HSR completed in slower players, mainly the forwards [5], and potentially, in this case, BR.

The frequency of accelerations and decelerations undertaken throughout a rugby union match are considered important indicators of the load placed on players in-game due to the large amount of eccentric load imposed by these actions [27]. In our data, there was no significant difference between forwards and backs for accelerations and decelerations in zones 4 and 5, but backs did have a significantly higher frequency of accelerations and decelerations compared to forwards in zone 6.

Further analysis between playing positions revealed that C had the highest frequency of AZ4, BR the highest AZ5 frequency, and BR, C and B3 all had significantly higher AZ6 entries than FR and SR. For DZ4 frequency, SR, BR, HB and C had significantly higher entries than B3, whilst in DZ5, C had significantly more entries than all other positions aside from HB. For DZ6, BR, HB, C and B3 had significantly higher entries than FR and SR. For most positions, frequency of AZ5 and AZ6 were lower than frequency of DZ5 and DZ6, which is in agreement with previous data reported for rugby union [27]. These findings suggest that this higher number of decelerations to accelerations relates to the spatial constraints placed on players in-game as there is limited opportunity for players to surpass the threshold of >5.5m•s-1 necessary for HSR, and so requires players to complete more sharp decelerations. Much like SP frequency, acceleration and deceleration frequency is associated with the roles placed on players through their position. A higher amount of more intense decelerations occurs in forwards though their involvement in large collisions tackles, and breakdowns, which in turn incur larger braking forces. Meanwhile, backs may use their higher acceleration and deceleration to attack spaces in the defensive line and deceive defenders into carrying the ball over the gain line. Out of all positions for this tier two side, aside from AZ4 and AZ5, C had the highest frequency of accelerations and decelerations. This may highlight the more direct style of play implemented by this tier two side, as the higher amount of both accelerations and decelerations may result offensively from this position having to accelerate hard towards the opposition's defensive line with ball in hand to draw in multiple defenders, thus resulting in multiple, rapid decelerations through collisions with these opposition players [28].

Ultimately an understanding of the acceleration, deceleration and collision demands that rugby players are exposed to in-game is vital in informing practitioner's post-match recovery protocols. Previous research into Australian Rules Football has revealed that these variables, along with high intensity running demands, are strong predictors for levels of Creatine Kinase (an indicator of muscle damage) post-match, which have been associated with decreases in neuromuscular function [27,29].

In addition, understanding and quantifying the collision-based demands of different playing positions will allow for the specification of training to more closely replicate demands faced by players in-game [30]. In this study, forwards had a significantly higher collision count than backs. FR, SR, BR, and C had a significantly higher number of collisions per minute than their counterparts in HB and B3 (Table 2). Our COL data was very similar to the data presented by Jones et al. on a Welsh professional rugby team [7] and an amateur club side [24] but was lower than data presented on a southern hemisphere professional side [3] and an Irish professional rugby team [31]. These data help highlight technical and tactical differences between teams and competitions.

Results support the study by Jones et al. [32] that although the lowest distances are covered by forwards, they are involved in many static exertions. This variance in positional demands should be reflected in the design and implementation of position-specific training and recovery protocols for the physiological preparation and monitoring of performance in players [32].

Similar to the GPS variables reported in this study, COL data presented in Table 2 are averages, and although they indicate practitioners the demands placed on different playing positions, they underestimate the peak demands placed upon players in-game. A recent study from Reardon et al. [33] reported that the peak collision demands relative to playing time from the European Champions Cup and the Pro12 domestic league across all positional groups from an elite tier one professional rugby union team were substantially higher than the average collision demands reported in the current study on a tier two international side [33].

