ORIGINAL ARTICLE

Anthropometry profiles of elite rugby players: quantifying changes in lean mass

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Objective: To demonstrate the utility of a practical measure of lean mass for monitoring changes in the body composition of athletes.

Methods: Between 1999 and 2003 body mass and sum of seven skinfolds were recorded for 40 forwards and 32 backs from one Super 12 rugby union franchise. Players were assessed on 13 (7) occasions (mean (SD)) over 1.9 (1.3) years. Mixed modelling of log transformed variables provided a lean mass index (LMI) of the form mass/skinfolds^x , for monitoring changes in mass controlled for changes in skinfold thickness. Mean effects of phase of season and time in programme were modelled as percentage changes. Effects were standardised for interpretation of magnitudes.

Results: The exponent x was 0.13 for forwards and 0.14 for backs (90% confidence limits ± 0.03). The forwards had a small decrease in skinfolds (5.3%, 90% confidence limits $\pm 2.2\%$) between preseason and competition phases, and a small increase (7.8%, 90% confidence limits $\pm 3.1\%$) during the club season. A small decrease in LMI ($\sim 1.5\%$) occurred after one year in the programme for forwards and backs, whereas increases in skinfolds for forwards became substantial (4.3%, 90% confidence limits $\pm 2.2\%$) after three years. Individual variation in body composition was small within a season (within subject SD: body mass, 1.6%; skinfolds, 6.8%; LMI, 1.1%) and somewhat greater for body mass (2.1%) and LMI (1.7%) between seasons.

Conclusions: Despite a lack of substantial mean changes, there was substantial individual variation in lean mass within and between seasons. An index of lean mass based on body mass and skinfolds is a potentially useful tool for assessing body composition of athletes.

The development of lean mass is desirable in rugby union players to enhance speed, strength, and power,^{1,2} fundamental components for competitive success.^{3,4} In the 1999 Rugby World Cup, the most successful teams were those that had greater total mass in the forwards.⁴ In contrast, high body fat levels increase energy expenditure, reduce a player's power to weight ratio, and decrease acceleration.³ A higher body mass is therefore better carried as lean mass rather than fat.^{5,6} Despite the necessity for development of lean mass, there is currently a lack of cross sectional and longitudinal data on the anthropometry of elite level rugby players.

Different dietary and training strategies within a season elicit variable changes in body composition of athletes.⁷ In rugby, desirable changes in body composition (increases in lean mass and/or decreases in skinfolds) occur primarily during preparation for competition when training volume is high.⁸ Longitudinally, the annual increase in body mass for rugby players from 1905 to 1996 was well above secular increases.⁴ The greater increase is attributed to improved selection procedures, specialised training, new techniques, better equipment and facilities, and greater attention to athlete support.⁴ Anthropometric techniques used in assessing elite rugby union players need to identify both trends within a season and longitudinally over several years.

A limitation of literature on within and between season changes in body composition is the focus on fluctuations in body fat rather than lean mass. One reason for this focus is the concern of using calculations based on doubly indirect methods of assessment.⁹ For example, establishing a measure of lean mass requires skinfold assessment and a prediction equation for a specific population based on hydrodensitometry equations from studies on several cadavers.¹⁰ There is a need to develop a simple and accurate method of assessing lean mass in rugby players based on easily conducted basic

anthropometric measurements. Accurate determination of within season changes in lean mass would be useful in monitoring the progress of athletes and assessing the effectiveness of training and nutritional interventions.

Because of time restraints, anthropometric assessment of elite athletes consists primarily of height, mass, and skinfold thicknesses.¹¹ Skinfolds provide an indication of fatness located in subcutaneous storage areas and can be used to monitor changes in peripheral fat stores over time.⁹ Despite the necessity for lean mass assessment, there is currently a lack of an easy to administer, accurate method of monitoring within subject changes in discrete aspects of body composition for elite rugby players. The purpose of this study was to model individual within and between season changes in the body composition for elite rugby players. We also sought to establish a rugby specific expression of the proportion of lean mass—that is, fat-free mass as the body mass minus fat mass—for forwards and backs.

