Three-compartment body composition changes in professional rugby union players over one competitive season: a team and individualised approach

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Abstract

The purpose of this study was to investigate longitudinal body composition of professional rugby union players over one competitive season. Given the potential for variability in changes, and as the first to do so, we conducted individual analysis in addition to analysis of group means. Thirty-five professional rugby union players from one English Premiership team (forwards: n=20, age: 25.5±4.7 years; backs: n=15, age: 26.1±4.5 years) received one total-body dual-energy X-ray absorptiometry (DXA) scan at preseason (August), midseason (January) and endseason (May), enabling quantification of body mass, total and regional fat mass, lean mass, percentage tissue fat mass (%TFM) and bone mineral content (BMC). Individual analysis was conducted by applying least significant change (LSC), derived from our previously published precision data and in accordance with International Society for Clinical Densitometry (ISCD) guidelines. Mean body mass remained stable throughout the season ($p>0.05$), but total fat mass and %TFM increased from pre to endseason, and mid to endseason ($p<0.05$). There were also statistically significant increases in total-body BMC across the season ($p<0.05$). In both groups, there was a loss of lean mass between mid and endseason ($p<0.018$). Individual evaluation using LSC and Bland-Altman analysis revealed a meaningful loss of lean mass in 17 players and a gain of fat mass in 21 players from pre to endseason. Twelve players had no change and there were no differences by playing position. There were individual gains or no net changes in BMC across the season for 10 and 24 players, respectively. This study highlights the advantages of an individualised approach to DXA body composition monitoring and this can be achieved through application of derived LSC.

Keywords: team sport; fat mass; lean mass; bone mineral content; imaging

Introduction

Rugby union is a field-based contact sport, contested by two teams of 15 players over 80 minutes of match play [1]. The Premiership constitutes the highest level of professional rugby union in England, comprising of 12 teams that compete from September to May. In addition to 22 league fixtures, teams also compete in both domestic and international cup competitions. Successful performance in rugby union requires players to possess high levels of muscular power, strength and speed, in addition to a high aerobic and anaerobic capacity [1-3]. To meet the physical demands of the game, an optimal power-to-weight ratio is desired through lean mass and the avoidance of unfavourably high levels of fat mass. This assists players in maximising their aerobic and anaerobic capacity [4, 5].

In rugby union, distinct physical differences exist between forwards and backs - forwards are taller, heavier and possess greater fat, lean and bone mass than backs [6, 7]. These differences are indicative of the discrete demands placed upon each positional group, whereby forwards typically spend more time engaging in static tasks such as rucking, mauling and scrummaging, and backs tend to cover greater total distances and perform more high-intensity running activity [3, 8, 9]. Hence, it is clear that divergent body composition profiles are required with regards to player position and these should be considered when assessing body composition.

Cross-sectional body composition data have been reported for academy and professional rugby players using skinfold assessment [10, 11] and dual-energy X-ray absorptiometry (DXA) [6, 7, 12, 13]. Although skinfold analysis is practical for field-based measurements, DXA provides more of an in-depth analysis, establishing individual levels of fat mass, lean mass and bone mineral content (BMC) and is recognised as a criterion method for the measurement of total [14, 15] and regional [16, 17] body composition.

In rugby union, the professional season is preceded by a preseason period before weekly competition begins [10]. During this time, increased lean mass and decreased fat mass are primary objectives for most players [2, 10]. The maintenance of this profile throughout the competitive season may be beneficial for performance and health, given the ergolytic effects of excess body fat on energy expenditure and movement economy [1], and that lean mass may attenuate the risk of contact injury [18]. However, seasonal changes in three-compartment body composition of rugby league players, but not rugby union players, have been reported elsewhere [19, 20]. Previous studies of athlete body composition change have also not evaluated data at the individual level, and hence rely solely on group differences that reach statistical significance. Interpretation of group means alone will not enable the capture of important information on potential heterogeneity in player response to exercise and recovery. Individual longitudinal change in body composition can be evaluated by applying least significant change (LSC) as determined from precision error for the specific group [21, 22]. The purpose of this study was to investigate both team and individual DXA-derived body composition changes across one competitive season in professional rugby union players.

Methods

Study design

The present study followed players from an English Premiership rugby union team over a period of ten months using an observational, longitudinal research design.

