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Movement Demands and Injury Characteristics in Under-20-Years University Rugby Union Players

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Context: Rugby union is a field-based collision sport with high injury rates. Associations between injury characteristics and global positioning system–derived movement demands in rugby union athletes are yet to be investigated.

Objective: To investigate associations between match injuries and movement demands, anthropometrics, and physical performance in under-20-years university-level rugby union players.

Design: Descriptive epidemiology study.

Setting: Competition season.

Patients or Other Participants: Rugby union players (n = 34, age = 19.3 ± 0.6 years) from a university club were recruited.

Main Outcome Measure(s): Acute medical attention non–time-loss (NTL), medical-attention time-loss (TL), and total medical-attention (MA) injuries sustained were recorded. Principal component (PC) analysis was performed on player-movement demand variables to identify independent-movement demand components. Pearson correlation and bivariate linear regression were used to test associations between match injuries and PCs. Anthropometric and physical performance measures were tested as predictors of match injuries using a forward stepwise multiple regression analysis.

Results: Backs had lower anthropometric and performance measures than forwards ($P < .05$), whereas forwards performed fewer weekly movement demands than backs ($P < .05$). Increases in body mass and skinfold thickness were associated with more injuries ($P < .05$). Principal component analysis revealed 3 PCs representing overall performance, high-intensity running (HIR) performance, and impacts. Increases in HIR were associated with decreases in NTL upper limb and trunk ($r = -0.32$, $P = .03$), NTL musculoskeletal ($r = -0.36$, $P = .05$), NTL total ($r = -0.46$, $P < .01$), TL musculoskeletal ($r = -0.30$, $P = .05$), MA musculoskeletal ($r = -0.41$, $P < .01$), and MA total ($r = -0.48$, $P < .01$) injuries. Increases in impacts were associated with increased TL ($r = 0.32$, $P = .03$) and MA ($r = 0.33$, $P = .03$) head or neck injuries.

Conclusions: Backs experienced greater weekly movement demands than forwards. Increases in HIR demands were associated with decreased acute injuries in university rugby players. Increases in impacts were associated with more acute head or neck injuries. Positional differences in movement demands, anthropometrics, and physical performance highlight the need for position-specific training.

Key Words: football, athletic training, adolescent, global positioning system, physical performance, injury incidence

Key Points

- Increases in weekly running demands and decreases in weekly contact demands were associated with decreases in injuries in university rugby union players.
- The weekly match and training demands in university rugby union were higher for backs than forwards.
- Musculoskeletal, upper limb and trunk, and lower limb injuries were the most frequent injuries in under-20-years university rugby union players.

Rugby union is a field-based collision sport with high injury rates.[1] A team's success in rugby union is compromised by an increased injury burden[2]; consequently, a major consideration for coaching and medical staff is injury prevention. Match injury incidence in university-level[3] and professional-level[4] rugby union players has been reported as 110.7 and 101.7 injuries per 1000 player-hours (PHs), respectively.

Injury risk in field-based contact sports has been associated with training and match loads.[4–6] *Training load*, classified as external or internal, quantifies the workload an athlete performs during a training session.[7] *External training load* refers to the external work performed or kinematic output measures (eg, distance covered), whereas *internal training load* refers to the internal or metabolic response to the external work (eg, heart rate or rating of perceived exertion [RPE]).[7] In under-20-years (U20) university rugby union players, greater internal loads, measured as session RPE (sRPE; Equation 1) have been associated with a lower injury incidence rates in backs.[3]

$$\text{sRPE} = \text{RPE} \times \text{session duration(min)}. \qquad (1)$$

In professional rugby union players, injury risk in the subsequent week increased linearly with weekly sRPE training load and absolute change in weekly training load.[4] High 4-weekly cumulative sRPE training loads (>8651 arbitrary units [AU]) present a higher injury risk, whereas moderate-to-high 4-weekly cumulative loads (5932–8651 AU) offer a likely beneficial reduction in injury risk.[4]

More recently, researchers[5,6] investigating associations between training and injury in field-based sports have used global positioning system (GPS) and accelerometer technology to quantify the movement demands of athletes. In elite Australian football, 4 GPS measures were associated with an increased injury risk: increases in preseason 3-week cumulative total distance (m) and sprint distance (at $>75\%$ maximum velocity; m), in-season 3-week cumulative force load (sum of foot strikes and collisions forces; AU), and 4-week relative velocity change (sum of accelerometer variables).[5] Conversely, a higher preseason 3-week cumulative velocity load (an arbitrary measure of running power and momentum) and in-season 2-week cumulative aerobic threshold distance were associated with lower injury risk.[5] In elite rugby league players, a very high acute workload (total weekly distance $>28\,798$ m) presented the greatest injury risk in the current week.[6]

