Training and Match Demands of Elite Rugby Union.

Running Head: Training and Match Demands.

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Abstract.

This study aimed to examine training and match demands associated with elite Rugby Union. Eighty-nine elite players were monitored using subjective (session ratings of perceived exertion) and objective (GPS: distance and high-speed running [defined as >70% of individual maximum speed] distance) methods, alongside key performance indicator variables in matches (e.g. number of tackles made). These were compared between positions (forwards vs. backs) and league of competition (Premiership vs. Championship). Statistical significance was accepted as $p<0.05$. Analysis revealed that backs covered greater distance (by 704 m, $p<0.001$) in training and greater distance (by 7.6 $m \cdot min^{-1}$, $p<0.001$) and high-speed running distance (by 1.22 $m \cdot min^{-1}$, $p<0.001$) in matches, compared to forwards. In matches, the forwards experience greater key performance indicator demand (tackles: 78%; tackle assists: 207%; breakdown entries: 324%; contact events: 117%; all $p<0.001$) compared to backs. The number of tackles (53%, $p<0.001$) and tackles missed (35%, $p=0.001$) was greater, whereas contact carries (12%, $p=0.010$) and breakdown entries (10%, $p=0.024$) were lower, in the Premiership compared to the Championship. Overall, these findings confirm that the running demands of Rugby Union are higher in backs, whilst contact actions are higher in forwards; with further differences between the Premiership and Championship. This comprehensive examination of the demands of elite Rugby Union could be used to ensure the specificity of training protocols for elite Rugby Union clubs, specific to both playing position (forward or back) and level of competition (Premiership or Championship).

Keywords: sRPE load; distance; high-speed running distance; contact actions; mixed effect models.

42 **INTRODUCTION.**

43 Rugby Union is an intermittent team sport, where short periods of maximal or high-speed
44 running exercise are punctuated by lower intensity exercise or rest (16). The sport is
45 estimated to have more than 6.6 million participants World-wide and a quadrennial World
46 cup consisting of 20 nations attracts over 4 billion viewers; therefore, Rugby Union has a
47 nationally and internationally significant presence (25). The top two leagues of Rugby Union
48 in England are classified as professional (Premiership and Championship), each comprising 12
49 teams (9).

50

51 A number of studies have attempted to quantify the physical demands of Rugby Union,
52 predominantly through the use of time-motion analysis and global positioning systems (GPS)
53 (8,19,7,12,4,3). The initial work exploring the match demands was undertaken using time-
54 motion analysis, a non-intrusive method of video analysis allowing information about players'
55 movement patterns (e.g., total distance covered and number of sprints). For example, 29
56 English Premiership Rugby Union players were monitored during five leagues matches across
57 the 2002-2003 and 2003-2004 seasons (19). To allow for inter-positional observations the
58 players were divided into forwards and backs, a common classification in Rugby Union due to
59 the different nature of match play between these positions. Results demonstrated that the
60 backs (6127 ± 724 m) covered more total distance than the forwards (5581 ± 692 m), also
61 covering a greater distance at higher speeds of 5.0-6.7 $m \cdot s^{-1}$ (backs: 448 ± 149 m; forwards:
62 297 ± 107 m) (19). Whilst this study provides a useful initial insight, the data were normalised
63 to a full 80 min based on the data collected in the second and third quarters (20-60 min) of
64 the matches. However, this approach is questionable given that the first 20 min and last 20
65 min are when the players are likely to be at their 'freshest' and most fatigued respectively,

and thus their movement patterns may be significantly different to the observed period (20-60 min) of the match. The lack of relative speed classifications (i.e. all players performance was evaluated using the same absolute thresholds) is a further limitation given that the true maximum speeds will vary considerably between players (and likely between forwards and backs in particular). Therefore, utilising a relative approach to high-speed running threshold (e.g., greater than *x*% of an individual's maximum speed) may provide further insight into the positional demands associated with Rugby Union match play (18,11).

