Seasonal variation and positional differences in anthropometry, strength, and power characteristics in English premiership women's rugby union players

ABSTRACT

Women's rugby is a collision sport that relies heavily on body composition and physical characteristics of strength and power to achieve competitive success. Furthermore, the seasonal nature presents a variety of physical challenges that can cause fluctuations in a player's physical development. Therefore, the purpose of this study is to determine the differences in anthropometry, strength and power characteristics between forwards and backs in women's rugby union athletes in England and to identify changes throughout a season. Forty-seven players were recruited from the English premiership women's rugby during the 2020–2021 season. Players were split into forwards and backs and underwent body composition testing via dual-X-ray absorptiometry, and strength and power tests (countermovement jump, drop jump, and isometric mid-thigh pull) on 3 separate occasions (pre-, mid-, post-season). Overall, forwards had significantly ($p < 0.01$) higher body mass, fat mass, lean mass, bone mineral content and take off momentum, and backs had significantly higher ($p < 0.01$, d > 0.5) jump height, reactive strength and shorter drop jump contact time. When observing seasonal changes, there were statistically significant differences ($p < 0.01$) or moderate to large practical differences ($d > 0.5$) in lean mass, reactive strength index modified, time to take off and drop jump flight time among forwards when comparing three testing time frames. For backs, statistically significant differences ($p < 0.01$) or moderate to large practical differences ($d > 0.5$) were reported in lean mass and drop jump flight time throughout the season. In conclusion, the strength and power testing and characteristics shown in this study could support coaches and junior women's rugby athletes to have a basic understanding of English premiership physical standards.

Keywords: physical, profile, longitudinal, female

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1. INTRODUCTION

Rugby union, different from other rugby codes (e.g., rugby league and sevens), is a collision sport that is played over two 40 minutes halves with 15 players a side (24). With the requirement of intermittent bouts of high-intensity (e.g., tackle, scrum and sprinting) and low intensity actions (e.g., walking), players rely heavily on the body composition and physical characteristics of strength and power to achieve competitive success (23,24,43). Players are categorized into groups of forwards and backs by specific positional demands (i.e., forwards are involved in lineouts and scrum set up) (24). Recent women's rugby union studies have focused across different playing levels including the Spanish women's team, English premiership, US collegiate team, and New Zealand rugby union players. These studies have shown that forwards have higher body mass (14,44), body fat percentage (14,21,44) and lean mass (21,34) compared to backs. However, backs have been shown to have higher relative lower body strength and jump performance in English international players (43). The results were similar to men's rugby union and women's rugby league studies, highlighting forwards are heavier and slower than backs (25,33). However, despite recent women's rugby union studies investigating players over different playing levels and countries (23,43,44), a distinct lack of comparative data currently exists on the physical characteristics of competitive women's English premiership players. Therefore, it is crucial to minimize the gap in the research for coaches to understand the physical profile of the competitive women's premiership athletes to support talent identification and training.

The English premiership women's rugby season is 36-40 weeks, with competitions on a weekly basis. The seasonal nature presents a variety of physical challenges that can cause fluctuations in a player's physical development during the season (22); these include a decrease in resistance training load to allow for increases in the volume of technical and tactical skill training. In addition, muscle damage and inflammation following a match, potentially causing decrements in muscle performance, may be problematic for developing or maintaining muscular strength and power (17,36). Hence, the players' ability to acquire and maintain appropriate body composition and physical characteristics, both pre- and in-season, is of paramount importance. Regarding anthropometry, research in the South African rugby union women's international team reported significant increases in body mass from pre- to mid-season in backs, whilst no statistically significant changes were noted in forwards (22). Hene & Bassett (22) also reported a significant drop in the sum of skinfolds for forwards when comparing pre- to post-season values (22). A study in English women's premiership rugby union players showed that body mass and bone mineral content significantly increased throughout a competitive season (9), however, no meaningful changes in fat mass, lean mass, or bone mineral density were evident (9). In contrast, a recent study in university women's rugby players reported no statistically significant differences in body mass when comparing pre- and post-season among both forwards and backs (32). Although somewhat speculative, the differing results may be due to the inherent differences in competitive level, schedule, and training volume. Regardless, it is necessary to have a better understanding of anthropometric changes throughout the season to make appropriate training and nutritional adjustments for athletes.

When considering strength and power characteristics, previous women's studies have monitored upper body strength and jump performance throughout competitive seasons (22,32). For upper body strength, no statistically significant differences in 1-repetition maximum bench press in the South African team (22) or grip strength in university players (32) were found across a season. When considering jump performance, studies have reported no statistically significant changes in vertical jump height across a season in either forwards or backs in both international and university level players (22,32). However, previous research has shown that jump height alone is a relatively crude measure of performance, which may be less sensitive to change than some strategy-based metrics (e.g., time to take-off or reactive strength index modified (3,20). In addition, besides university (32) and international squads (22) no research has focused on the English women's premiership season which might report different results due to the elevated level and the length of competition in this league.