Previous studies[3,4] of the injury-workload relationship in rugby union have quantified load using nondescriptive methods, such as sRPE and training volume. Rugby union players' match demands, training demands, and weekly workload demands derived from GPS have been described in isolation from player injuries. In International U20 players, backs experienced greater total distance (6.23 $\pm$ 0.80 versus 5.37 $\pm$ 0.83 km), relative distance (69.1 $\pm$ 7.6 versus 61.5 $\pm$ 8.0 $m \cdot min^{-1}$), and high-speed running (>18.1 $km \cdot h^{-1}$, 656.9 $\pm$ 182.7 versus 284.2 $\pm$ 134.9 m) during matches than forwards.[8] These differences are also typical in senior professional players, with backs performing higher total distance (6545 versus 5850 m), relative distance (71.1 versus 64.6 $m \cdot min^{-1}$), and maximum velocity (30.4 versus 26.3 $km \cdot h^{-1}$) during matches than forwards.[9] The introduction of GPS in field-based sports has provided coaches, athletic trainers, and sport physiotherapists with information on the specific movement demands of the sport while allowing for individual training-load monitoring of athletes and objective feedback for return-to-play processes.[10]

Unlike rugby league and Australian football (AF), the association between injury characteristics and both training and match demands derived from GPS in rugby union has yet to be investigated. Therefore, the aims of this study were to investigate associations between match injury and match and training demands, anthropometrics, and physical performance in U20 university-level rugby union players.

METHODS

This prospective descriptive epidemiologic study was conducted in 2017 during a U20 rugby union competition season over 22 weeks (18 round games, 3 finals, 1 bye). Thirty-four U20 first-grade university rugby union players (age = 19.3 $\pm$ 0.6 years; backs = 18, forwards = 16) were recruited. The team participated in the top U20 club competition in the state. All players had previous rugby playing experience at the U20 (n = 17) or schoolboy (n = 17) level. Fifteen players had junior representative rugby union experience (national U20 = 3, state U20 = 5, national schoolboy = 3, state schoolboy = 4). All players participated in the main preseason training block (12 weeks) before the competition season. The study was approved by The University of Sydney Human Research Ethics Committee (Protocol 2014/153) in accordance with the Declaration of Helsinki. Participants provided written informed consent before the study.

Anthropometric and physical performance measures were tested by club physical performance staff at the beginning, midpoint, and end of the competition season and reported as the average across the season.[3] Body mass (kg) was measured using digital scales (models unavailable; Wedderburn, Ingleburn, New South Wales, Australia). Skinfold thickness (sum of 8 sites: biceps, triceps, subscapular, abdominal, iliac crest, suprailiac, thigh, and calf; mm) was measured by an International Society for the Advancement of Kinanthropometry–accredited anthropometrist using skinfold calipers (Harpenden skinfold calipers; British Indicators Ltd, St Albans, UK). Muscular strength was measured using the 3-repetition maximum (RM) for the squat, deadlift, and bench-press exercises, from which 1-RM was calculated.[11] Peak lower body power was calculated from the vertical-jump test using the best height of 3 countermovement jumps, measured with a vertical-jump yardstick (Swift Performance, Wacol, Queensland, Australia; Equation 2).[12]

$$\begin{aligned}\text{Peak power (W)} &= 60.7\ (\text{jump height [cm]}) \\ &\quad + 45.3(\text{body mass [kg]}) - 2055. \quad (2)\end{aligned}$$