METHODS

Subjects

Subjects (42 forwards and 30 backs) were players on contract with the ACT Brumbies Super 12 franchise between 1999 and 2003. Super 12 is the premier provincial rugby competition in the southern hemisphere. Players provided written informed consent for participation in scientific and medical assessment under the auspices of the Australian Capital Territory Rugby Union.

Experimental design and procedures

A level 2 accredited anthropometrist (International Society for the Advancement of Kinanthropometry, ISAK) performed 705 assessments of body mass and sum of seven skinfold thicknesses over six years. To monitor within season changes

Table 1 Descriptive statistics of the number of assessments, period of analysis, age, and mean body composition of individual players at recruitment

	Forwards (n = 40)	Backs (n = 32)	Magnitude of difference
Number of assessments	13 (7)	12 (7)	Trivial
Period of analysis (years)	2.0 (1.2)	1.8 (1.3)	Trivial
Age (years)	24.7 (3.5)	24.1 (3.0)	Trivial
Mass (kg)	107.6 (8.0)	89.0 (6.6)	Very large
Sum of seven skinfolds (mm)	84 (19)	60 (13)	Large
Lean mass index (kg/mm ^{0.14})	58.8 (3.6)	52.4 (3.4)	Large

Values are mean (SD).

in body composition, each year was divided into four phases: preseason (November to January, 68 players, 298 assessments), Super 12 games (February to May, 76 players, 223 assessments), club games (June to September, 35 players, 132 assessments), and off-season (October, 27 players, 42 assessments). Training duration ranged from three to ten hours a week, typically higher during the preseason and Super 12 compared with the club and off-season phases. Training for individual players was based on the demands of their specific playing position. Generally, improving endurance and strength qualities formed the focus of training for the forwards, whereas speed development was the priority for the backs.

Body composition was assessed between 0800 and 1200 hours with the athletes presenting in a fasted state. Measurements taken were body mass (kg) and skinfold thickness (mm) from seven sites. In accordance with prescribed methods,⁹ the sites measured for the sum of seven skinfolds were: triceps, subscapular, biceps, supraspinale, abdomen, thigh, and calf. All skinfold measurements were taken using Harpenden skinfold callipers (model HSK-BI; Baty International, Burgess Hill, West Sussex, UK). Body mass was measured with digital scales (model AND UC-300; Precision Calibration Services, Wetherill Park, Australia) to the nearest 0.01 kg. The between test technical error for sum of seven skinfolds and body mass was 2.0 mm (2.8%) and <0.2% respectively based on repeated measurements on 20 rugby union players.

Theoretical background

We analysed the relation between changes in log transformed mass and sum of skinfolds using repeated measures multiple linear regression. Back transformation yielded a function of mass and sum of skinfolds of the form M/S^x , where M = body mass, S = sum of skinfold thickness, and x is a constant estimated from the analysis. We interpreted this function as a lean mass index (LMI),¹² because statistically it tracks changes in mass controlled for changes in skinfold thickness. With certain assumptions, it is possible to show that the LMI is indeed such an index and to assign a meaning to the constant x .¹³ Lean mass in this anthropometrical model refers to fat-free mass—that is, body mass minus fat mass. The proposed LMI has been subsequently validated against the reference method four compartment (4C) model. Over 10 weeks of preseason training, the LMI showed an ability to monitor changes in the lean mass as good as, or better than, a variety of other skinfold based anthropometrical measures.¹³

Statistical analysis

We used the mixed linear modelling procedure (Proc Mixed) in the Statistical Analysis System (version 8.1; SAS Institute, Cary, North Carolina, USA) to estimate means and within and between subject variations (random effects). The random effects were a between subject variance, residual variance representing within subject variation between

assessments, and additional within subject variances for assessments separated by one or more calendar years, for assessments performed in the preseason phase, and for each athlete's very first assessment in the programme. Combined appropriately and expressed as a standard deviation, the random effects represent typical variation in measures of body composition within and between subjects according to methods outlined previously.¹⁴