To the authors' knowledge, there have been only three women's rugby union studies looking at changes in anthropometry or strength and power characteristics across a competitive season (9,22,32). Hene & Bassett (22) reported anthropometric profiles using sum of skinfolds, and vertical jump height. Curtis et al. (9) using dual-energy X-ray absorptiometry (DEXA), compared a whole squad between pre- and post-season without any information regarding positional differences or data during mid-season. In addition, Neto et al. only reported body mass and height as anthropometric variables in the pre- and post-season in university level players (32). When considering English premiership players using a cross-sectional design, Yao et al. (44) did not report positional differences in anthropometric and physical characteristics for international players in the squad. Therefore, to date, there is a distinct gap in the literature relating to detailed profiling for anthropometry and strength and power characteristics of English women's rugby union players that encompasses positional differences (i.e., forwards vs. backs) throughout a competitive season; this is therefore the primary aim of this study. Based on the available studies in women's rugby union, it was hypothesized that forwards would have higher lean mass, fat mass and absolute strength performance, and backs would have higher absolute power performances. Furthermore, it was theorized that players would not exhibit statistically significant changes in anthropometry, strength and power characteristics throughout the season.

2. METHODS

2.1 Experimental Approach to the Problem

In order to monitor anthropometric profiles and physical characteristics of women's rugby union players across a season, a retrospective longitudinal design was used. Playing position and pre-, mid-, post-season testing time points were the independent variables, and anthropometric, strength and power characteristics were the dependent variables. The following anthropometric and physical tests were administered: DEXA scan, isometric mid-thigh pull (IMTP), countermovement jump (CMJ), drop jump (DJ).

2.2 Subjects

Forty-two (n = 42) women's rugby union players from a single team volunteered for this study. The 42 players were separated into forwards (n = 24, age: 28.04 ± 5.98yrs, height: 171.75 ± 7.98cm, weight: 87.66 ± 12.60kg) and backs (n = 18, age: 25.77 ± 3.87yrs, height: 168.44 ± 4.67cm, weight: 70.92 ± 4.40kg). Players in this study competed in the English women premiership, which is the highest level in English women's rugby union in the UK. All players had at least three years of experience in rugby training and strength training in a structured rugby club and took part in 2 rugby team practices and 2 individual gym sessions per week. Tests included in this study were part of the 2020-2021 annual season monitoring test battery, agreed by both the medical, and strength and conditioning staff. The study was approved by the London Sport Institute research ethics subcommittee at Middlesex University. Players were informed of the benefits and risks of the investigation before signing written informed consent to participate in the study.

2.3 Procedures

Anthropometric and physical performance measurements were conducted on 3 separate occasions during a 9-month season, with the pre-season testing in September 2020 (1 week before the season starts), mid-season testing in February 2021, and post-season testing in June 2021 (the week after the premiership final which the team participated in). During the three separate testing time frames, players with a medical condition or injury were excluded from the physical fitness assessment (number of players are shown in table 3-5). All subjects refrained from intensive exercise in the 24-hour period prior to testing. At the beginning of laboratory-based tests, anthropometric measurements were taken for each participant. Following this, subjects underwent a standardized warm-up, consisting of 10 minutes of dynamic stretching followed by 2 practice trials for each of the strength and jump assessments. Subjects were familiar with all tests, which were also conducted during their regular annual performance monitoring and gym training programs.

2.3.1 Anthropometry

The stature of each player was measured to the nearest 0.1 cm using a SECA 213 stadiometer

(SECA Corp, Hamburg, Germany), and body mass (BM) was measured using a SECA 703 calibrated scale (SECA Corp) with accuracy to the nearest 0.1 kg (44). Body composition was measured using DEXA scan (Lunar Prodigy; GE Healthcare, Madison, WI), with analysis performed using GE Encore 12.20 software (GE Healthcare). Subjects were asked to wear minimal clothing (sports bra and shorts). All jewelry and metal objects were removed before each scan to improve the accuracy of the scan results (31). Variables of lean mass (LM), fat mass (FM), fat percentage (fat%), and bone mineral content (BMC) were recorded.

2.3.2 Power characteristics

The CMJ was performed on a portable force plate (Kistler type 9260AA; Kistler Group, Winterthur, Switzerland), and data were sampled at 1000 Hz using an analysis software package (Bioware, Winterthur, Switzerland). Once familiarized with the standardized protocol, 2 trials were performed by each participant with a 3-minute rest between trials. Each trial, the force plate was zeroed prior to the participant standing on the force plate. Once zeroed, the participant was asked to stand on the force plate with hands on their hips, at which point the data acquisition began. Subjects were told to remain motionless for at least 1-second prior to initiating the jump, to obtain body weight (6). All jumps were performed using a self-selected depth to avoid causing unwanted changes to jump coordination, and subjects were encouraged to "jump as high as possible" for each trial. All raw data were extracted as a text file and analyzed in a custom-built Microsoft Excel spreadsheet (Microsoft Corp, Redmond, WA) as outlined by Chavda et al. (6). The detection of the initiation of the jump was calculated as the average vertical ground reaction force of the 1-second motionless period ± 5 SDs, −30 ms (6). Jump height (JH), takeoff velocity (TOV), time to take-off (TTT) and modified reactive strength index (RSI_{mod}) were extracted utilizing the impulse momentum method (6). Jump momentum (JM) was also calculated as TOV multiplied by BM (29).

The DJ was performed from a box height of 0.3 m in line with previous research (28,38) onto a portable force plate (Kistler type 9260AA; Kistler Group, Winterthur, Switzerland), and data were sampled at 1000 Hz using an analysis software package (Bioware, Winterthur, Switzerland). Strict instructions were given to each participant; keep hands on hips during jumps to constrain any involvement from the upper body, avoid hopping off the box, avoid a tucking motion in the air (i.e., legs kept straight), and attempt to land in the same position as takeoff. Subjects were instructed to minimize ground contact time while also attempting to achieve maximal height during the jump. Two trials were performed with a 3-minute rest between each to avoid any residual effects of fatigue on performance. Contact time (CT), and flight time (FT) were captured from the force plate, and reactive strength index (RSI) was then calculated as FT / CT.