Participants

Thirty-seven professional male rugby union players from one English Premiership rugby union club were recruited for participation in the study, constituting the entire senior playing staff. Two players (forwards) were excluded due to experiencing an injury which kept them from normal training and inclusion in games. The final sample consisted of 35 players (forwards: *n*=20, age: 25.8±4.7 years, height: 186.0±7.1 cm; backs: *n*=15, age: 26.1±4.5 years, height: 183.3±4.0 cm), with all players successfully completing the study. There were no instances of missing data or players lost to follow-up after beginning the study. Positional forwards consisted of six props, five hookers, two locks, and seven back-row forwards, and positional backs consisted of three centres, three scrum-halves, three fly-halves, three wingers and three fullbacks. By ethnic group, there were 17 Caucasian, one Black and two Polynesian forwards and 12 Caucasian, one Black and two Polynesian backs. Prior to testing, all participants provided signed, informed consent and the study was approved by the University Faculty Research Ethics Committee.

Physical measurements

For all tests, players wore shorts without buckles or catches and removed all jewellery. Height was measured using a stadiometer (SECA Alpha, Birmingham, UK) to the nearest millimetre and body mass was measured using calibrated electronic scales (SECA Alpha 770, Birmingham, UK) to the nearest gram. Players received one total-body DXA scan (Lunar iDXA, GE Healthcare, UK) at the end of preseason (August), midseason (January) and endseason (May) in a euhydrated state (urine osmolality <700 mOsmol·kg^{-1}) [23] to ensure that lean mass was not affected by hydration status [17]. Participants were positioned supine on the scanning table with arms situated to their side and ankles supported using the Lunar ankle strap. The standard mode scans took approximately 6.5 minutes, whereas heavier participants (those above 100 kg in body mass) necessitated the use of the thick mode scan, of which the duration was approximately 12.5 minutes. For consistency the scan mode and position selected for the preseason measurement was used for the mid and endseason measurements. From each scan, total and regional fat mass, lean mass, percentage tissue fat mass (%TFM) and BMC values were obtained. These values were determined from the ratio of soft tissue attenuation of 2 X-ray energy beams for each pixel containing a minimal amount of soft tissue but no significant bone [24]. All scanning and analysis procedures were completed by the same trained operator using the Lunar Encore software package (Version 15.0), with subsequent interpretation by a Certified Clinical Densitometrist. The machine was calibrated and checked on a daily basis in accordance with the manufacturer's recommendations.

The published *in-vivo* short-term precision (root-mean-square standard deviation (RMS-SD) and coefficient of variation (%CV)) and corresponding LSC in professional rugby players using the same Lunar iDXA [21] are provided in Table 1.

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

Data were collected on the type and number of training sessions completed during the competitive season (both gym and field-based sessions) in addition to the number of fixtures completed each week (see supplementary material). The total number of games played by the team was 36 competitive games, which included both league and cup fixtures. The mean number of matches played was as follows: forwards 15±10; backs 17±9.

Statistical analyses

All statistical analysis procedures were completed using SPSS (Version 22.0, IBM Corp., Armonk, NY). Prior to analysis, assumptions of normality in the data were made using the Shapiro-Wilk test and visualisation of normality plots. In the event that a variable was not normally distributed (total fat mass, arm lean mass, leg lean mass, leg BMC, trunk fat, trunk BMC), log transformation was performed prior to conducting parametric analysis. Changes in seasonal body composition for each positional group were analysed using mixed-model analysis of variance (ANOVA), with the testing phase as the within-subject factor and playing position as the between-subject factor. Significant overall effects were subsequently explored using Bonferroni *post hoc* tests for multiple comparisons. Sphericity of the data were assessed using Mauchly's test; for instances in which sphericity was violated, the Greenhouse-Geisser correction was applied. Data are presented as mean ± standard deviation (SD) with statistical significance for all analyses defined as $p \leq 0.05$.

Individual changes were evaluated through the application of LSC derived from our precision data using repeated (i.e., re-positioned) DXA measurements of 45 professional male rugby players [21]. Precision error was calculated as root-mean-square standard deviation (RMS-SD), with LSC subsequently derived as RMS-SD x 2.77 (95% CI). Individual values at each time point were then plotted and visually interpreted using Bland-Altman analysis.