Players completed a standardized warm-up and submaximal repetitions before completing RM attempts.[11] They were instructed to recover completely between RM attempts. Match and training injuries were recorded by the club physiotherapist after every match and training session using a generic spreadsheet for recording injuries (Excel 2010; Microsoft Corp, Redmond, WA). Injuries were categorized as *medical attention non–time loss* (NTL): "an injury that results in a player receiving medical attention"; *medical-attention time loss* (TL): "any injury that results in a player being unable to take a full part in future rugby training or match play"; and *total medical attention* (MA): the sum of NTL and TL injuries, for separate analysis.[13] Injuries were further categorized as *new* (the first occurrence of an injury) or *recurrent* (an injury of the same type and location as a previous injury that occurred after return to full training and match participation).[13] Only new injuries that occurred during matches were included in the data analysis. Injury type was classified according to the following categories: musculoskeletal (muscle and tendon, joint [nonbone] and ligament, skin, and bone); brain, spinal cord, and peripheral nervous system; and other.[13] Injury anatomical location was classified as head or neck, upper limb and trunk, or lower limb. Injury incidence (Equation 3) was calculated[14] for the team as

$$\text{Injury Incidence} = \frac{\text{Number of Match Injuries}}{\text{Match Volume (h)}} \times 1000\ \text{PH}. \quad (3)$$

Players participated in on-field rugby training 2 times per week. Training sessions typically consisted of rugby skills (contact and noncontact) and conditioning drills and games. Player movement data were collected during all training sessions and matches using GPS units (model SPI HPU; GPSports Systems, Canberra, Australia) recording at 5 Hz (interpolated to 15 Hz) with an built-in triaxial accelerometer. The GPS technology has been reported as accurate for measuring total distance in field-based team sports.[15] Data were analyzed using the manufacturer's software (Team AMS version R1 2016.7; GPSports Systems). Data recorded during half-time breaks in matches were excluded

Table 1. Global Positioning System Variables and Classification of Variable Zones

Variable	Classification and Unit of Measurement
Distance	Total distance: m
	Relative distance: $m \cdot min^{-1}$
	High-intensity running: 18.0–21.6 $km \cdot h^{-1}$
	Sprinting: >21.6 $km \cdot h^{-1}$
Acceleration	Zone 1: 1.5–2.5 $m \cdot s^{-2}$
	Zone 2: 2.5–3.5 $m \cdot s^{-2}$
	Zone 3: High-intensity accelerations >3.5 $m \cdot s^{-2}$
	Sprint: acceleration >1.5 $m \cdot s^{-2}$ sustained for >1.0 s
	Body load: arbitrary units (AU)
Deceleration	Zone 1: 2.0–3.0 $m \cdot s^{-2}$
	Zone 2: 3.0–4.0 $m \cdot s^{-2}$
	Zone 3: High-intensity decelerations >4.0 $m \cdot s^{-2}$
Impacts	Zone 1: 2.0–4.0*g*
	Zone 2: 4.0–6.0*g*
	Zone 3: 6.0–8.0*g*
	Zone 4: 8.0–10.0*g*
	Zone 5: High-intensity impacts >10.0*g*
Collision	Collision: >3.5*g*
High-intensity efforts	Sprints + Zone 2 accelerations + high-intensity accelerations + Zone 2 decelerations + high-intensity decelerations + collisions: n

from analysis. Distance, accelerations and decelerations, impacts, and body load variables were included (Table 1).[16,17] Impacts were derived from the vector of the 3 movement axes (x, y, z) to describe the impact forces players experienced and were reported in *g* force.[18,19] Impacts ranged from *light* (hard acceleration, deceleration, or change of direction) to *severe* (high-intensity collision with another player).[16,18] Collisions were a count of the total collision events above a set threshold that occurred during rugby matches and training. Collisions were detected from accelerometer data using a collision-detection algorithm designed by the GPS manufacturer.[20,21] *Body load*, an arbitrary measure of the total external load to which a player is exposed, was determined from the accumulated acceleration, deceleration, change of direction, and impact activity along all 3 movement axes and was calculated by the manufacturer's software.[19]

Data were reported as the mean ± standard deviation or 95% confidence intervals (95% CIs), and normality was confirmed using probability plots. Independent *t* tests were used to test differences in anthropometrics, physical performance characteristics, and GPS-derived variables between forward and back positions.

The Pearson correlation was used to test the associations between the GPS variables. Due to the large number of GPS variables and their highly interrelated nature, principal component analysis (PCA) using correlation was performed to identify independent movement components and reduce their complexity by extracting the principal components (PCs) that explained >90% of the cumulative variance in the dataset.

The Pearson correlation was also used to test associations between the presence of match injuries and each of the PCs retained from the PCA, with injury as the dependent variable and the PC as the independent variable. Anthropometric and physical performance measures were tested as predictors of injury using a forward stepwise multiple-regression analysis for team injuries and injuries between backs and forwards. Significance was set at $P < .05$. Data were analyzed using SPSS (version 22.0; IBM Corp, Armonk, NY).