2.3.3 Strength Characteristics

The IMTP was performed on a portable force plate (Kistler type 9260AA), which was attached to a custom adjustable power rack (Absolute Performance, Cardiff, Wales) that allows fixation of a horizontal bar at any height. The bar was adjusted to a height that allowed the subjects to assume a position that approximated the beginning of a second pull of the clean (42). Knee angle was assessed using a handheld goniometer to verify a knee angle of 125°± 5°and a hip angle of 175°± 5°. Subjects' hands were fixed to the bar using weightlifting straps to prevent hand movement and to ensure that a maximum effort could be given without limitation of hand grip strength (1). Each subject performed 2 warm-up trials at 50% and 75% of perceived maximal effort, followed by 1 maximal voluntary isometric contraction with a 1-minute rest between each pull. Two 3 sec maximal effort trials were performed, with a 3-minute rest between. The force plate was zeroed prior to the participant taking position between each trial. Once in position, the participant was asked to take minimal tension on the bar and stand as still as possible. Following this, a countdown was given of "3, 2, 1, Pull!" and subjects were verbally instructed to "pull against the bar with maximal effort as quickly as possible and push the feet down into the force plate". This instruction has previously been shown to optimize peak force (39). Peak force (PF), and relative peak force (RPF) was extracted from a customized Microsoft Excel spreadsheet (7) using an average of the motionless baseline plus 5 SD threshold to determine the onset of initiation (7). The average of the baseline was also subtracted from the absolute force time curve to provide net force.

2.4 Statistical Analyses

Subjects were separated into 2 groups: forwards and backs. All data were presented as mean ± standard deviation. A Shapiro–Wilk test of normality revealed that all data were normally distributed ($p > 0.05$). Reliability of variables within each time point was examined using a 2-way random intraclass correlation coefficient (ICC) with absolute agreement and 95% confidence intervals and the coefficient of variation (CV). Average variability taken from across both measures (ICC and CV) was interpreted as small for an ICC > .67 and CV < 10%, moderate when ICC < .67 or CV > 10%, and large when ICC < .67 and CV > 10% (4). An independent samples *t*-test was used to compare the difference between forwards and backs, with statistical significance set at $p < 0.05$. Changes in anthropometry and physical characteristics at the 3 time-points in the season between playing positions were compared using a repeated measures ANOVA via SPSS (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp). Where statistically significant main effects were identified, a Bonferroni correction was applied. Hedges *g* effect sizes (ES) were calculated for both the *t*-test and the repeated measure and interpreted as: (0 < ES < 0.2 = trivial, 0.2 < ES < 0.5 = small, 0.5 < ES < 0.8 = medium, > 0.8 = large) (30).

3. RESULTS

3.1 Positional Differences

3.1.1 Anthropometric Characteristics

The positional differences of anthropometric characteristics across the season are shown in Table 1. Effect sizes are also provided to report the magnitude of difference and thus provide applied practitioners with some measure of 'practical significance' (40).There were no statistically significant differences in stature between forwards and backs throughout the season (pre-, mid-, post-season). Forwards had statistically significantly higher BM, fat%, FM, LM, and BMC ($p < 0.05$, $g = 0.76$ to 1.69) than backs throughout the 3-testing times.

***** Insert Table 1 here*****

3.1.2 Strength and Power characteristics

The positional differences of strength and power characteristics across the season are shown in Table 2. Backs showed statistically significantly higher CMJ JH, RSImod, TOV, DJ FT, and DJ RSI throughout the 3-testing time points across the season ($p < 0.05$, $g = 0.78$ to 1.91). Forwards had significantly higher JM in post-season compared to backs ($p = 0.03$, $g = 0.77$, 95%CI = 0.05 to 1.49). There were no statistically significant differences in PF and RPF in IMTP between forwards and backs throughout the season.

***** Insert Table 2 here*****

3.2 Seasonal Changes

3.2.1 Anthropometric Characteristics

The seasonal changes in anthropometry characteristics in forwards and backs are shown in Tables 3 and 4. There was a statistically significant increase in LM among the forwards from pre- to mid-season ($p = 0.001$, $g = 0.23$, 95%CI = 0.09 to 0.37). For backs, there was a statistically significant increase in LM when looking at pre- vs post-season ($p = 0.001$, $g = 0.19$, 95%CI = 0.03 to 0.35). There were no other statistically significant changes in any other anthropometric variables among the forwards and backs throughout the season.

***** Insert Table 3 and 4 here*****

3.2.2 Strength and Power characteristics

The seasonal changes of strength and power characteristics in forwards and backs are shown in Tables 5 and 6. Among forwards, RSImod demonstrated statistically significant differences between mid- and post-season ($p = 0.006$, $g = 0.56$, 95%CI = 0.18 to 0.95). Although no other statistically significant differences were reported, TTT was shown to have a medium decrease in forwards from mid- to post-season (*g* = -0.56, 95%CI = -1.29 to 0.17). DJ FT was shown to have a medium increase from pre- to mid-season (*g* = 0.56, 95%CI = 0.05 to 1.06) and pre- to post-season (*g* = 0.63, 95%CI = 0.05 to 1.21). Among backs, DJ FT was shown to have statistically significant differences from pre-to mid-season (*p* = 0.04, *g* = 0.83, 95%CI = 0.02 to 1.64) and a medium difference from pre-to post-season (g = 0.76, 95%CI = 0.01 to 1.51).