Reardon et al. [33] suggested that to successfully deal with the peak ball in-play demands, it would be necessary for the number of collisions faced by all playing positions to be increased [33]. However, it would be difficult and potentially unwise to attempt to replicate the higher collision demands and static exertions placed on players, particularly forwards, in the days leading up to a game. Consideration by practitioners should be given to the cost-benefit of such activities and the time course for recovery. Doeven et al. [34] suggest that it can take between 48-72 hours for muscle damage markers associated with collisions and eccentric activity to return to normal post-game [34]. It must be asked whether it is necessary to place a similar or higher amount of stress on players during the training week through an increase in the number of collisions undertaken, which then may result in players' less than optimal recovery and potentially impede their performance in-game. Practitioners should consider drills that develop the specific physical qualities that equal or exceed these demands through the use of skill-based conditioning games that are interspersed with grappling or wrestling drills or that replicate the movement demands placed on playing positions to ensure a sufficient stimulus for adaption, but not so much that it detracts from performance in-game [13,35].

MPI data collected from the notational analysis has provided this study with data that will give practitioners a holistic view of tier two international rugby union positional demands. This combination of GPS and MPI data is necessary for understanding the demands of the game placed upon all positions. Although GPS is a potent tool for measuring the locomotive demands of rugby union, consideration needs to be given to the occurrence and frequency of other game-specific actions that place significant physiological stress on players. These include the isometric exertions encountered in activities such as rucks, mauls, and tackles. Excluding this data from the analysis would result in underestimating the demands of a game from a practitioner's standpoint and would potentially translate to poor performance on-field through players being chronically underprepared for the tasks they are to undertake in-game.

The necessity for the inclusion of MPI data in the analysis of the positional demands of international rugby union is particularly evident when assessing the differences between forwards and backs. GPS data, as shown in Table 1, suggests that for all running-based demands, forwards cover the least amount of distance at significantly lower speed compared to backs. However, this is not to say that the match involvements and positional demands of the forwards are low. Compared to backs, forwards had a significantly higher frequency of mauls, rucks, and tackles per minute. Conversely, backs had a higher number of passes completed per minute than the forwards. There was no significant difference between backs and forwards for the number of balls carries per minute. The MPI data provided here mirrors the findings of previous studies on the positional demands of international rugby union [3,30,31,36-38] and shows that the forwards have substantially higher involvement in activities that induce similar or even higher levels of stress than those from the locomotor demands. If ignored by practitioners, training would underrepresent some of the most intense demands of the game.

To further understand the demands placed on playing positions, analysis between playing positions were completed for every MPI variable and revealed that BR and C had a significantly higher frequency of BC than HB and B3. This pattern displayed for ball carry frequency highlights the role that the tactical aspects of rugby union play on the physiological demands placed on players, particularly as our results differ significantly from the results presented by Lindsay et al., which show that carries were significantly higher in outside backs than any other position [3]. The higher number of balls carries in BR and C from our study may highlight a tactical emphasis on a more direct game that uses the physical characteristics of larger and more force-dominant players to carry the ball over the gain-line [28].

This more direct playing style is highlighted through the significantly higher frequency of passes completed by HB than all other positions. However, BR and SR equally have the second highest number of passes. These shorter passes that are nearer to the breakdowns and the gain line result in a higher amount of ball carries in the forwards and centres [28], resulting in a higher number of collisions for these positions and a higher level of physiological stress [27,29]. The effect of style of play on physiological demands should not be underestimated. Adopting a less direct approach, focusing on greater width and more offloads, may reduce collisions for certain positions and result in greater distance and high-speed running completed by all positions [28].

Playing positions within the forwards (FR, SR and BR) and C had the highest number of TA per minute. TA frequency between positions is very similar to previous findings [3,30] and similar to our collision data. For these positions, significant consideration is needed for the higher collision load experienced by these players and must be reflected in position-specific training programmes and recovery protocols particularly in-season, where optimal recovery from training during the week and post-game is necessary for peak performance in-game.