RESULTS

Anthropometric and physical performance characteristics of forwards and backs are shown in Table 2. Backs had lower values for body mass, skinfold thickness, squat 1-RM, deadlift 1-RM, and peak lower body power compared with forwards ($P < .05$). For weekly average movement demands, backs had higher values for weekly average total distance ($P < .001$), relative distance ($P < .001$), high-intensity running (HIR) distance ($P < .001$), sprinting distance ($P < .001$), high-intensity acceleration (HIA; $P < .001$), high-intensity deceleration (HID; $P < .001$), collisions ($P = .023$), sprints ($P < .001$), and high-intensity effort ($P < .001$) than forwards.

A total of 45 MA match injuries (backs = 12, forwards = 33) were reported throughout the season, made up of 23 NTL injuries (backs = 3, forwards = 20) and 22 TL injuries (backs = 9, forwards = 13; Table 3). An additional 3 MA training injuries (2 NTL, 1 TL) were reported. Team match injury incidence was 107.1 MA injuries/1000 PHs (backs = 61.2/1000 PHs, forwards = 147.3/1000 PHs), 54.8 NTL injuries/1000 PHs (backs = 15.3/1000 PHs, forwards = 89.3/1000 PHs), and 52.4 TL injuries/1000 PHs (backs = 45.9/1000 PHs, forwards = 58.0/1000 PHs; Table 2). Training injury incidences were 3.1 MA injuries/1000 PHs, 2.1 NTL injuries/1000 PHs, and 1.0 TL injuries/1000 PHs.

Table 2. Player Anthropometric and Physical Performance Measures

Participant Characteristic	Sample, Mean ± SD			*P* Value
	Total	Backs	Forwards	
Age, y	19.3 ± 0.6	19.5 ± 0.4	19.0 ± 0.7	
Anthropometric measures				
Body mass, kg	91.2 ± 9.4	85.6 ± 5.1	97.5 ± 9.3	<.01[a]
Sum of 8 skinfolds, mm	77.2 ± 28	63.5 ± 11.6	92.7 ± 33.0	<.01[a]
Physical performance measures				
Squat 1-RM, kg	151.4 ± 17.6	143.9 ± 14.3	159.5 ± 17.6	<.01[a]
Deadlift 1-RM, kg	160.6 ± 21.9	153.9 ± 20.1	167.9 ± 22.3	.07
Bench press 1-RM, kg	103.2 ± 13.6	100.3 ± 12.3	106.8 ± 14.7	.10
Lower body power, W	5978.3 ± 466.7	5793.4 ± 387.6	6163.2 ± 477.2	.01[a]

Abbreviation: RM = repetition maximum.

[a] Different from forwards ($P < .05$).

Table 3. Player Match Injury Incidence and Severity by Injury Definition and Position[a]

Participant Characteristic	Sample		
	Total	Backs	Forwards
Non–time-loss injuries			
Injury type			
Total injuries	54.8	15.3	89.3
Musculoskeletal	33.3	10.2	53.6
CNS or PNS	16.7	5.1	26.8
Other	4.8	0.0	8.9
Time-loss injuries[b]			
Injury type			
Total injuries	52.4 (9.4)	45.9 (7.3)	58.0 (10.8)
Musculoskeletal	38.1 (9.2)	30.6 (6.2)	44.6 (11.0)
CNS or PNS	9.5 (11.8)	10.2 (11.0)	8.9 (12.5)
Other	4.8 (6.0)	5.1 (7.0)	4.5 (5.0)
Injury location			
Head or neck	14.3 (9.5)	10.2 (11.0)	17.9 (8.8)
Upper limb and trunk	21.4 (10.9)	15.3 (7.3)	26.8 (12.7)
Lower limb	16.7 (7.3)	20.4 (5.5)	13.4 (9.7)
Medical-attention injuries			
Injury type			
Total injuries	107.1	61.2	147.3
Musculoskeletal	71.4	40.8	98.2
CNS or PNS	26.2	15.3	35.7
Other	9.5	5.1	13.4
Injury location			
Head or neck	31.0	10.2	49.1
Upper limb and trunk	42.9	20.4	62.5
Lower limb	33.3	30.6	35.7
Injury location			
Head or neck	16.7	0.0	31.3
Upper limb and trunk	21.4	5.1	35.7
Lower limb	16.7	10.2	22.3

Abbreviation: CNS or PNS, central or peripheral nervous system.