***** Insert Table 5 and 6 here*****

4. DISCUSSION

The aim of this study was to identify anthropometric profiles, and strength and power characteristics between playing positions in English women's rugby union players and to observe seasonal changes. To the authors' knowledge, this study was the first to show respective positional characteristics and seasonal changes of women's English premiership rugby union players at a competitive level in a full squad capacity. When comparing positions, forwards had statistically significantly higher BM, fat%, LM, FM, BMC and JM, and backs had statistically significantly better CMJ JH, RSImod, TOV, DJ FT, DJ CT and RSI scores throughout the 3-testing times in the season. When observing seasonal changes, the results showed that there were statistically significant differences or moderate to large practical differences in LM (mid- > pre-season), RSImod (post- > mid-season), TTT (post- < mid-season) and DJ FT (mid- and post- > pre-season) among forwards. For backs, statistically significant differences or moderate to large differences were reported in LM (post- > pre-season) and DJ FT (mid- and post- > pre-season) throughout the season (23).

When comparing positional differences in anthropometric profiles, there were no statistically significant differences in height. Forwards had statistically significantly higher BM, fat%, LM, FM, and BMC throughout the 3 testing timings. Similar results were presented in previous studies showing forwards had a higher sum of skinfolds BM, FM, LM, higher fat % and tend to be an endomorph somatotype (9,14,21,23,27,34,35,41,43,44). These general findings align to the match demands of forwards typically facing a greater number of collision activities (e.g., tackle, maul, ruck, scrum), where BM (fat and lean mass) could support as a protective buffer (12). In contrast, Yao *et al.* (44) was the only previous study to observe positional differences in English premiership women's rugby union players, reporting only a small difference in LM between forwards and backs. The difference in results might be due to the number of subjects missing the pre-season testing to attend international training camps (44), thus decreasing the difference in LM between positions.

When comparing strength and power characteristics between positions, backs demonstrated statistically significantly higher scores in CMJ, and DJ compared to forwards in all three testing timeslots. Specifically, backs produced statistically significantly higher CMJ JH, TOV, RSImod, and DJ FT and RSI and lower DJ CT, compared to forwards. There were no significant differences in TTT between forwards and backs, therefore, the significantly higher RSImod scores in backs was largely driven by higher JH. This should not be seen as surprising, given similar results have been previously reported whereby backs demonstrate higher CMJ JH than forwards, across all playing levels (23,35,43,44). During the DJ, backs performed shorter DJ CT and higher FT scores which leads to RSI being significantly greater than forwards, with similar results again found in previous English international women's rugby players (43). Despite backs producing significantly higher reactive strength scores (both RSI and RSImod), unlike DJ CT, there were no significant differences in TTT between forwards and backs. The reason for longer DJ CT might be due to forwards having significantly higher FM, which is likely to serve as additional unwanted load, when the desired outcome is minimal time on the ground between landing and take-off (11). Therefore, during reactive strength jump testing it would be crucial to not only monitor the ratio but also report component variables (FT and CT) of RSI to further identify jump characteristics.

Momentum (mass x velocity) is an important attribute for collision sports. Players with higher sprint momentum should be able to win in collision scenarios in both offence and defense (29). Research has reported JM to be a valuable metric to indirectly inform sprint momentum (29). Forwards in this study created higher JM throughout the season with a statistically significant difference in post-season testing compared to the backs. Despite significantly lower TOV, forwards had significantly higher BM, which would be the confounding factor for increased JM compared to backs. Although greater BM in forwards may be considered an asset to generate higher momentum for positional specific duties, it may also have a negative effect on locomotive performances (jumping and running) (10). Therefore, it is important for practitioners to understand how the momentum was generated and the balance between BM and TOV. To the authors' knowledge, this is the first study to determine jump momentum variables in women's rugby union. With the contact nature of collision sports, it may be practically useful to monitor JM which does not have the inherent limitations of a metric like JH, which is almost certainly biased towards lighter athletes (29).

There were moderate differences in IMTP PF between forwards and backs in mid-season and post-season, and trivial differences in RPF. Similar results were found using isometric max strength tests (IMTP and isometric squat) in English premier 15 and international women's rugby union players showing forwards created higher PF but not when it was reported relative to body mass (43,44). RPF showing trivial to small differences might be due to the significantly higher BM and FM which does not support producing higher PF (5). Furthermore, the dissociation between forwards having significantly higher LM but no statistically significant differences in PF output, might be due to the fact that an increase in LM is not correlated to a concomitant increase in force output. It can instead be suggested that changes in PF may be more closely associated with changes in neuromuscular control and adaptations in the muscle fibers after resistance training rather than changes in LM. (37). Another reason might be most players were in a semi-professional setting with full time jobs, thus had remote resistance training without supervision, affecting retraining adherence and strength gains compared to being supervised (8).