Magnitudes of standardised change scores were assessed by calculating an effect size from the observed percentage change and the coefficient of variation between subjects and expressed qualitatively on the basis of the following thresholds: <0.2, trivial; <0.6, small; <1.2, moderate; <2.0, large; ≥ 2.0 , very large.¹⁵ Observed differences and change scores are presented as the mean difference or change with 90% confidence limits, and likelihoods are expressed qualitatively (<1%, almost certainly not; <5%, very unlikely; <25%, unlikely or probably not; <50%, possibly not; >50% possibly; >75%, likely or probable; >95%, very likely; >99% almost certain) based on previous recommendations.¹⁶

RESULTS

Table 1 shows the mean number of assessments, period of analysis, age, mass, sum of seven skinfold thicknesses, and lean mass index of individual players. The lean mass of players was calculated as $LMI = M/S^x$, where M = body mass, S = sum of seven skinfold thicknesses, and x = the LMI exponent. The LMI x exponent was slightly lower for the forwards (0.13, 90% confidence limits ± 0.03) than for the backs (0.14, 90% confidence limits ± 0.03). Variation in the exponent between individual players, expressed as a standard deviation, was 0.04 (90% confidence interval 0.03 to 0.10) for the forwards and 0.06 (90% confidence interval 0.04 to 0.11) for the backs.

Within subject changes

Figure 1 show the mean pure within and between season changes in body mass, sum of seven skinfold thicknesses, and LMI for forwards and backs. Trivial changes in the body mass were observed for forwards and backs during a competitive season. These trivial within season changes were superimposed on trivial mean within athlete changes in body mass for time in the programme. The typical random variation in an individual player's body mass was 1.6% between tests during a season and 2.1% between tests in different seasons (represented in fig 1 as within athlete variation between tests).

All the mean within athlete changes in the sum of skinfolds for the backs were trivial, both within a season and for the time spent in the programme. For the forwards it was likely that there was a small 5.3% (90% confidence limits $\pm 2.2\%$) decrease in the sum of seven skinfolds from the preseason to Super 12 competition. This decrease was followed by a small 7.8% (90% confidence limits $\pm 3.1\%$) increase in skinfolds during the club season. Despite trivial

Figure 1 Within subject, within season, and time in the programme percentage changes in body mass, sum of seven skinfolds (SSF), and lean mass index (LMI) in forwards and backs during the preseason, Super 12, and club seasons, and over three years in the programme. Typical error of measurement is the short term technical error. The within athlete variation is the normal variation seen between tests during and between seasons for the respective plots. The smallest worthwhile change is 0.2 times the observed between athlete variation. Uncertainty in the true mean change for time in the programme is represented as 90% confidence limits (shaded bar or area).

mean changes in skinfolds during the first and second year in the programme, it was possible that the forwards had a small increase of 4.3% (90% confidence limits $\pm 2.3\%$) in the third year. The typical random variation in an individual player's

sum of skinfolds was 6.8% between tests during a season and 10.9% between tests in different seasons, both at least twofold greater than the measurement error associated with skinfold assessment.

Figure 2 Individual values of body mass, sum of seven skinfolds (SSF), and lean mass index (LMI) for forwards and backs for the period 1999–2003. The fitted curves are quadratics, and the shading represents 90% confidence limits for population means at a given year of recruitment.

Forwards and backs had similar mean trivial changes in LMI during a season. In the first year in the programme, it was likely that there was a small decrease in LMI for the forwards (-1.6% , 90% confidence limits $\pm 0.7\%$) and backs (-1.4% , 90% confidence limits $\pm 0.6\%$). All other changes for time in the programme were trivial. Superimposed on these changes in the mean LMI were typical variations in an individual player's LMI of 1.3% between tests during a season

and 1.7% between tests in different seasons, both much greater than the 0.5% error associated with LMI assessment, derived by combining independently the measurement errors of 0.2% for body mass and 2.8% for sum of skinfold thicknesses.