As expected, FR, SR, and BR had significantly higher RUCK and MAUL involvements than all positions in the backs. This MPI data is similar to what has been presented previously and shows that the larger anthropometry and physical traits possessed by those in the forwards allow them to effectively complete their 'position-specific roles' of retaining possession and impede the progress of the opposition [3,32]. Although their involvements in BC, TA, Ruck, and Maul result in lower D and HSR in comparison to their counterparts in the backs, their increased time spent in these static exertions, as previous studies have shown, corresponds to a similar stress outcome for to those experienced by positions in the backs in-game [3]. Although no significant difference was existed between FR, SR and BR for COL, BC, TA, RUCK and MAUL, the roles undertaken by 'tight forwards' (FR, and SR) during scrums must be considered when assessing the positional demands of international rugby union players, particularly as accelerometers in GPS devices do not track the lengthy static exertions experienced during scrums. The levels of force expended by and on FR and SR in scrums are much higher than those experienced compared to BR [39,40]. They can result in large amounts of 'transient fatigue', which results in an initial reduction in high-intensity activity and can be shown through the reduced high intensity activity from FR and SR compared to BR following a scrum [32].

Whilst the use of collision metrics from GPS is valuable in tracking the external loads placed on players, the inclusion of MPI data allows us to quantify the physiological demands placed on players and precisely replicate these demands in training. Practitioners can use the combination of GPS and MPI data presented in our study to alter training and recovery protocols dependent on the unique physical demands presented playing position during games and can be used to match or replicate these specific game demands during training to ensure adequate preparation for optimal performance throughout a season [32].

Understanding the demands of the game at the tier-two level has been discussed from the perspective of locomotor data from GPS and MPI data, which has its uses in giving practitioners and coaches an idea of the demands placed on positions and allows for a more individualized approach to the preparation and implementation of training programmes. However, these tables drastically underestimate the peak demands placed on players in the most intense periods of the game and if ignored, a potential decrease in performances and increase in the risk of injury in-game may occur when these 'spikes' in workload appear [13]. The concept of Worst-Case Scenarios (WCS) comes from risk-management, where the planner, in planning for potential disasters, considers the most severe possible outcome that can reasonably be projected to occur in a given situation. The idea of a WCS translates to rugby as the worst possible outcome out of several possibilities in planning or simulation. The practitioner's role is to ensure that they set aside enough reserves to cushion the impact if the event or situation occurred. Understanding the demands encountered in these so-called 'Worst-Case Scenarios' will allow coaches and practitioners to better prepare their players for the rigors of elite international rugby.

When assessing the peak running demands for this tier-two nation side, as expected, all positions recorded substantially higher total distance and HSR than the mean values reported for these variables in Table 1. In both WCSD AND WCSHSR across all time epochs from 60-300s (Tables 3 & 4), backs covered significantly more ground than their counterparts in the forwards. When considering the difference between forwards and backs in-regards to their on-field roles, this is in agreement with previous studies that have examined the peak running demands of international tier-one standard rugby [13].

WCSD distances covered by tier-two standard players were very similar, if slightly higher than the tier one international players for both forwards and backs at every time epoch. Our WCSHSR per minute data reported slightly higher HSR distance being covered per minute for forwards, while backs covered slightly less HSR distance per minute than the backs reported by Cunningham [13]. These similarities extend to the between playing position assessment of peak running demands for international rugby union. When assessing the differences between playing positions for WCSD, HB, C and B3 covered significantly more distance than all other playing positions at every time epoch. FR covered significantly less distance at every time epoch compared to all other playing positions. There was no significant difference between the distance travelled at every time epoch between SR and BR. These results are similar to the trends reported in Cunningham and Sheppy for both male and female tier one international rugby union [8,13].

The lower distance for the FR and SR compared to other playing positions originate from the primary role of these 'tight five' forwards. These players contest possession at breakdowns, set pieces, and tackles, where there is a high level of static activity, especially within scrums. These have previously been shown to create a high level of transient fatigue and reduce the distance covered by players in these positional groups in a worst-case scenario [2,8].