When looking at anthropometric changes across a season, forwards gained statistically significantly higher LM from pre- to mid-season and backs gained statistically significantly higher LM comparing pre- to post- season. However, with trivial to small effect sizes reported (0.23 and 0.19), there were no practically significant differences. Similar results were previously reported in English premiership women's rugby union players (9), whereby no statistically significant differences or significant but trivial ES in BM, FM, LM and BMC were found when comparing pre- and post-season data. The lack of statistically significant differences found in anthropometric characteristics throughout a season were similar in men's study across different rugby codes (13,18). This might be due to the competitive phase of the season when gym training loads were reduced compared to pre-season, but whilst match loads, rugby training and injuries were at their highest (13,18). FM and fat% were maintained throughout the season among both forwards and backs. However, Hene & Bassett (22) reported forwards had statistically significantly lower sum of skinfolds when comparing pre- to post-season, and backs statistically significantly increased BM from pre- to mid-season. The differences might be caused by a drop in participant numbers (forwards from 17 in pre-season to 14 in post season). With no differences in anthropometric characteristics throughout the season, the result may reflect that the players in this study maintained their LM during a 9-month season and did not gain extra FM that might affect performance (26).

When assessing seasonal variations in jump performance, there were moderate differences in CMJ RSImod, and TTT in forwards from mid- to post-season. Similar results were shown in backs with small improvements in RSImod and TTT from mid- to post-season. This might be due to the training focus having a greater emphasis on plyometric and power training in the gym (22). For DJ performance, forwards had a moderate increase in DJ FT from pre- to mid and pre- to post-season. Similar results were found in backs with statistically significantly improved DJ FT from pre- to mid-season and a moderate increase from pre- to post-season. However, there were no statistically significant differences in DJ RSI. The reason for this might be due to the small increase in backs in DJ CT (g = 0.36 to 0.30), which seems like a strategy that may have been employed, enabling more time to produce force (15). When looking at the trend of power characteristics among forwards and backs, performance either dropped or was maintained from pre- to mid-season and improved from mid- to post-season. Similar trends were shown in academy footballers using jump tests (CMJ and DJ) to monitor performance throughout the season (2). These results might be due to the fatigue caused by a competitive season and most women's rugby union players were semi-professional, requiring them to train and compete alongside a full-time job, which might also affect recovery and therefore affect CMJ output and altered jump mechanics (20). Throughout the latter phase of the season, players in this study were more focused on training for the play-offs and the final, resulting in a taper being utilized to help balance the trade-off between enhanced performance and managing fatigue.

For a collision sport, maximizing muscular strength in pre-season and maintaining it throughout the season is critical for match performance (13,16,22). In this study, the IMTP PF and RPF remained constant for backs and forwards throughout the season, which was similar to a men's rugby union study using the isometric squat (19). Similar results were reported in upper body strength using 1RM bench press (22) and maximum repetition push-ups (32). This maintenance may be due to the training focus during the in season, which was periodized to perform more plyometric work, and to control training volume to prevent fatigue before match days. Furthermore, as mentioned due to the semi-professional setting and having other full-time jobs, most of the players in this study were on a remote strength and conditioning program with no direct supervision. Consequently, this is likely to have resulted in an insufficient training frequency and volume that is required to increase lower-body strength (8). However, this, still adds important information on the ability for strength to be maintained throughout a competitive season, despite being caught up in a global pandemic and the programming being centered around power training.

In summary, this study was the first to provide a seasonal change of anthropometric, strength and power characteristics in women's English Premiership rugby union players, along with reported position-specific data. The lab-based strength and power testing in this study were able to discriminate between playing positions and changes throughout the season, but not to directly assess physical changes in performance on the pitch. Therefore, further field based locomotive action testing such as sprinting and change of direction might be useful to understand and monitor on pitch performance changes in women's rugby union throughout the season. In this study, some limitations must also be noted. Due to the nature of rugby as a collision sport, some players were injured during the season. Furthermore, some players were recruited by the club mid-season, meaning they would have missed pre-season testing sessions. The addition of these players potentially provides a greater understanding of seasonal change in anthropometry, strength and power characteristics as a competitive group. Secondly, the total number per positional group was restricted, such that forwards and backs could not be separated into more detailed rugby positional groups (i.e., front row, winger) for position analysis. Finally, subjects in this study were recruited from 1 rugby club and thus, some caution is advised when inferring this data to the wider population of English premiership players. More studies should focus on anthropometric, strength and power seasonal observation in women's rugby union players at different levels and positions to identify position-specific characteristics and changes throughout a competitive season. This would allow practitioners to make informed recruitment and training decisions for semi-professional athletes to improve performance.

5. PRACTICAL APPLICATIONS

This is the first study to determine seasonal changes and positional differences with internationals included in English premiership women's rugby union. This study revealed that even throughout the rugby season, athletes can maintain or have small improvements. Backs produced significantly high-power variables, and forwards generated higher jump momentum and absolute isometric peak force. The strength and power characteristics shown in this study could support coaches and junior women's rugby athletes to have a basic understanding of English premiership physical standards. For sport practitioners, isometric max strength tests and jump tests could be useful monitoring tools to understand strength and power changes throughout the season. Furthermore, for ratio metrics such as RSImod, RSI and JM, component variables should also be monitored to identify the training needs. It is suspected that players in this study may have greater improvements in anthropometric, strength and power characteristics throughout a season from supervised gym training programs.