The most comprehensive study to date examined the demands of Rugby Union match play in 8 professional clubs in the 2010-11 English premiership season using GPS technology (3). The most noteworthy characteristics of the movement patterns underpinning the two positional groups were that the backs moved predominantly (46.3%) in the lowest speed category (<20% of maximum speed) whereas the forwards covered most of their distance (46.2%) whilst jogging (20-50% of maximum speed). The backs covered a greater total distance (6545 m vs. 5850 m), greater total distance per minute (71.1 $m \cdot min^{-1}$ vs. 64.6 $m \cdot min^{-1}$) and had a higher maximum speed (30.4 $km \cdot h^{-1}$ vs. 26.3 $km \cdot h^{-1}$) when compared to forwards. However, a significant omission was that the training demands associated with Rugby Union were not examined; with players training 3-4 times per week and thus training forming a significant amount of the total demand placed on elite Rugby Union players.

The only insight that we currently have regarding the training demands of Rugby Union comes from comparing training and match demands in male adolescent players using time-motion analyses (12). The main finding demonstrated the disparity between physical match demands and on-field training demands in adolescent players, where the total distance, time spent

jogging, time spent striding and time spent sprinting were all observed to be greater in matches compared to training (12). However, this study was in adolescent players and its relevance to the professional game is unclear. Furthermore, the research to date has only considered the objective load demands placed on players (e.g., distance covered) and no study to date has considered the subjective load demands (e.g., session RPE [sRPE]) of either training or matches in Rugby Union, despite the demonstrated utility of this method in assisting with the moderation of load management for both performance enhancement and injury / illness prevention (6,5). Another important determinant of the demands of Rugby Union are key performance indicators, such as the number of tackles made, and ball carries completed (15). However, these key performance indicators have not been studied in terms of the demands of Rugby Union. Furthermore, it is not known whether the demands of Rugby Union differ between the very highest level of domestic competition (i.e. Premiership) and the second tier (i.e. Championship); where the difference in standard could well affect the demands placed upon players.

Therefore, the aims of this study were to examine and identify the training and match demands associated with professional Rugby Union. In addition to quantifying the overall demands, the study also sought to identify the influence of position (forward/back) and the league of competition (Premiership/Championship) on objective (GPS) and subjective (sRPE) demands, as well as on key performance indicators (e.g., the number of tackles). The study followed a professional Rugby Union team that, across two seasons, played in both levels of competition and thus, allows a unique comparison between these leagues of play within the same club.

METHODS.

Experimental Approach to the Problem

A two-season prospective cohort study of elite Rugby Union players, where all training sessions and matches were monitored using both subjective (session ratings of perceived exertion; sRPE) and objective (GPS-derived) load methodologies. In addition, key performance indicator variables, such as the number of tackles made and number of contact carries completed, were analysed in matches.

Subjects

A total of 89 Rugby Union players were studied across two-season of competition (Premiership: n = 60; Championship: n = 56; n = 27 players were common between the two seasons). All players were registered in the first team squad of an elite professional English Rugby Union club, playing in the top two tiers (English Premiership and Championship; given that the club was relegated [14% win rate] / promoted [95% win rate] in the two seasons under investigation) across two seasons of competition. Descriptive characteristics are displayed in Table 1. Ethical approval was provided by the host institution's Ethical Advisory Committee and all players provided their written consent to participate.

Table 1. Descriptive characteristics for position across each level of competition.

Level	Position	n	Age (years)	Height (m)	Body Mass (kg)
Premiership	Full squad	60	27.7 ± 4.2	1.86 ± 0.07	103.9 ± 12.6
	Forward	34	28.2 ± 4.0	1.89 ± 0.07	111.9 ± 8.1
	Back	26	27.4 ± 4.6	1.82 ± 0.06	93.2 ± 8.6
Championship	Full squad	56	25.7 ± 4.5	1.86 ± 0.08	104.4 ± 14.1
	Forward	35	25.5 ± 4.1	1.88 ± 0.07	112.1 ± 10.8
	Back	21	25.6 ± 5.0	1.81 ± 0.05	91.9 ± 9.1

Procedures

Rating of Perceived Exertion (RPE): For every field- and gym-based training session and match, an RPE rating, using the modified Borg CR-10 RPE scale (10), was obtained, individually from players, within 30 min of the end of the exercise, in line with the recommendations of Kraft et al (14). Players were familiarised with the sRPE scale at the start of the study. Session RPE load (sRPE load) in arbitrary units (AU) was then calculated for each player by multiplying the given RPE by the session duration (min) (10). This was performed for all players across both seasons of data collection. Session RPE load has previously been shown to be a valid method for estimating relative exercise intensity (13).