[a] Injury incidence is shown as injuries per 1000 player-hours. Injury severity for time-loss injuries is shown as the average number of days lost due to injury.

[b] Parentheses indicate the average number of days lost due to injury.

Injury severity for TL injuries is presented in Table 2. On average, TL injuries were responsible for 9.4 training or match days (backs = 7.3, forwards = 10.8) missed due to injury.

Multiple regression models revealed increased player body mass was associated with increased MA ($\beta = 0.526$, $R^2 = 0.277$, $P = .014$, 95% CI = 0.019, 0.149), TL ($\beta = 0.582$, $R^2 = 0.339$, $P = .006$, 95% CI = 0.029, 0.148), MA musculoskeletal ($\beta = 0.467$, $R^2 = 0.218$, $P = .033$, 95% CI = 0.005, 0.099), NTL musculoskeletal ($\beta = 0.593$, $R^2 = 0.351$, $P = .005$, 95% CI = 0.02, 0.095), MA central nervous system (CNS) or peripheral nervous system (PNS; $\beta = 0.574$, $R^2 = 0.33$, $P = .006$, 95% CI = 0.01, 0.056), NTL CNS or PNS ($\beta = 0.543$, $R^2 = 0.295$, $P = .011$, 95% CI = 0.007, 0.045), NTL upper limb and trunk ($\beta = 0.47$, $R^2 = 0.221$, $P = .004$, 95% CI = 0.004, 0.076), and NTL lower limb ($\beta = 0.518$, $R^2 = 0.268$, $P = .016$, 95% CI = 0.006, 0.048) injuries. Increased body mass ($\beta = 0.931$, $R^2 = 0.438$, $P = .002$, 95% CI = 0.025, 0.088) and decreased skinfold thickness ($\beta = -0.704$, $R^2 = 0.438$, $P = .011$, 95% CI = –0.03, –0.004) were associated with increased MA lower limb injuries.

The PCA revealed 3 PCs (PC1, PC2, PC3; Figure). Principal component 1 was considered to represent overall performance given that it loaded highly on most GPS variables except relative distance and sprinting. Principal component 2 was considered to represent HIR performance but not impacts given that it loaded on relative distance, sprinting, total high-speed distance (sum of HIR and sprinting), HIA, and relative high-intensity effort but negatively loaded on impacts in Zones 2 to 4, high-intensity impact (HII,) and body load. Principal component 3 was considered to represent impacts but not collisions. Increases in PC2 were associated with decreases in NTL upper limb and trunk ($r = -0.32$, $P = .03$), NTL musculoskeletal ($r = -0.36$, $P = .05$), NTL total ($r = -0.46$, $P < .01$), TL musculoskeletal ($r = -0.30$, $P = .05$), MA musculoskeletal ($r = -0.41$, $P < .01$), and MA total ($r = -0.48$, $P < .01$) injuries. Increases in PC3 were associated with increased TL head or neck injuries ($r = 0.32$, $P = .03$) and MA head or neck ($r = 0.33$, $P = .03$) injuries (Table 4).

DISCUSSION

To our knowledge, this is the first study to investigate associations between match injuries and movement demands, anthropometrics, and physical performance in U20 university rugby union players. Increased body mass was associated with more injuries in all categories, whereas increased body mass in combination with decreased skinfold thickness was associated with more lower limb MA injuries. These findings support the work of Quarrie et al.[22] Their players with a higher body mass index (>26.5 $kg \cdot m^{-2}$) sustained a higher injury rate than players with a lower body mass index (<23 $kg \cdot m^{-2}$).[22] Greater body mass and fat mass may indicate players with lower fitness levels.[23] However, this result may also reflect the differences in anthropometrics and injury incidence rates between backs and forwards. Forwards were heavier, had greater skinfold thickness, and experienced more injuries across all categories compared with backs. The association between anthropometric measures and injuries may suggest that players with greater fat mass and lower fitness levels are unable to tolerate the demands of matches and more likely to be injured than players with less fat mass and greater fitness levels.[23,24] This finding highlights the importance of developing physical characteristics to improve rugby union performance and protect players against injury.