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Table 1. Anthropometric characteristics and differences between forwards and backs

	Variable	Forwards	Backs	ES (95%CI)
Pre-season Forwards: n = 20 Backs: n = 16	Height (cm)	171.05 ± 7	169.16 ± 4.64	0.31 (-0.37, 1.00)
	Body mass (kg)	85.27 ± 13.7	70.58 ± 5	**1.38** (0.62, 2.14)
	Fat%	32.07 ± 9.34	24.75 ± 6.02	**0.92** (0.20, 1.64)
	Fat mass (kg)	28.3 ± 11.69	17.59 ± 5	**1.16** (0.42, 1.90)
	Lean mass (kg)	53.37 ± 5.1	49.87 ± 4.05	**0.76** (0.05, 1.47)
	BMC (kg)	3.6 ± 0.36	3.09 ± 0.33	**1.48** (0.70, 2.25)
Mid-season Forwards: n = 24 Backs: n = 18	Height (cm)	171.75 ± 7.98	168.44 ± 4.67	0.49 (-0.15, 1.13)
	Body mass (kg)	87.66 ± 12.6	70.92 ± 4.4	**1.69** (0.96, 2.43)
	Fat%	32.23 ± 7.97	24.14 ± 6.51	**1.11** (0.43, 1.78)
	Fat mass (kg)	28.98 ± 10.34	17.24 ± 5.28	**1.38** (0.68, 2.09)
	Lean mass (kg)	54.99 ± 5.06	50.55 ± 4.42	**0.93** (0.27, 1.60)
	BMC (kg)	3.67 ± 0.38	3.12 ± 0.34	**1.52** (0.80, 2.24)
Post-season Forwards: n = 23 Backs: n = 16	Height (cm)	171.58 ± 8.12	168.56 ± 4.9	0.44 (-0.23, 1.10)
	Body mass (kg)	87.68 ± 12.99	71.2 ± 4.09	**1.61** (0.85, 2.37)
	Fat%	32 ± 7.63	24.68 ± 7.11	**1.00** (0.30, 1.70)
	Fat mass (kg)	28.8 ± 10.12	17.69 ± 5.79	**1.30** (0.57, 2.03)
	Lean mass (kg)	55.23 ± 5.36	50.39 ± 4.77	**0.95** (0.26, 1.65)
	BMC (kg)	3.63 ± 0.4	3.11 ± 0.03	**1.45** (0.71, 2.91)

ES= effect size; Bold effect size = $p < 0.05$

Table 2. Strength and power characteristics and differences between forwards and backs

	Variable	Forwards	Backs	ES (95%CI)
Pre-season Forwards: CMJ: n = 19 IMTP: n = 20 DJ: n = 19 Backs: CMJ: n = 16 IMTP: n = 15 DJ: n = 16	CMJ JH (cm)	25.00 ± 4.97	32.26 ± 4.23	**-1.58** (-2.38, -0.78)
	RSImod	0.35 ± 0.07	0.46 ± 0.08	**-1.49** (-2.27, -0.70)
	Time to take off	0.71 ± 0.12	0.69 ± 0.07	0.20 (-0.49, 0.89)
	Take off velocity	2.20 ± 0.22	2.51 ± 0.166	**-1.59** (-2.39, -0.79)
	Jump momentum	188.00 ± 29.5	180.24 ± 15.16	0.33 (-0.37, 1.02)
	IMTP PF (N)	2483.92 ± 505.54	2446.65 ± 397.36	0.08 (-0.61, 0.78)
	IMTP RPF (N)	1489.95 ± 380.5	1526.19 ± 424.16	-0.09 (-0.79, 0.60)
	DJ CT (sec)	0.24 ± 0.04	0.208 ± 0.028	**0.92** (0.20, 1.65)
	DJ FT (sec)	0.42 ± 0.06	0.478 ± 0.041	**-1.12** (-1.87, -0.38)
	DJ RSI	1.82 ± 0.43	2.329 ± 0.38	**-1.26** (-2.02, -0.50)
Mid-season Forwards: CMJ: n = 22 IMTP: n = 23 DJ: n = 22 Backs: CMJ: n = 17 IMTP: n = 16 DJ: n = 17	CMJ JH (cm)	23.55 ± 4.47	31.54 ± 3.93	**-1.90** (-2.69, -1.11)
	RSImod	0.32 ± 0.06	0.426 ± 0.089	**-1.45** (-2.19, -0.71)
	Time to take off	0.73 ± 0.10	0.75 ± 0.11	-0.19 (-0.85, 0.46)
	Take off velocity	2.14 ± 0.2	2.483 ± 0.155	**-1.91** (-2.70, -1.11)
	Jump momentum	187.34 ± 23.57	176.75 ± 14.75	0.53 (-0.14, 1.19)
	IMTP PF (N)	2485.65 ± 499.43	2344.13 ± 355.466	0.32 (-0.34, 0.98)
	IMTP RPF (N)	1399.87 ± 441.92	1347.69 ± 334.485	0.13 (-0.53, 0.79)
	DJ CT (sec)	0.25 ± 0.06	0.23 ± 0.047	0.46 (-0.21, 1.12)
	DJ FT (sec)	0.44 ± 0.05	0.503 ± 0.03	**-1.47** (-2.21, -0.73)
	DJ RSI	1.81 ± 0.45	2.263 ± 0.462	**-1.00** (-1.69, -0.30)
Post-season CMJ: n = 22 IMTP: n = 22 DJ: n = 22 Backs: CMJ: n = 14 IMTP: n = 15 DJ: n = 14	CMJ JH (cm)	25.06 ± 4.73	32 ± 5.2	**-1.43** (-2.21, -0.65)
	RSImod	0.36 ± 0.08	0.462 ± 0.09	**-1.23** (-1.99, -0.47)
	Time to take off	0.69 ± 0.09	0.70 ± 0.07	-0.12 (-0.82, 0.57)
	Take off velocity	2.20 ± 0.20	2.497 ± 0.2	**-1.50** (-2.29, -0.71)
	Jump momentum	193.88 ± 25.24	177.55 ± 13.21	**0.77** (0.05, 1.49)
	IMTP PF (N)	2576.59 ± 488.16	2343.4 ± 279.21	0.56 (-0.13, 1.26)
	IMTP RPF (N)	1549.27 ± 399.42	1477.13 ± 328.41	0.20 (-0.49, 0.88)
	DJ CT (sec)	0.25 ± 0.06	0.216 ± 0.027	**0.78** (0.06, 1.50)
	DJ FT (sec)	0.44 ± 0.05	0.509 ± 0.044	**-1.22** (-1.98, -0.47)
	DJ RSI	1.81 ± 0.42	2.387 ± 0.368	**-1.43** (-2.21, -0.65)