Results

Positional descriptives

Body mass, fat mass, lean mass, %TFM and BMC were greater in forwards than backs at all testing phases ($p < 0.001 – 0.010$) (Table 2). For regional body composition, forwards demonstrated significantly greater values for all variables ($p \leq 0.004$) at all testing phases except for arm and leg BMC, which did not significantly differ ($p > 0.05$). No significant interaction effects were observed between time and playing position.

Changes in total and regional body composition

Seasonal changes in total and regional body composition characteristics by playing position are presented in Table 2. Significant main effects of time were found for fat mass (F = 5.545; $p < 0.001$), lean mass (F = 8.899; $p < 0.001$), %TFM (F = 13.172; $p < 0.001$), and BMC (F = 15.714; $p < 0.001$). No significant change in body mass was observed during the competitive season (F = 3.070; $p = 0.053$).

In forwards, endseason fat mass ($p = 0.041$) and %TFM ($p = 0.008$) were significantly higher than preseason. There was also a concomitant decrease in lean mass from mid to endseason ($p = 0.018$). BMC was higher at midseason ($p = 0.001$) and endseason ($p < 0.001$) compared to preseason. In backs, endseason fat mass and %TFM were significantly higher than preseason ($p = 0.009$; $p = 0.008$) and midseason ($p = 0.024$; $p = 0.013$). A loss of lean mass from mid to endseason ($p = 0.003$) was also observed. BMC was higher at endseason compared to preseason ($p = 0.005$).

****insert Table 2 about here****

For regional body composition, significant main effects of time were found for arm fat mass (F = 12.571; $p < 0.001$), arm lean mass (F = 3.386; $p = 0.040$), arm BMC (F = 11.346; $p < 0.001$), leg fat mass (F = 7.370; $p = 0.001$), leg BMC (F = 8.213; $p = 0.001$), trunk fat mass (F = 9.108; $p < 0.001$), trunk lean mass (F = 6.143; $p = 0.004$) and trunk BMC (F = 4.559; $p = 0.014$).

In forwards, fat mass significantly increased in all regions from pre to endseason ($p \leq 0.017$). In the arms, a significant decrease in lean mass was observed from mid to endseason ($p = 0.022$). Arm BMC increased from pre to midseason ($p < 0.001$) and decreased from mid to endseason ($p = 0.001$). Trunk BMC significantly increased between pre and endseason ($p = 0.010$). In backs, arm fat mass increased from pre to endseason ($p = 0.002$). Trunk lean mass reduced from pre to endseason ($p = 0.024$) and pre to midseason ($p = 0.004$). Arm BMC increased from pre to midseason ($p = 0.004$).

Individual player changes by LSC

Utilising LSC from our recent precision study in rugby players [21], individual changes in total lean mass and fat mass are shown in Figures 1 and 2. Seven players lost lean mass (exceeding LSC) pre-midseason, 17 players, mid-endseason, and 3 players lost lean mass during *both* pre-mid and mid-end season. Ten players did not lose lean mass at anytime during the season, and 6 players gained lean mass. Eighteen players gained fat mass pre-midseason, 19, mid-endseason, and 8 players gained fat mass during *both* pre-mid and mid-endseason. Three players did not gain fat mass at anytime during the season. Only one player, a forward, completed the season without any significant changes in lean or fat mass. Twelve players gained BMC pre-midseason and 7 players had a reduction in BMC mid-endseason. Over the course of the season (pre to end), only one player demonstrated a loss of BMC that was outside of the LSC range. There were no differences in baseline characteristics (age, height, body mass, percentage tissue fat mass) or playing position between players who did or did not have changes in body composition through the season.

****insert Figures 1, 2 and 3 about here****

Discussion

This study is the first to apply an individualised approach to analysis of longitudinal body composition change in athletes. In doing so, we were able to capture individual heterogeneity in body composition shifts at different time points over the course of the 10 month competitive season. Further, to our knowledge, this is the first study reporting seasonal changes in three-compartment body composition of professional male rugby union players. Statistically, fat mass increased over the competitive season; these changes were accompanied by a decrease in lean mass from mid to endseason in backs and preseason to endseason in forwards, respectively. Importantly however, individual analysis revealed that loss of lean mass was more common mid-endseason regardless of playing position. Fat mass gains were equally prevalent pre-mid and mid-endseason, suggesting that a gain of fat mass may precede loss of lean mass. Further, few players had a *continuous* loss of lean mass (n = 3) or gain in fat mass (n = 8) over the season. Statistically significant seasonal increases in regional fat mass among both groups were also observed. At all time points, forwards were heavier and possessed greater amounts of total fat and lean mass in addition to BMC. By region, similar trends were observed for fat and lean mass at the arms, legs and trunk.