Analysis of WCSHSR similarly revealed that FR and SR covered significantly less HSR distance than all other positional groups. Interestingly there was no significant difference between BR and HB, whilst B3 covered significantly more ground than all other playing positions at all time epochs. The differences in HSR distances mainly occur due to the tactical role of these positions. As stated previously, the primary role of FR and SR involves a higher frequency of static activity within set pieces and breakdowns and collisions with other players, resulting in a limited opportunity for these positions to accelerate past 5.5m•s-1 before contacting another player. In BR and HB, the primary roles comprise of running from breakdown to breakdown to "clear out" the opposition and contest for possession for BR, and for the HB to then distribute the ball to C and B3, whose role is to make the most of the open space available to them and their higher MV to contest the gain-line and create further attacking opportunities. These differences between playing positions support providing a position-specific approach to implementing training programmes.

In this study, only epochs from 60 to 300s were included. According to Cunningham et al., there is no additional benefit for analyzing peak running demands in epochs longer than 300s. Values higher than this have been shown to under-represent the intensity of in-game worst-case scenarios, as the intensity of the WCS, expressed as relative values relative to epoch length, decrease as epoch length increases [13,14]. Although these time epochs of ≥300s provide a more appropriate stimulus for replicating the worst-case scenarios faced in-game through the individualization of running intensities and distances in a training programme, there needs to be an integration of these peak running demands with other locomotor and MPI data, as seen in Pollard et al. [25]. Although there is a place for separate skills and conditioning sessions, an integrated approach will allow for a far greater return on time investment and accelerate improvement [35].

The similarities of peak running demands between tier-one and tier-two international sides suggest that a tier-two side can match the peak-running demands of those at the highest level of competition. Therefore, the dissimilarity in performance between these levels of competition may come from the ability to repeat these high-intensity periods or from limitations in technical and tactical aspects of the game. Both elements should be emphasized by tier-two international sides to continue to be competitive at an elite level through the adjustment of training to further replicate the comprehensive demands of elite international rugby union through the invention of a battery of drills that develop the qualities necessary for success at the highest levels of the game. For instance, practitioners need to consider whether players are exposed to periods of ball-in-play that regularly exceed 3 minutes [33] and whether players execute general and position-specific skills under similar fatigue experienced in-game. Lastly, practitioners should examine whether sessions are designed to replicate the work-to-rest ratios seen in the game's highest levels, considering the duration of rest periods between activity periods.

Integration of MPI data and GPS data needs to be considered when replicating the peak demands of the game for positions that are involved in a higher frequency of static exertions as experienced by FR, SR, BR, and C, where their actual peak demands may be under-represented when only assessing peak running-based demands. The ability to alter the identification of a WCS would allow for a more appropriate stimulus to be applied for each playing position during a training cycle and allow for a higher level of transfer from training into performance. STAT Sports have recently developed a metric that will allow practitioners to calculate the WCS during any session or game for each individual player, for a variety of variables. USA Rugby has analysed the WCS for both the maximum distance and collisions for a 180 second period. This unpublished data revealed that there was a substantial difference between distances covered when prioritizing max distance versus collisions as the primary focus of the WCS analysis, with distances decreasing substantially as collisions increased for every position aside from BR, where there was only a minor drop in distance covered as their collisions increased. For example, the distance covered by FR and B3 decreased by 51m and 104m, respectively, while their collisions increased from 5 to 8 for FR and from 3 to 6 for B3. BR's distance covered only decreased by 14m as their number of collisions increased from 5 to 6, covering more distance than all other positions when collisions were the focus of the WCS analysis. This data agrees with previous studies that have combined indicators of stressors placed on players in-game and have shown that BR has the highest match involvement out of all positions. Knowledge of these demands needs to be taken into consideration by practitioners when designing training programmes, especially as the higher levels of Creatine Kinase (a marker for muscle damage) has been associated with both a higher number of collisions and high-speed running efforts, both of which are high for the BR position. Future research combining both peak running and collision-based demands would be of use to practitioners when replicating the most intense periods of a game in training. As the integration collision metrics have been shown to alter the peak demands faced by each playing position, with both been associated with higher physiological stress placed on players, they should be considered when aiming to replicate the actual peak demands of the international game.