CMJ = countermovement jump; JH = jump height; RSImod = modified reactive strength index.

IMTP = isometric mid-thigh pulls; PF = peak force; RPF = relative peak force; DJ = drop jump; CT = contact time.

FT = flight time; RSI = reactive strength index; ES= effect size; Bold effect size = p < 0.05

Table 3. Forwards anthropometry characteristics changes across pre-, mid-, and post-season

Variable	Pre-season N = 19	Mid-season N = 19	Post-season N = 19	ES (95%CI) Pre- vs Mid-	ES (95%CI) Pre- vs Post-	ES (95%CI) Mid- vs Post-
Height (cm)	170.82 ± 7.11	171.36 ± 7.84	171.36 ± 7.84	0.07 (-0.01, 0.14)	0.07 (-0.01, 0.14)	0.00 (0.00, 0.00)
Body mass (kg)	85.25 ± 14.08	85.97 ± 13.44	85.74 ± 13.38	0.05 (-0.03, 0.13)	0.03 (-0.10, 0.17)	0.00 (-0.25, 0.25)
Fat%	31.74 ± 9.47	31.04 ± 8.25	31.14 ± 7.63	-0.08 (-0.22, 0.07)	-0.07 (-0.23, 0.10)	0.01 (-0.25, 0.27)
Fat mass (kg)	28.07 ± 11.96	27.50 ± 10.84	27.48 ± 10.26	-0.05 (-0.17, 0.08)	-0.05 (-0.20, 0.10)	0.01 (-0.27, 0.25)
Lean mass (kg)	53.60 ± 5.14	54.82 ± 5.11	54.63 ± 5.20	**0.23** (0.09, 0.37)	0.19 (0.02, 0.36)	-0.01 (-0.22, 0.20)
BMC (kg)	3.58 ± 0.36	3.64 ± 0.39	3.61 ± 0.39	0.14 (-0.03, 0.31)	0.07 (-0.10, 0.25)	-0.02 (-0.14, 0.09)

ES= effect size; Bold effect size = $p < 0.05$

Table 4. Backs anthropometry characteristics changes across pre-mid and post-season

Variable	Pre-season	Mid-season	Post-season		ES (95%CI)	
	N = 14	N = 14	N = 14	Pre- vs Mid-	Pre- vs Post-	Mid- vs Post-
Height (cm)	169.36 ± 4.94	168.68 ± 5.18	168.68 ± 5.18	-0.13 (-0.33, 0.07)	-0.13 (-0.33, 0.07)	0.00 (-0.78, 0.78)
Body mass (kg)	70.45 ± 3.71	70.53 ± 3.50	70.55 ± 3.64	0.02 (-0.30, 0.35)	0.02 (-0.24, 0.29)	0.00 (-0.77, 0.78)
Fat%	24.86 ± 5.92	23.59 ± 5.91	23.67 ± 5.94	-0.20 (-0.46, 0.06)	-0.19 (-0.42, 0.05)	0.01 (-0.76, 079)
Fat mass (kg)	17.56 ± 4.60	16.68 ± 4.53	16.72 ± 4.42	-0.18 (-0.47, 0.10)	-0.18 (-0.44, 0.09)	0.01 (-0.77, 0.79)
Lean mass (kg)	49.79 ± 4.28	50.74 ± 4.66	50.71 ± 4.67	0.20 (0.01, 0.39)	**0.19** (0.03, 0.35)	-0.01 (-0.78, 0.77)
BMC (kg)	3.07 ± 0.31	3.11 ± 0.35	3.10 ± 0.31	0.11 (-0.04, 0.26)	0.09 (-0.02, 0.21)	-0.02 (-0.80, 0.75)

ES= effect size; Bold effect size = $p < 0.05$

Table 5. Forwards strength and power characteristics changes across pre-, mid-, and post-season