Concurrent with previous investigations of seasonal body composition changes in professional rugby league players [19, 20], body mass did not significantly alter during the season. However, body composition shifts were evident - backs and forwards demonstrated an increase in total fat mass and %TFM over the season, with a loss of lean mass in both groups. Importantly, further insights were gained by applying individual analysis. The loss of lean mass was more prevalent between mid-endseason (n = 17), in contrast with pre-midseason (n = 7), whereas fat mass gains were comparatively similar between both phases. Moreover, this would suggest that fat mass gains preceded losses in lean mass. The decreased duration of gym-based training sessions and reduced competitive demands (see supplementary material) towards the end of the season, in contrast with the beginning, serves as a potential rationale. The development and maintenance of lean mass has been related to an attenuated risk of contact injury, thus posing practical considerations for player health [18], although further research is required. Increases in fat mass could theoretically attenuate force production according to Newton's second law of motion ($a = F/m$), whereby increases in fat mass (m) without a corresponding increase in muscle force (F) will reduce acceleration (a) [2, 6]. This is noteworthy given the crucial role of momentum in determining the outcome of a tackle contest [25]. As such, the maintenance of a body composition profile preserving lean mass should be considered by practitioners during periods of competition. In terms of regional body composition, fat mass increases were relatively spread equally across regions in forwards, and in the arms for backs. The explanation for these differences may lie in the fact that forwards engage in more static activity such as rucking, mauling and scrummaging whereas backs tend to cover greater total distances and engage in more high-intensity running in open play [3, 9].

Similar to the study by Harley et al. [19], there were significant seasonal increases in total BMC among forwards and backs. Individual analysis provided greater insights, with a meaningful increase in BMC in 12 players from pre-midseason and a loss of BMC in 7 players from mid-endseason. Most players maintained BMC, and the gain of bone mass in 12 players pre-midseason might suggest an osteogenic response of bone to a change in loading with the onset of competition in these players [26]. The loss of BMC in 7 players from mid-endseason warrants further exploration with assessment of bone metabolism markers to inform on a potential consolidation effect on bone turnover [26].

Unlike existing studies of body composition change, we utilised LSC from our earlier precision study in rugby players in order to obtain a greater insight into the data. In doing so, meaningful gains in fat mass and losses in lean mass were observed for at least half of the sample. However, not all players demonstrated unfavourable changes, thus highlighting the need for an individualised approach to evaluating changes in body composition in sports science research and practice. A similar proportion of forwards and backs demonstrated meaningful losses of lean mass from mid to endseason and pre to endseason (Figure 1), concurrent with increases in fat mass (Figure 2). Additionally, the changes observed from pre to endseason can be misleading in that players may have significant increases/decreases in lean or fat mass over the time periods (pre to mid and mid to endseason) which result in a statistically non-significant change over the pre to endseason time period. Determining the precision error of DXA at a given Centre, specific to the population of interest, can enable the interpretation of true change by application of LSC [16, 21, 22, 27] and is recommended by the International Society for Clinical Densitometry [28]. In this study, individual analysis using LSC was particularly insightful for all body compartments.

Our study is limited in that we could only group players according to their primary positional group (i.e., forwards and backs). A larger sample would have facilitated the further classification of forwards (prop, hooker, second-row and loose forward) and backs (full-back, winger, centre and half back). This would be desirable given the unique and disparate roles of each position within the team [9, 12]. Future studies would also benefit from investigating body composition changes across multiple professional clubs to reduce any potential recruitment bias. Finally, our results should not be generalised given the potential disparities in training, competitive demands and recovery between clubs and levels.

To conclude, consistent body mass across the season in professional rugby union players does not reflect an unchanged body composition. We have reported both team and individual significant changes in fat, lean and bone mass. Rugby union players may benefit from maintaining their pre-season body composition profile for the duration of the competitive season, adopting a highly individualised approach on the part of coaches and conditioning professionals. We recommend that DXA-monitoring of body composition in groups should also include an individualised approach, using the same protocol as reported in this study. Future work exploring interactions between body composition, bone metabolism, performance, and injury/ health over the course of a competitive season, with a larger sample group, would also be of value.