Conclusion

This study found that significant differences exist between forwards and backs across all variables, aside from frequency of accelerations and decelerations in zones 4 and 5, sprints, and ball carries. Ultimately, backs reported higher distances for relative distance, high speed running, maximum velocity and acceleration and decelerations in zone 6. Backs also covered the highest distance across all worst-case scenario epochs for both maximum distance and high-speed running. Forwards, conversely, had a significantly higher number of collisions and involvements in tackle attempts, rucks, and mauls. When assessing the differences between playing positions, back three players covered the most distance per minute, high-speed running per minute and attained the highest maximum velocity out of all positions, while the front row had the lowest values for these variables. Collisions, tackle attempts, maul and ruck involvements were highest in the second row, while centres had the highest number of ball carries. The assessment of worst-case scenarios for maximum distance and high-speed running revealed that backs and players in the backs three position covered significantly higher distances than all other positions across all time epochs. All positions covered substantially higher distances than reported in the mean GPS values.

This study has provided a detailed evaluation of the positional demands of tier-two international rugby union. The information derived from GPS and MPI data, along with the analysis of peak running-based demands of the game, confirmed that for this tier two rugby team, backs cover the highest distance at any speed while forwards have higher involvement in collision-based activities and will provide practitioners with detailed and relevant information to enable the planning of training protocols designed to replicate the specific demands of the game at the elite level.

The challenge facing practitioners working with tier-two international players is that at the domestic club level, few players are regularly exposed to the levels of intensity of the peak demands found in international rugby within their club training environments, even in tier-one domestic leagues. Further research comparing the differences in peak demands between domestic rugby union in the MLR and the tier-two international level would help prepare domestic players for the physical demands of the international game.

To prepare players appropriately for the challenges of the international rugby union, training should focus on the peak running-based demands of the game to account for the acute spikes in intensity and workload faced by players. Basing training on the average demands of the game may leave players chronically underprepared and may result in underperformance or potential injury when these spikes arise on-field. Training methods should be based upon position-specific 'top-ups' with more velocity-based repeated sprint ability focus on centres and outside backs and repeated high-intensity efforts involving both high-speed running and collisions for positions such as back rowers.

Increasing practitioner's awareness and understanding of the maximal demands of workload and work rate while accounting for positional differences in training allows for a greater positive transfer to in-game performance. It is suggested that developing the ability to repeat extended bouts of high-intensity activity, execute position-specific skills and effective decision making under game-like fatigue is necessary to increase competitiveness against higher-level teams.

Practical Applications

This study provides a comprehensive overview of the position-specific demands of tier-2 rugby union that can be used to ensure players are appropriately prepared to compete at this level. In addition, by comparing these data with research conducted on tier-one rugby players, it is apparent that there are key areas where there are differences in both workload and work rate between the two playing standards.

To ensure that players are adequately prepared to compete effectively at the international level, it is suggested that both GPS and MPI metrics are combined with the data from the worst-case scenarios and used to inform the planning of both team and position-specific preparation. This study recommends that training should include a focus on the game's peak running-based demands to account for the acute spikes in intensity and workload faced by players. Players should be regularly exposed to repeated periods of play that concurrently replicate the position-specific demands and worst-case scenarios highlighted in this study, emphasizing skill execution and decision-making.

This study recommends that incorporating activities such as grappling and wrestling that replicate the movement demands placed on playing positions can provide a sufficient stimulus without the deleterious effects and risks of full contact. Regardless, the timing of such activities within the training week should be carefully considered, ensuring that there is sufficient time to recover before a competition to limit any negative impact on the development of the physical qualities that are the foundation for effective performance in the contact area. Future research combining both peak running and collision-based demands would be of use to practitioners when replicating the most intense periods of a game in training, as the inclusion of collisions has been shown to alter the peak running demands of each playing position.

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