Variable	Pre-season CMJ N = 15 IMTP N = 17 DJ N = 15	Mid-season CMJ N = 15 IMTP N = 17 DJ N = 15	Post-season CMJ N = 15 IMTP N = 17 DJ N = 15	ES (95%CI) Pre- vs Mid-	ES (95%CI) Pre- vs Post-	ES (95%CI) Mid- vs Post-
CMJ JH (cm)	24.84 ± 4.84	24.80 ± 4.58	26.14 ± 4.62	-0.01 (-0.21, 0.19)	0.26 (-0.11, 0.63)	0.28 (-0.01, 0.56)
RSImod	0.35 ± 0.07	0.33 ± 0.07	0.38 ± 0.09	-0.26 (-0.65, 0.13)	0.32 (-0.16, 0.79)	**0.56** (0.18, 0.95)
Time to take off	0.71 ± 0.13	0.74 ± 0.08	0.69 ± 0.09	0.29 (-0.24, 0.81)	-0.16 (-0.80, 0.48)	-0.56 (-1.29, 0.17)
Take off velocity	2.19 ± 0.21	2.19 ± 0.20	2.25 ± 0.19	0.01 (-0.20, 0.22)	0.28 (-0.11, 0.67)	0.28 (-0.02, 0.58)
Jump momentum	188.11 ± 22.86	187.13 ± 24.77	191.14 ± 23.65	-0.04 (-0.24, 0.16)	0.12 (-0.20, 0.45)	0.16 (-0.07, 0.38)
IMTP PF (N)	2437.97 ± 478.95	2434.06 ± 442.59	2495.18 ± 431.80	-0.01 (-0.32, 0.30)	0.12 (-0.21, 0.45)	0.13 (-0.30, 0.56)
IMTP RPF (N)	1457.95 ± 350.70	1387.35 ± 397.21	1495.53 ± 358.07	-0.18 (-0.51, 0.15)	0.10 (-0.32, 0.52)	0.27 (-0.19, 0.74)
DJ CT (sec)	0.23 ± 0.03	0.25 ± 0.05	0.24 ± 0.03	0.26 (-0.14, 0.66)	0.10 (-0.32, 0.52)	-0.19 (-0.74, 0.36)
DJ FT (sec)	0.42 ± 0.06	0.45 ± 0.04	0.46 ± 0.04	0.56 (0.05, 1.06)	0.63 (0.05, 1.21)	0.11 (-0.20, 0.41)
DJ RSI	1.82 ± 0.44	1.89 ± 0.47	1.93 ± 0.38	0.14 (-0.17, 0.45)	0.24 (-0.07, 0.56)	0.08 (-0.25, 0.42)

CMJ = countermovement jump; JH = jump height; RSImod = modified reactive strength index; IMTP = isometric mid-thigh pull; PF = peak force; RPF = relative peak force; DJ = drop jump; CT = contact time; FT = flight time; RSI = reactive strength index
ES= effect size; Bold effect size = $p < 0.05$

Table 6. Backs strength and power characteristics changes across pre-mid and post-season

Variable	Pre-season CMJ N = 11 IMTP N = 10 DJ N = 11	Mid-season CMJ N = 11 IMTP N = 10 DJ N = 11	Post-season CMJ N = 11 IMTP N = 10 DJ N = 11	ES (95%CI) Pre- vs Mid-	Pre- vs Post-	Mid- vs Post-
CMJ JH (cm)	33.23 ± 4.20	32.57 ± 3.93	33.24 ± 4.75	-0.15 (-0.60, 0.30)	0.00 (-0.41, 0.42)	0.14 (-0.22, 0.50)
RSImod	0.48 ± 0.07	0.45 ± 0.08	0.48 ± 0.09	-0.29 (-0.81, 0.23)	0.05 (-0.48, 0.59)	0.31 (-0.14, 0.76)
Time to take off	0.69 ± 0.05	0.72 ± 0.08	0.69 ± 0.07	0.38 (-0.35, 1.12)	0.00 (-0.72, 0.72)	-0.34 (-0.90, 0.22)
Take off velocity	2.55 ± 0.16	2.52 ± 0.15	2.54 ± 0.18	-0.15 (-0.58, 0.29)	-0.01 (-0.44, 0.42)	0.13 (-0.24, 0.49)
Jump momentum	181.59 ± 13.52	178.35 ± 11.81	178.62 ± 13.87	-0.24 (-0.48, 0.01)	0.20 (-0.53, 0.13)	0.02 (-0.24, 0.28)
IMTP PF (N)	2334.88 ± 400.87	2359.50 ± 410.35	2291.00 ± 267.97	0.06 (-0.27, 0.38)	-0.12 (-0.33, 0.09)	-0.18 (-0.43, 0.06)
IMTP RPF (N)	1411.58 ± 401.54	1419.30 ± 398.42	1436.00 ± 330.77	0.02 (-0.47, 0.51)	0.06 (-0.32, 0.44)	0.04 (-0.32, 0.40)
DJ CT (sec)	0.20 ± 0.02	0.21 ± 0.03	0.21 ± 0.02	0.36 (-0.20, 0.93)	0.30 (-0.55, 1.14)	-0.12 (-0.86, 0.63)
DJ FT (sec)	0.48 ± 0.02	0.51 ± 0.03	0.51 ± 0.04	**0.83** (0.02, 1.64)	0.76 (0.01, 1.51)	0.10 (-0.42, 0.22)
DJ RSI	2.42 ± 0.35	2.42 ± 0.39	2.46 ± 0.36	-0.02 (-0.51, 0.48)	0.08 (-0.70, 0.86)	0.09 (-0.54, 0.73)

CMJ = countermovement jump; JH = jump height; RSImod = modified reactive strength index; IMTP = isometric mid-thigh pulls; PF = peak force; RPF = relative peak force; DJ = drop jump; CT = contact time; FT = flight time; RSI = reactive strength index
ES= effect size; Bold effect size = $p < 0.05$