Global Positioning Systems (GPS): An objective measure of match and training load was obtained through GPS for every field-based training session (33 out of the 60 players in the squad for season one and for all 56 players in season two) and matches (all 89 players were monitored during matches). Overall, 27 players completed both seasons and 62 players completed one of the two seasons. Two GPS systems were used during season one, with each

player using the same GPS unit for the entire season (Catapult OptimEye S5 monitoring system, 10 Hz, Canberra, Australia, n = 18 and GPSports SPI-Pro, 5 Hz, Canberra, Australia, n = 15). In season two all 56 players used the same GPS system (STATSports APEX, 10 Hz, Newry, Northern Ireland, n = 56). The number of satellites was satisfactory on all days for all systems, with an average of 9 ± 1 satellites per day being used and a horizontal dilution of precision of 0.58 ± 0.06. The firmware of the systems was the same for all units for the respective manufacturer and the firmware was not updated at any stage during the study. The manufacturer's software was used to download all sessions and the software was not updated at any stage during the study. Previous research has demonstrated the reliability and validity of each of the GPS systems used (GPSports SPI-Pro: Waldron et al. (22); Catapult OptimEye S5: Thornton et al. (21); STATSports APEX: Beato et al. (1)). High-speed running distance was determined as the distance covered at greater than 70% of an individual player's maximum velocity, determined during pre-season testing (40 m sprint testing) and updated if bettered at any stage across the season for subsequent sessions; thus, providing an individualised approach relative to the maximum running speeds of each player (5).

Key Performance Indicators: For all league matches (Premiership and Championship), a host of key performance indicator variables were coded by the club's performance analyst. All variables were coded by the same performance analyst to ensure consistency between matches using performance analytics software (Sportscode Version 11, Hudl, Lincoln, Nebraska). The following variables were coded:

- *Tackles*: all 'first up' tackles made by an individual player
- *Tackle assists*: all tackles made by an individual player where they were not the first player into that particular tackle scenario (i.e. secondary, tertiary tackler)

- *Tackles missed*: all tackles attempted by an individual player but where the player failed to effectively stop the opposing player and perform a completed tackle scenario
- *Contact carries*: all carries made by an individual player where they took the ball into contact/collision
- *Breakdown entries*: all breakdown entries by an individual player, on either the attacking (i.e. 'cleaner'; removing defenders from the ruck) or defending (i.e. 'jackler'; attempting to win a turnover at the ruck) side of the breakdown
- *Contact events*: a sum of the above five variables to provide a total count of contact/sport specific actions.

Data Handling: All load variables (sRPE load, distance and high-speed running distance) were aggregated for all training sessions and matches in a single day to provide a single daily value for each variable. All match key performance indicator variables for first team league matches were calculated for each individual player per match. All players who played any part in a match (full match, starter, replacement) were included in the match analyses. Training demand distance and high-speed running distance is expressed in absolute terms (given the greater amounts of technical/tactical elements of training), with match demand expressed per minute to account for differences in match duration between starters and replacements.

Statistical Analyses

All analyses were performed using the R software package (www.r-project.org). Mixed effect models were conducted using *lme* or *glmer* functions depending upon the distribution of the data and the subsequent transformation required (as suggested by Windt et al. (24)); to examine the effect of position (forward/back; forward as the baseline) and league of

competition (Premiership/Championship; Premiership as the baseline) on all load and key performance indicator variables; as well as the interaction between position and level of competition. When assessing training demands, sRPE load, total distance and high-speed running distance were analysed; whilst in matches the same three load variables (sRPE load, total distance and high-speed running distance), along with match duration and the six key performance indicator variables (tackles, tackle assists, tackles missed, contact carries, breakdown entries, and contact events) were assessed. Random effects for player were included in all models.