In an average week, backs performed greater activity than forwards for most GPS variables. This is consistent with previously reported[8] movement demands for International-level U20 matches. The differences in weekly demands between positions reflect the positional roles of backs and forwards. Traditionally, forwards participate in more non-running activities such as scrummaging, line-outs, rucks, mauls, and tackling, whereas backs are more likely to participate in running and kicking activities.[25] We find it interesting that the backs were involved in more collisions than forwards, although HII, an indicator of high-intensity contact between players traveling at high velocity, did not differ.[18] Given that the backs had greater HIR, sprinting, HIA, and HID compared with forwards, the increased acceleration activity for backs may explain discrepancies in

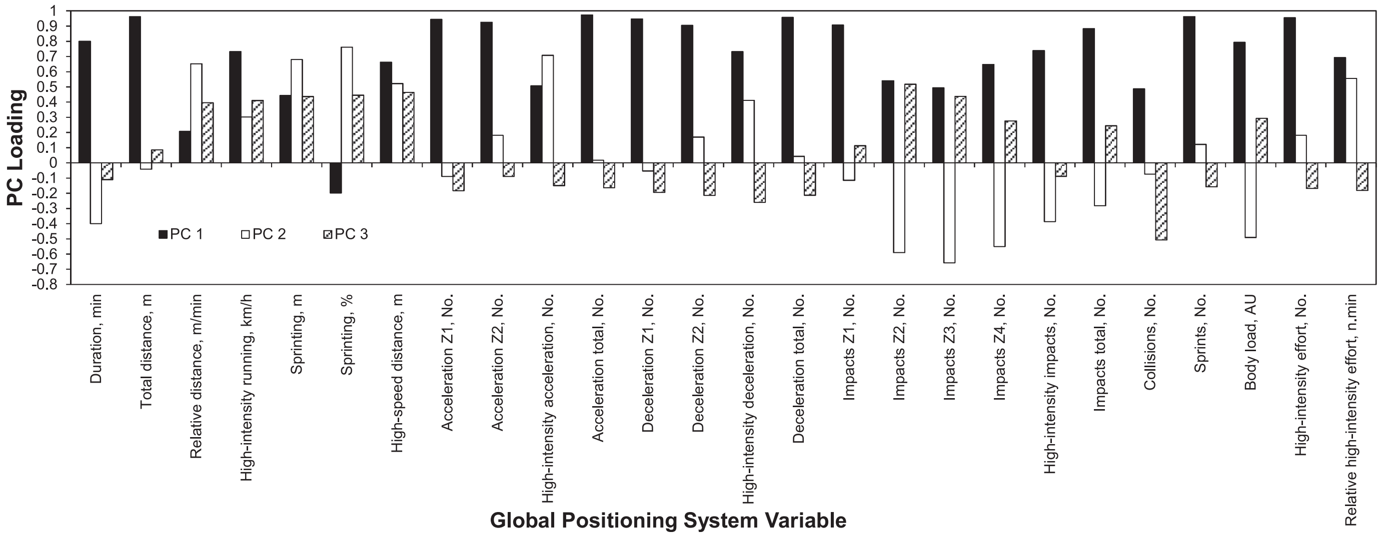

Figure. Principal component analysis results for team GPS variables. Abbreviations: AU, arbitrary units; HIA, high-intensity acceleration (>3.5 m·s^{-2}); HID, high-intensity deceleration (>4.0 m·s^{-2}); HIE, high-intensity effort; HII, high-intensity impact (>10.0 g); HIR, high-intensity running (18.0–21.6 km·h^{-1}); PC, principal component; PC1 = overall performance; PC2 = high-intensity running activity; PC3 = impact activity; RD, relative distance; Z, zone.