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Figure Legends

Figure 1. Individual rugby union player seasonal changes in total lean mass by least significant change (LSC) as determined by Barlow et al [21].

Figure 2. Individual rugby union player seasonal changes in total fat mass by least significant change (LSC) as determined by Barlow et al [21].

Figure 3. Individual rugby union player seasonal changes in total bone mineral content (BMC) by least significant change (LSC) as determined by Barlow et al [21]. *TBBMC*, total-body bone mineral content.

Table 1. The *in-vivo* short-term precision and corresponding least significant change in professional rugby players using the same Lunar iDXA [21].

			LSC – 95%CI	
	RMS - SD	**%CV**	**RMS - SD**	**%CV**
Total-Body				
Fat mass (g)	280	2.3	775	6.4
Lean mass (g)	321	1.6	888	4.5
%TFM	0.32	2.3	0.89	6.4
BMC (g)	24	1.7	65	4.6
Regional				
Arms				
Fat mass (g)	63	4.2	175	11.5
Lean mass (g)	137	2.4	380	6.7
BMC (g)	4.7	2.1	13	5.7
Legs				
Fat mass (g)	145	3.1	403	8.7
Lean mass (g)	369	2.1	1023	6.0
BMC (g)	9.5	1.7	22.6	4.6
Trunk				
Fat mass (g)	299	4.1	828	11.5
Lean mass (g)	402	2.0	1115	5.5
BMC (g)	16.3	2.0	45.3	5.6

Notes: %TFM, percentage tissue fat mass; BMC, bone mineral content; CV, coefficient of variation; LSC, least significant change; RMS-SD, root-mean-square standard-deviation

Table 2. Differences in total and regional (arms, legs and trunk) body composition characteristics over the course of one competitive season in professional rugby union forwards (*n* = 20) and backs (*n* = 15). Data reported as mean ± standard deviation.

	Preseason	Midseason	Endseason
<u>**Total-Body**</u>			
Forwards			
Body mass (kg)	110.6 ± 7.6	111.7 ± 7.8	111.5 ± 7.5
Fat mass (g)	20640 ± 4935	21524 ± 5096	22199 ± 5443[a]
Lean mass (g)	85386 ± 5376	85554 ± 5503	84663 ± 5358[b]
%TFM	19.3 ± 3.8	20.0 ± 3.9	20.6 ± 4.3[a]
BMC (g)*	4564 ± 383	4632 ± 395[a]	4616 ± 391[a]
Backs			
Body mass (kg)	92.5 ± 6.3	93.3 ± 7.4	92.9 ± 7.5
Fat mass (g)	13473 ± 3276	14045 ± 3920	14959 ± 4090[a, b]
Lean mass (g)	74774 ± 5755	74993 ± 5680	73735 ± 5479[b]
%TFM	15.3 ± 3.5	15.7 ± 3.9	16.7 ± 3.9[a, b]
BMC (g)*	4212 ± 362	4260 ± 385	4256 ± 367[a]

Regional			
Forwards			
Arms			
Fat mass (g)	1988 ± 463	2073 ± 479	2134 ± 479[a]
Lean mass (g)	11202 ± 937	11325 ± 893	11055 ± 922[b]
BMC (g)*	653 ± 86	666 ± 84[a]	653 ± 87[b]
Legs			
Fat mass (g)	7070 ± 1425	7351 ± 1758	7507 ± 1641[a]
Lean mass (g)	30739 ± 2572	30987 ± 2516	30575 ± 2704
BMC (g)	1772 ± 206	1784 ± 215	1790 ± 215
Trunk			
Fat mass (g)	10675 ± 3682	11172 ± 3586	11638 ± 3917[a]
Lean mass (g)	39982 ± 2639	39717 ± 2780	39529 ± 2567
BMC (g)	1583 ± 172	1612 ± 184	1618 ± 171[a]
Backs			
Arms			
Fat mass (g)	1352 ± 330	1424 ± 390	1543 ± 385[a]

Lean mass (g)	9978 ± 1238	10038 ± 1165	9920 ± 1250
BMC (g)*	598 ± 63	608 ± 63[a]	605 ± 63
Legs			
Fat mass (g)	4595 ± 1081	4626 ± 1185	4955 ± 1271
Lean mass (g)	26034 ± 2853	26128 ± 2735	25841 ± 2593
BMC (g)	1648 ± 169	1660 ± 164	1664 ± 157
Trunk			
Fat mass (g)	6604 ± 2117	7068 ± 2577	7523 ± 2641
Lean mass (g)	35229 ± 2147	35283 ± 2198	34400 ± 2052[a, b]
BMC (g)	1369 ± 110	1386 ± 138	1380 ± 132

Notes: *%TFM*, percentage tissue fat mass; *BMC*, bone mineral content; *Greenhouse-Geisser correction applied; [a]significantly different from preseason ($p < 0.05$); [b]significantly different from midseason ($p < 0.05$).