The load variables (for both matches and training) were assessed using the *lme* function, which applies linear mixed effect models (high-speed running distance analysis was undertaken using a square root transformation due to the distribution of the data). Due to the key performance indicator variables being count variables, these models were run using the *glmer* function (which applies generalised linear mixed effect models) with a Poisson (where variance < 2x mean) or negative binomial distribution (where variance > 2x mean) as appropriate. Match duration was also included in the key performance indicator models, given the impact of the length of time played on these variables. The use of mixed effect multi-level models allows for the calculation of expected key performance indicator of any match duration for both forwards and backs and by level of competition (Premiership/Championship). For all analyses, statistical significance was accepted as $p<0.05$.

RESULTS.

Training Demands

Training demands of Rugby Union (sRPE load, distance and high-speed running distance) are detailed in Tables 2 (forward vs. back) and 3 (Premiership vs. Championship) and supplementary Figures 1 and 2.

Table 2. Training demands of Rugby Union expressed as mean (±SD), for session RPE load, total distance and high-speed running distance. Split by position; full squad, forward and back.

Load variable	Position	Training demand	Intercept	Parameter estimate	Std. error	p-value
sRPE load (AU)	**Full squad**	438 (±271)	428	-14.824	8.960	0.102
	Forward	442 (±276)				
	Back	431 (±264)				
Distance (m)	**Full squad**	3403 (±1836)	3765	704.421	68.573	<0.001
	Forward	3069 (±1578)				
	Back	3776 (±2023)				
High-speed running distance (m)	**Full squad**	58 (±100)	64	12.200	7.000	0.080
	Forward	50 (±110)				
	Back	67 (±88)				

When comparing forwards and backs, backs run on average 704 m further per training session compared to the forwards ($p<0.001$; Table 2). However, there was no difference in training demand for either sRPE load or high-speed running distance ($p>0.05$) between forwards and backs.

Table 3. Training demands of Rugby Union expressed as mean (±SD), for session RPE load, total distance and high-speed running distance. Split by league of competition; combined, Premiership and Championship for the full squad.

Load variable	Level of competition	Training demand	Intercept	Parameter estimate	Std. error	p-value
sRPE load (AU)	**Combined**	438 (±271)	428	15.930	5.282	0.003
	Premiership	427 (±271)				
	Championship	448 (±271)				
Distance (m)	**Combined**	3403 (±1836)	3492	-190.698	59.380	0.001
	Premiership	3517 (±1913)				
	Championship	3338 (±1788)				
High-speed running distance (m)	**Combined**	58 (±100)	59	-3.000	3.000	0.438
	Premiership	57 (±76)				
	Championship	59 (±112)				

In the Premiership season the squad averaged 16 AU per session less sRPE load compared to the Championship season ($p = 0.003$; Table 3), whereas the squad ran on average 191 m more distance per training session in the Premiership season compared to the Championship season ($p = 0.001$; Table 3). However, there was no difference in training demands for high-speed running distance ($p>0.05$) between the Premiership and Championship seasons.

Interactions between position and level of competition

Position and level of competition interacted to affect sRPE load (position * level of competition, $p = 0.003$). Specifically, whilst sRPE load was similar for the forwards between the Premiership and Championship seasons (477 AU vs. 438 AU respectively), for backs it was higher in the Championship season than the Premiership season (449 AU vs. 413 AU respectively). However, there was no interaction between position and level of competition in terms of distance ($p = 0.502$). Position and level of compeition did however interact to

affect high-speed running distance ($p < 0.001$), whereby the forwards high-speed running distances were higher in the Championship season (average daily high-speed running distance: 57 m) compared to the Premiership (37 m), whereas the backs high-speed running distances were higher in the Premiership (76 m) compared to the Championship (62 m).

Match Demands

The was no difference in match duration between forwards and backs ($p = 0.281$) or between the Premiership and the Championship ($p = 0.197$).

Table 4. Match demands of Rugby Union and the multilevel model characteristics expressed as mean (±SD), for session RPE load, distance ($m \cdot min^{-1}$) and high-speed running distance ($m \cdot min^{-1}$). Split by position; full squad, forward and back.