Table 4. Pearson Correlation Results for Principal Components and Match Injuries

	Principal Component					
	1		2		3	
Variable	Pearson *R*	*P* Value	Pearson *R*	*P* Value	Pearson *R*	*P* Value
Non–time-loss injuries						
Injury type						
Total injuries	−0.01	.95	−0.46	<.01[a]	−0.03	.85
Musculoskeletal	−0.02	.89	−0.36	.05[a]	−0.18	.24
CNS or PNS	−0.03	.87	−0.25	.10	−0.10	.53
Other	0.11	.47	−0.22	.16	0.18	.25
Injury location						
Head or neck	0.09	.56	−0.25	.10	0.19	.22
Upper limb and trunk	−0.13	.40	−0.32	.03[a]	−0.12	.42
Lower limb	0.04	.82	−0.20	.19	−0.20	.19
Injury type						
Total injuries	0.09	.55	−0.48	<.01[a]	0.07	.63
Musculoskeletal	0.09	.57	−0.41	<.01[a]	−0.03	.85
CNS or PNS	−0.03	.83	−0.23	.13	0.24	.12
Other	0.12	.43	−0.20	.20	0.17	.27
Injury location						
Head or neck	0.04	.80	−0.27	.07	0.33	.03[a]
Upper limb and trunk	0.01	.96	−0.41	.01	0.00	.99
Lower limb	0.11	.47	−0.16	.31	−0.19	.21
Time-loss injuries						
Injury type						
Total injuries	0.17	.26	−0.30	.05	0.19	.22
Musculoskeletal	0.18	.24	−0.30	.05[a]	0.07	.67
CNS or PNS	−0.02	.91	−0.02	.91	0.25	.10
Other	0.05	.76	−0.03	.84	0.04	.82
Injury location						
Head or neck	−0.09	.56	−0.08	.60	0.32	.03[a]
Upper limb and trunk	0.16	.31	−0.28	.07	0.14	.37
Lower limb	0.16	.30	−0.07	.67	−0.13	.40

Abbreviations: CNS or PNS, central or peripheral nervous system; PC1 = overall performance; PC2 = high-intensity running activity; PC3 = impact activity; RM = repetition maximum, TL = time loss.

[a] Significant ($P < .05$).

collision and HII by position. Due to their different positions, backs are more likely to be traveling at a higher velocity than forwards when involved in a collision, increasing the magnitude of a collision to a level that meets the collision-inclusion threshold of $>3.5g$. Furthermore, greater acceleration may increase the likelihood of recording false-positive collisions (ie, when a player is not involved in a collision but the GPS records a collision) for backs, indicating GPS collision-detection error.[21] Kelly et al[21] reported that GPS technology allowed for accurate collision detection, with recall (collision detection with low false-negatives) and precision (collision detection with low false-positives) ratings of 0.933 and 0.958, respectively, yet caution is needed when interpreting collision data.[18–20,24–26] Although we did not use video analysis in this study, it remains the most accurate method of collision detection for coaches attempting to understand the weekly collision demands of rugby union.

Match NTL (54.8 injuries/1000 PHs), TL (52.4 injuries/1000 PHs), and MA (107.1 injuries/1000 PHs) injury incidences in the current study were lower for a U20 university rugby club (110.7 TL injuries/1000 PHs)[3] and higher than a Japanese university club (48.4 TL injuries/1000 PHs).[27] In comparison, the injury incidence for International-level U20 players during international tournaments was 49.7 injuries/1000 PH.[28] The training injury incidence in this study was also lower (NTL = 2.1 injuries/1000 PHs, TL = 1.0 injuries/1000 PHs, MA = 3.1 injuries/1000 PHs) than for U20 university players (5.3 injuries/1000 PHs).[3] It is interesting that our NTL, TL, and MA injury incidences were higher than the combined NTL and TL injury incidence in American collegiate rugby players (16.9 injuries/1000 PHs) from 122 collegiate clubs.[29] The discrepancies in the combined incidence rates for the collegiate players may be due to inconsistent injury-recording methods across the included clubs, resulting in underreporting of total injuries. In contrast, we used injury definitions that included all injuries recorded by designated medical personnel for 1 university club, reducing the likelihood of missed injuries.

Injury characteristics in our study varied from those of previous studies. We noted that the upper limb and trunk (42.4%) and lower limb (50.0%) were the most commonly injured anatomical locations across all injury definitions for forwards and backs, respectively. In contrast, the lower limb (51.8%),[3] head or face (22%), and ankle (22%)[27] were the most frequently injured anatomical locations for total team injuries. The higher proportions of upper limb and trunk injuries for forwards we found likely reflect the contact nature of the game and the position of forwards, with the majority of rugby union injuries being attributed to tackling or being tackled.[27,29] Similarly, the higher proportion of lower limb injuries for backs likely reflects their running and kicking activities.[25] Musculoskeletal injuries were the most common injury type for both forwards and backs (66.7% for each), consistent with research showing that joint or ligament injuries were responsible for 31.1%[27] and 29.5%[3] of overall injuries. We found it interesting that CNS or PNS injuries were responsible for the most days missed due to TL injury for both positions. Greater time lost due to CNS or PNS injuries is likely the result of Rugby Australia's concussion-management policy.[30] The earliest recommended return to full training after a concussion is 11 days for those 19 years of age and older and 18 days for those 18 years of age and younger.[30]