Table S1. The training and competition schedule of the 36-week professional season, grouped into cycles of 4 weeks. Data represent the range and mean duration of training sessions in addition to matches completed each week.

Training Cycle	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Gym-based sessions									
Frequency	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2
Duration (min)	73.1 ± 3.8	75.0 ± 0	75.0 ± 0	69.4 ± 3.8	63.8 ± 4.3	65.6 ± 7.2	65.6 ± 3.8	61.9 ± 3.8	60.0 ± 0
Field-based sessions									
Frequency	3-4	3-4	3-4	4	3-4	3-4	3	3	2-3
Duration (min)	70.6 ± 0.7	71.9 ± 2.2	70.6 ± 0.7	67.5 ± 0	68.8 ± 1.4	68.8 ± 1.4	75.0 ± 4.1	66.9 ± 4.7	67.5 ± 5.0
Matches/week	1	1	1	1	0-1	1	1	0-1	0-1

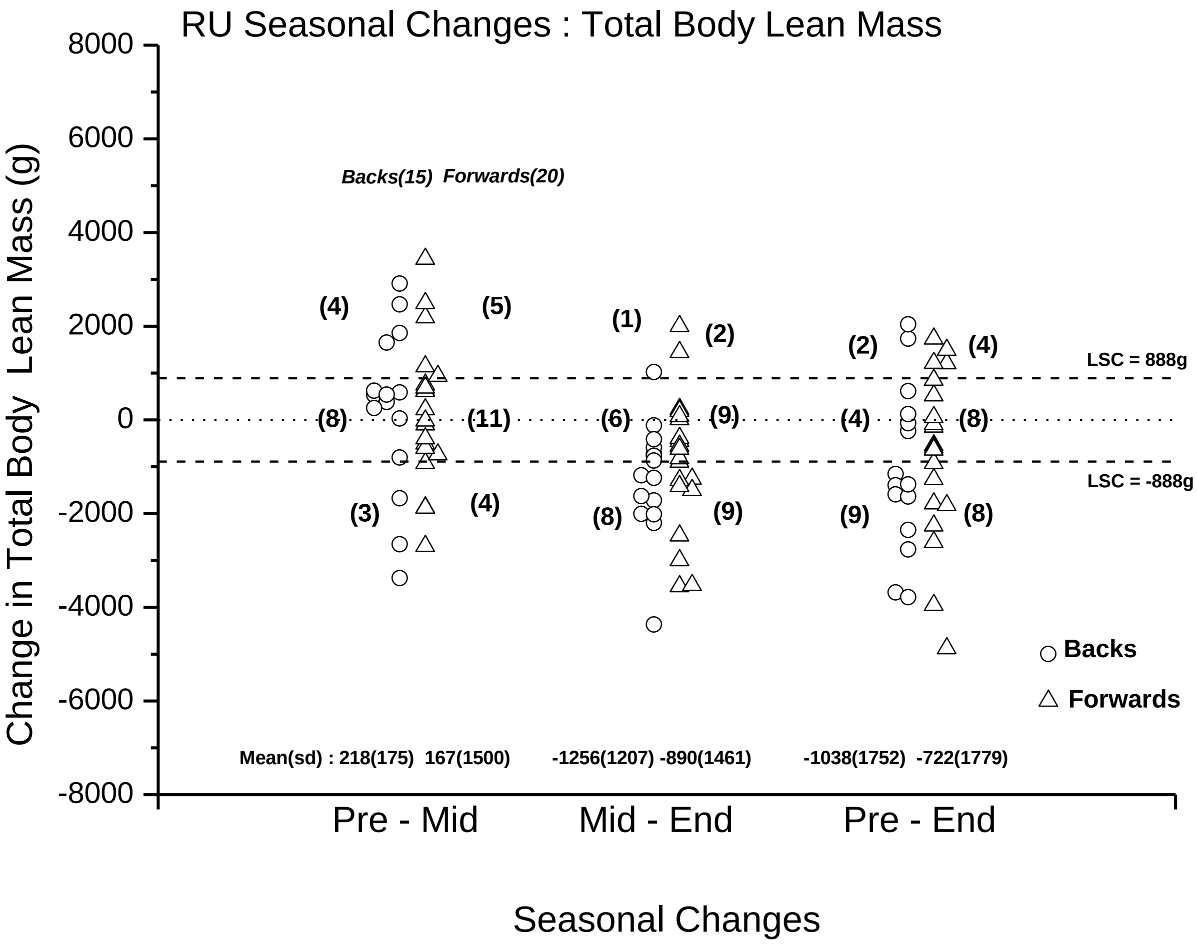

Figure 1. Individual rugby union player seasonal changes in total lean mass by least significant change (LSC) as determined by Barlow et al [21].

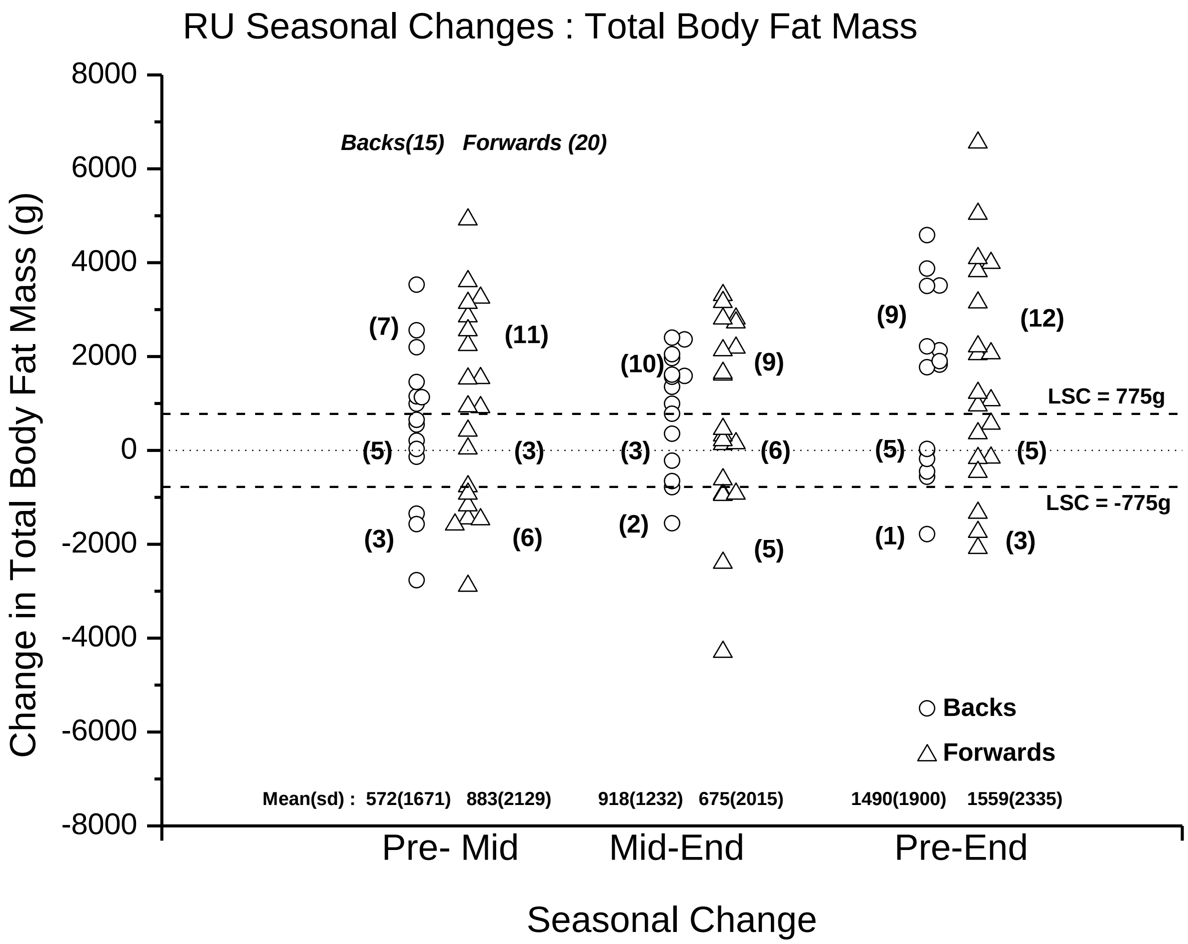

Figure 2. Individual rugby union player seasonal changes in total fat mass by least significant change (LSC) as determined by Barlow et al [21].