Load variable	Position	Match demand	Intercept	Parameter estimate	Std. error	p-value
sRPE load (AU)	**Full squad**	670 (±312)	676	-2.541	41.924	0.952
	Forward	674 (±322)				
	Back	666 (±303)				
Distance ($m \cdot min^{-1}$)	**Full squad**	69.8 (±10.3)	66.3	7.566	1.422	<0.001
	Forward	66.3 (±8.3)				
	Back	74.3 (±10.8)				
High-speed running distance ($m \cdot min^{-1}$)	**Full squad**	1.29 (±1.14)	0.75	1.223	0.130	<0.001
	Forward	0.79 (±0.83)				
	Back	1.91 (±1.16)				

The backs averaged 7.6 $m \cdot min^{-1}$ greater distance and 1.22 $m \cdot min^{-1}$ greater high-speed running distance than the forwards (both $p<0.001$; Table 4; and supplementary Figure 3). No difference was seen between forwards and backs for sRPE load ($p = 0.952$).

Table 5. Match demands of Rugby Union and the multilevel model characteristics expressed as mean (±SD), for session RPE load, distance ($m \cdot min^{-1}$) and high-speed running distance ($m \cdot min^{-1}$). Split by league of competition; combined, Premiership and Championship for the full squad.

Load variable	Level of competition	Match demand	Intercept	Parameter estimate	Std. error	p-value
sRPE load (AU)	**Combined**	689 (±303)	743	-45.098	23.118	0.051
	Premiership	704 (±318)				
	Championship	673 (±287)				
Distance ($m \cdot min^{-1}$)	**Combined**	70.0 (±10.0)	68.7	0.435	0.712	0.541
	Premiership	69.6 (±9.6)				
	Championship	70.3 (±10.5)				
High-speed running distance ($m \cdot min^{-1}$)	**Combined**	1.30 (±1.14)	1.50	-0.165	0.081	0.043
	Premiership	1.40 (±1.22)				
	Championship	1.20 (±1.05)				

The Premiership demand was on average 0.17 $m \cdot min^{-1}$ greater for high-speed running distance than the Championship demand (p = 0.043; Table 5; and supplementary Figure 4). No difference was seen between the Premiership and Championship match demands for sRPE load or distance ($m \cdot min^{-1}$) (p = 0.051 and p = 0.541, respectively).

Interactions between position and level of competition

Position and level of competition did not interact to affect sRPE load (p = 0.970), distance covered ($m \cdot min^{-1}$; p = 0.450) or high-speed running distance ($m \cdot min^{-1}$; p = 0.208).

Match Key Performance Indicator Variables Demands

Results of the mixed effect models that were conducted to examine the difference of position (forward/back) or league of competition (Premiership/Championship) on the match key

295 performance indicator variables when controlling for match duration are presented in Tables
296 6 and 7 respectively (and supplementary Figures 5 and 6).
297
298 The number of tackles (78% greater, p<0.001), the number of tackle assists (207% greater,
299 p<0.001), the number of breakdown entries (324% greater, p<0.001) and the number of
300 contact events (117% greater, p<0.001) were all higher in forwards compared to backs (Table
301 6). However, the number of tackles missed (p = 0.634) and number of contact carries (p =
302 0.458) were not different between forwards and backs, when controlling for match duration.
303
304 The number of tackles (53% greater, p<0.001) and the number of tackles missed (35% greater,
305 p<0.001) were higher in the Premiership compared to the Championship, whereas the
306 number of contact carries (12% less, p = 0.010) and the number of breakdown entries (10%
307 less, p = 0.024) were lower in the Premiership compared to the Championship (Table 7). The
308 number of tackle assists (p = 0.055) and the number of contact events (p = 0.129) were not
309 different between the Premiership and Championship, when controlling for match duration.
310
311 *Interactions between position and level of competition*
312 Position and level of competition did not interact to affect any of the key performance
313 indicator variables (position * level of competition interactions: tackles, p = 0.240; tackle
314 assists, p = 0.363; tackles missed, p = 0.303; contact carries, p = 0.128; brakdown entries, p =
315 0.570; contact events, p = 0.815).