Associations were also observed between movement demands and injuries in all categories. Increases in PC2, representing HIR, were associated with decreased NTL (total, musculoskeletal, and upper limb and trunk), TL (musculoskeletal), and MA (total and musculoskeletal) injuries. In contrast, increases in PC3, representing impacts, were associated with increases in head or neck MA and TL injuries. Our findings vary from those of previous authors who investigated running loads and injury risk in team sports. They used individual movement variables to describe training load,[5,31] whereas we grouped movement variables into 3 components in an attempt to reduce the likelihood of false-positive results by reducing the dimensionality of the movement variables using PCA. In an elite AF cohort, increases in 3-week velocity load (6737–8046 AU) and 3-week sprint distance (864–1453 m) were associated with a reduced injury risk when compared with a lower-load reference group.[5] In elite rugby league players, the risk of MA injury was 2.7 times higher when very HIR (>25.2 km·h^{-1}) exceeded 9 m per session, whereas the relative risk of injury was lower when low-intensity running (3.6–10.8 km·h^{-1}) distance per session increased.[31] Given that the GPS variables contributing to PC2 are positively weighted by relative distance, sprinting distance, high-speed distance, and HIA and are negatively weighted by Zone 2 to 4 impacts, the combination of increased HIR demands and decreased contact demands explains the decreases in upper limb and trunk, musculoskeletal, and total injuries. In turn, when impact demands (PC3) are positively weighted, it is comprehensible that increases in TL head or neck and MA injuries are associated with increases in impacts. Previous researchers[16,18] categorized impacts ranging from light ($<6.0g$) to severe ($>10.0g$) and included activities such as hard acceleration, deceleration, change of direction; minor collisions with other players or contact with the ground; making tackles or being tackled; and high-intensity collision with an opposition player while traveling at high velocity. Furthermore, positional differences in movement demands and injury incidence characteristics may influence the observed associations. Forwards had higher injury incidence rates across most injury definitions, types, and anatomical locations than did backs, whereas backs handled greater movement demands than forwards. Considering these movement demands and injury incidence differences, increases in weekly movement demands by backs may influence PC weighting and the resulting associations with injuries.

Although the only significant associations with TL injuries were for head or neck and musculoskeletal injuries, the association between NTL and MA injuries and performance variables holds practical significance. Players who sustain an NTL injury during matches can lose active playing time, resulting in a mismatch of the number of players on competing teams. The opposition team has an advantage for a period of the match, until a referee stops the official time to allow for MA to an injured player. Furthermore, any player who sustains a bleeding injury is required to leave the field until the bleeding is controlled and may be replaced temporarily by a player who is likely not a first-choice starter, potentially benefiting the opposing team.[32] After an NTL injury, a player who rejoins match play may be at increased risk of exacerbating the original injury, eventually leading to a more severe TL injury. Future investigation of NTL injuries as a risk for subsequent TL injuries in rugby union may yield interesting results.

A limitation of the current study is the use of only 1 external measure to quantify weekly load. Difficulty obtaining complete sRPE data for the current cohort led to the omission of an internal-load variable. Inclusion of internal-load measures, as studied in university rugby union players,[3] would allow for a more comprehensive understanding of the training demands of university players. Given the lifestyle of the current sample, examination of other factors contributing to injury, such as sleep behavior and academic stress, may be warranted. Furthermore, this study was limited to a single squad over a single competition season and may not be applicable to other levels of competition. Due to the injury-recording methods of the medical staff, injury-mechanism details were not included. To better understand the causes of injuries, future authors should include injury-mechanism details. This is possible through a more extensive injury-reporting protocol and video analysis of matches and training.

CONCLUSIONS

Our findings demonstrated associations between movement demands, anthropometric and physical performance characteristics, and acute match injuries in U20 university rugby union players. Backs were exposed to greater weekly match and training demands than forwards. Increases in weekly HIR demands, in combination with decreases in weekly impact demands, were associated with decreases in injuries across all categories in university rugby union players. Increases in body mass and skinfold thickness were associated with increases in upper limb and trunk, lower limb, and musculoskeletal injuries. Musculoskeletal injuries and injuries to the upper limb and trunk (forwards) and lower limb (backs) were the most frequent injuries by type and anatomical location. Coaches, sports scientists, and sports medicine clinicians should consider the positional differences in terms of movement demands and the contact nature of rugby union when designing tactical, technical, and physical programs to prepare players for the demands of the game.

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