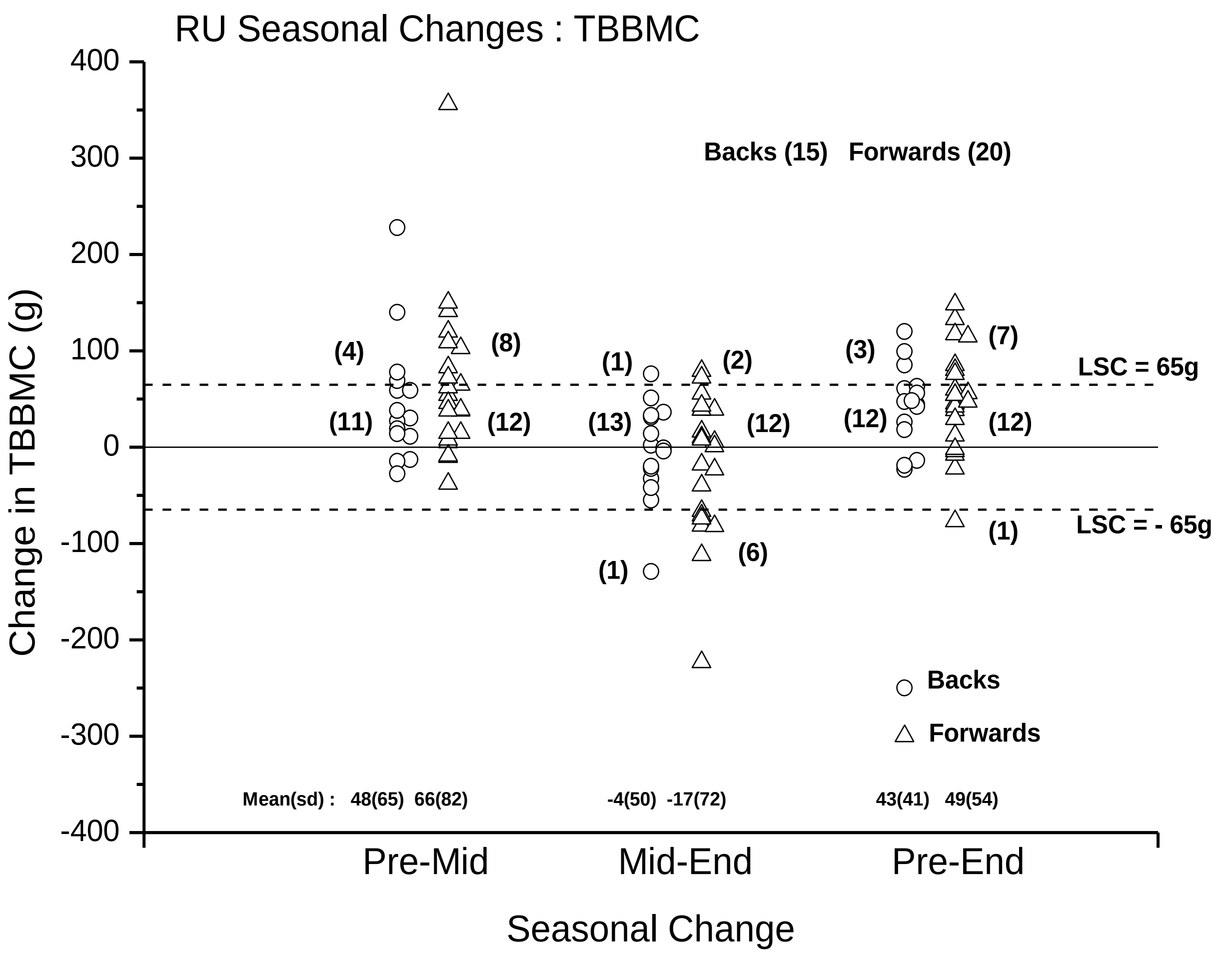

Figure 3. Individual rugby union player seasonal changes in total bone mineral content (BMC) by least significant change (LSC) as determined by Barlow et al [21]. *TBBMC*, total-body bone mineral content.