Table 6. Multilevel model characteristics for position (forward vs. back) when controlling for match duration.

Variable	Intercept	Position				Match duration				AIC	BIC	Distribution of the model
		Parameter estimate	Std. error	z-value	p-value	Parameter estimate	Std. error	z-value	p-value			
Tackles	0.658	-0.576	0.080	-7.176	<0.001	0.019	0.001	22.60	<0.001	4763	4787	Negative binomial
Tackle assists	-0.456	-1.120	0.131	-8.50	<0.001	0.019	0.002	12.20	<0.001	3095	3119	Negative binomial
Tackles missed	-1.531	0.056	0.117	0.477	0.634	0.017	0.002	10.10	<0.001	2189	2208	Poisson
Contact carries	0.134	-0.087	0.117	-0.742	0.458	0.017	0.001	20.10	<0.001	4275	4299	Negative binomial
Breakdown entries	1.285	-1.444	0.113	-12.80	<0.001	0.020	0.001	26.10	<0.001	5234	5258	Negative binomial
Contact events	2.059	-0.777	0.051	-15.40	<0.001	0.019	0.001	43.90	<0.001	6198	6222	Negative binomial

Table 7. Multilevel model characteristics for league of competition (Premiership vs. Championship) when controlling for match duration.

Variable	Intercept	League of competition				Match duration				AIC	BIC	Distribution of the model
		Parameter estimate	Std. error	z-value	p-value	Parameter estimate	Std. error	z-value	p-value			
Tackles	1.085	-0.427	0.049	-8.973	<0.001	0.018	0.001	22.320	<0.001	4726	4751	Negative Binomial
Tackle assists	-1.153	0.181	0.094	1.917	0.055	0.018	0.002	1.151	<0.001	3141	3166	Negative Binomial
Tackles missed	-1.077	-0.300	0.088	-3.422	0.001	0.017	0.002	10.280	<0.001	2177	2197	Poisson
Contact carries	-0.090	0.127	0.050	2.563	0.010	0.018	0.001	20.270	<0.001	4269	4293	Negative Binomial
Breakdown entries	0.560	0.103	0.046	2.259	0.024	0.019	0.001	25.270	<0.001	5313	5338	Negative Binomial
Contact events	1.817	-0.041	0.027	-1.158	0.129	0.018	0.001	41.930	<0.001	6297	6322	Negative Binomial

Calculating Key Performance Indicator Variable Rate

The mixed effect models provided above can be used to calculate the key performance indicator variable rate (e.g. number of tackles). For example, the calculation for the number of tackles made if the position is a forward, is as follows:

Number of tackles = exp(intercept + (match duration parameter estimate x match duration))

For example, a forward playing 60 minutes, the calculation would be:

exp(0.658 + (0.019 x 60))
=exp(1.798) = 6.04 = 6 tackles

When calculating the key performance indicator variable rate for a back, the calculation requires the position effect parameter estimate:

Number of breakdown entries = exp(intercept + position effect parameter estimate + (match duration parameter estimate x match duration))

Therefore, a back playing 70 minutes, the calculation for breakdown entries would be:

exp(1.285 + -1.444 + (0.020 x 70))
=exp(1.241) = 3.46 = 3 breakdown entries

This follows the same process when calculating the Premiership or Championship demand. The Championship equation must include the league of competition parameter estimate in the same manner of calculating the backs position demand.

DISCUSSION.

The aim of the present study was to examine and identify the training and match demands associated with elite level Rugby Union in England. This is the first study to comprehensively examine both training and match demands of an elite level Rugby Union club, whilst also considering both the effect of position (forward vs. back) and the league of competition the

club is competing at (Premiership vs. Championship) on these variables. Furthermore, the inclusion of both subjective and objective measures of load, the inclusion of both training and match data, and the inclusion of key performance indicator variables in matches make this work both novel and insightful for researchers and practitioners alike.

The main findings of the present study were that running demand was greater in backs whereas the key performance indicator demands, sport specific contact actions, were greater in forwards. Specifically, backs covered on average 704 m more total distance per training session than forwards. Additionally, the sRPE load demand placed on players in training was higher (on average 16 AU) in the Championship season compared to the Premiership season, whereas, the distance demand was higher in the Premiership season (on average 191 m) compared to the Championship season. The match demands between the two positional groups also elicited differences with backs covering more distance (on average 7.6 $m \cdot min^{-1}$) and more high-speed running distance (on average 1.22 $m \cdot min^{-1}$) compared to forwards. The Premiership high-speed running distance demand in matches was also greater than that of the Championship (on average by 0.17 $m \cdot min^{-1}$). The match key performance indicator demands also elicited differences between positions with forwards averaging more tackles, tackle assists, breakdown entries and contact events compared to backs. Furthermore, the comparisons between league of competition also drew differences, with the Premiership demand greater for tackles and greater number of missed tackles whereas the Premiership had fewer contact carries and fewer breakdown entries compared to the Championship.

This is the first study to directly compare training demands between forwards and backs and between two levels of professional competition in elite Rugby Union. The difference in

training demand observed between forwards and backs is unsurprising given the positional demand associated with matches. As demonstrated, backs cover more total distance than forwards in training, which is also seen in match demand, this finding therefore allows practitioners to align the training to match demands. The sRPE load training demands in the Premiership season were on average 16 AU lower than that of the Championship season whereas the amount of distance covered in training was 191 m more in the Premiership season. Therefore, suggesting the training sessions in the Premiership season were of higher volume in terms of the overall distances covered per training session, but at a lower intensity due to the lower sRPE load demand. The increased focus on technical/tactical skills required in the Premiership may be a contributing factor to the training demands associated with the Premiership season.

Match demands presented in Tables 4 and 5 (and supplementary Figures 3 and 4) demonstrate the differences in position and league of competition associated with elite Rugby Union. The distance and high-speed running distance demands were higher for backs compared to forwards, therefore in agreement with the findings of previous work (3). The findings of the present study extend previous work reporting differences in the high-speed running demand between forwards and backs, backs averaging 1.22 $m \cdot min^{-1}$ more than the forwards (3). The positional differences in the physical characteristics may provide an explanation to the difference in high-speed running distance outputs between forwards and backs. It has been shown that backs have a higher maximum speed and lower body fat percentage compared to forwards, therefore conducive for the greater running demands of a back (20). Another original feature of the current study was the comparison between matches in the top two levels of competition in England (Premiership and Championship). Of

400 the three 'load' variables (sRPE load, distance and high-speed running distance), only high-
401 speed running distance presented a difference, with players on average covering 0.17 m·min^{-1}
402 more high-speed running distance in the Premiership when compared to the Championship.
403 Although no study has yet sought to identify physical differences between the players of the
404 Premiership and Championship, by virtue of the higher playing division, the players operating
405 in the Premiership may be physically superior to that of the Championship and therefore
406 produce higher speed / power outputs than that of their Championship counterparts.
407
408 This study was the first to directly compare the potential differences in key performance
409 indicator variables in matches between positions (forward vs. back) and league of
410 competition (Premiership vs. Championship). When assessing disparities between the
411 forward and back positions the forwards made a greater number of tackles (78%), greater
412 number of tackle assists (207%) a greater number of breakdown entries (324%) and were
413 involved in a greater number of contact events (117%). The number of tackles missed, and
414 number of contact carries was not different between the positional groups. These findings
415 are in agreement with those of southern-hemisphere Super 15 matches, where it was
416 demonstrated that forwards were involved in more impacts, tackles and rucks compared to
417 backs, as a result of their proximity to the tackle / breakdown contest and their physiological
418 profile being more suited to the actions associated with tackling and the breakdown. The
419 finding that backs had higher running demands (distance and high-speed running distance) is
420 also in line with previous work (15,17). Therefore, summarising, the findings of the present
421 study demonstrate that the close quarters contact elements of Rugby Union are completed
422 predominantly by forwards, whereas the running load demands are principally completed by
423 backs.

When evaluating the variance in key performance indicator variable match demands between the two leagues of competition analysed in the present study, interesting differences are observed. The number of tackles were greater (53%) in the Premiership compared to the Championship along with a greater number of missed tackles (35%), whereas the number of contact carries (12% less) and number of breakdown entries (10% less) were lower in the Premiership. No differences were seen for the number of tackle assists and the number of contact events between the two levels of competition. The present study allows a unique comparison between the leagues of competition, in the same club, given that the club was relegated / promoted in the two seasons under investigation. The findings of the present study suggest that the defensive (e.g., tackling) demands were greater in the Premiership compared to the Championship, whilst the attacking (e.g., ball carrying) demands were greater in the Championship. Whilst these findings are unsurprising given the different win / loss rates in the two seasons, the present study provides novel evidence of the differences in match demand between the Premiership (where the club had a 14% win rate) and Championship (where the club had a 95% win rate). Further studies should look to consider how the demands of elite Rugby Union are affected by match outcome, by collecting data in a Club with an approximately equal win/loss rate within a given level of competition. Unfortunately, such analyses are not possible in the present study.

Whilst the present study provides important novel findings regarding the training and match demands of elite Rugby Union, it is not without limitation. Firstly, the findings are based on data from a single professional club, therefore its applicability to all clubs is unknown. In addition, key performance indicators were not assessed in training; future research could

consider this. Furthermore, breaking down the positional demands may provide greater resolution as to specific demands (e.g., prop, hooker, second row, back row, scrum-half, fly-half, centre and back 3), however this would require a significantly larger dataset than two seasons of competition from a single club. Future work could therefore investigate multiple clubs over multiple seasons; however, achieving this will be challenging, not least due to the variation in monitoring and key performance indicator assessment between clubs. Some work has been done assessing the effect of key performance indicator variables on match outcome (win, lose, draw), however the addition of load variables (such as sRPE load, distance and high-speed running distance) may provide additional insight into the factors affecting match performance (2). A further potential limitation of the current study was the use of different GPS monitoring systems, future work should endeavour to use the same GPS monitoring system for the duration of the data collection process to avoid potential conflicts between units. Furthermore, the impact of match outcome; teams defending for long periods would naturally make more tackles and teams attacking for sustained periods would make more contact carries; therefore, future research could assess the key performance indicator variables alongside match outcome. Finally, it is well accepted that Rugby Union has one of the highest reported incidences of match injury amongst all team sport; therefore, assessing the influence of the aforementioned key performance indicator variables on match injury rates may provide further understanding of the factors contributing to this (23).

Conclusions

Training demand was higher for backs, averaging a greater total distance per session compared to the forwards, however, no difference was observed between sRPE load and high-speed running distance between positions. The match demand was higher for the backs

from a running load perspective (greater distance and high-speed running distance demand vs. forwards) with the forwards experiencing greater key performance indicator demand (greater number of tackles, tackle assists, breakdown entries and contact events vs. backs). The distance covered in training was higher during the Premiership season whereas the sRPE load demand in training was higher during the Championship season. In matches, the high-speed running distance demand was higher in the Premiership compared to the Championship. The number of tackles and number of missed tackles was greater in the Premiership with the number of contact carries and breakdown entries higher in the Championship. In summary, the running demands are higher in backs (from an absolute perspective in training and a relative perspective in matches), with the close quarter contact actions of Rugby Union more closely related to the forwards, which falls in-line with the physiological characteristics of the two positional groups. The study quantifies the positional match demands of Rugby Union which ultimately allows the specificity of subsequent training protocols.

PRACTICAL APPLICATIONS.

The findings of this study provide practitioners with the objective and subjective load demands associated with both match play and training in elite Rugby Union. The discrepancies between the positional demands (forward vs. back) could be used to inform the physical preparation methods that are required to ensure that training adequately prepares players for the matches, ultimately contributing to potential enhanced performance. Furthermore, a comparison between the top two tiers of competition in England (Premiership and Championship), provides clubs with knowledge of the increased demands they could face should they be promoted from the Championship and the subsequent training alterations

required to adequately prepare for Premiership match play. Additionally, the equations provided can be used to calculate expected key performance indicator occurrence in matches, which ultimately provides sports performance and medical specialists with objective markers for rehabilitation protocols for the return of injured players.

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