Between subject differences

Figure 2 shows representative plots of individual values for body mass, sum of skinfolds, and LMI for the forwards and backs recruited to the programme each calendar year (1999–2003). There were small between subject secular differences (annual trend) in mean body mass, sum of skinfolds, and LMI in both forwards and backs over the study period. The between subject variations for measurements in any given assessment were $\sim 8\%$ for body mass, $\sim 25\%$ for sum of skinfolds, and $\sim 6\%$ for the LMI. Although the mean body mass of players recruited into the programme each year decreased moderately over the study period for forwards (-7.6% , 90% confidence limits $\pm 10.0\%$) and backs (-5.0% , 90% confidence limits $\pm 7.0\%$), there was a trend for the forwards to have higher mean skinfolds (5.0% , 90% confidence limits $\pm 26.6\%$) whereas backs had trivial differences in skinfolds (0.2% , 90% confidence limits $\pm 1.1\%$) over the study period. Together these results show that players recruited more recently (2003) were more likely, on average, to have moderately lower LMI values than the forwards (-8.4% , 90% confidence limits $\pm 8.4\%$) and backs (-4.8% , 90% confidence limits $\pm 5.5\%$) recruited in 1999.

We also examined the anthropometric characteristics of players of different age entering the programme. The older players at recruitment probably had a moderately higher mean body mass; this difference was evident for forwards (5.9% , 90% confidence limits $\pm 8.2\%$) and backs (6.7% , 90% confidence limits $\pm 15.6\%$). As a group, the older recruited forwards possibly had a lower (-23% , 90% confidence limits $\pm 22\%$) sum of skinfolds than their younger counterparts, and the older backs possibly had a lower mean sum of

Figure 3 Body mass, sum of skinfolds, and changes in lean mass index (LMI) from the first assessment for one athlete (an outside centre) in this study.

skinfolds (-5% , 90% confidence limits $\pm 47\%$) than the younger backs. Together these changes in body mass and sum of skinfolds resulted in the LMI probably being higher for older players than younger players for forwards (9.9% , 90% confidence limits $\pm 6.9\%$) and backs (7.5% , 90% confidence limits $\pm 12.2\%$).

Case study

Figure 3 presents an example of longitudinal body composition monitoring (20 observations, about five years) of a typical Super 12 and international rugby outside centre. After initial increases in LMI, there was a clear decrease in March 2001 when a long term injury limited the player's training. The data show that, when in proportion, rises in body mass and sum of skinfolds can elicit an improved LMI. The greatest increase in LMI occurred when there was an increase in body mass accompanied by a decrease in sum of skinfolds.

DISCUSSION

We have established an index of lean mass—that is, fat-free mass as the body mass minus fat mass—for elite rugby players and systematically modelled and quantified the magnitude of within season changes, longitudinal and age differences in body composition for Super 12 rugby players. By accounting for changes in body fat, the classical two component model allows the tracking of lean tissue, and we have provided a theoretical basis for such an analysis. The observed changes in LMI indicate that on average there was a decrease in the proportion of lean mass within individual athletes (for time spent in the programme) and between athletes (calendar year and age at recruitment). These data provide a framework for the modification of training programmes to promote the overall development of lean mass in elite rugby players, and limit negative changes occurring during the off-season and periods of rehabilitation.

During a competitive season, a variety of factors, including the amount of playing time, training, dietary practices, illness, injury, and travelling, may lead to changes in body composition. The typical decrease in sum of skinfolds during the preseason was $\sim 5\%$, the same as that reported during the preseason preparation of international English players.⁸ These changes reflect small but positive adaptations in body composition and physical condition achieved during this period. Despite trivial mean changes, the LMI was able to track proportional increases in lean mass. Individual changes in measures of body composition within and between seasons were typically much larger than the respective typical error (fig 1), indicating that substantial changes in body composition of individual players can be assessed confidently.

The difference in the magnitude of change in body mass and skinfolds for forwards and backs during a season (fig 1) reflects previous findings for American footballers.¹⁷ In general, players with lower skinfolds typically have an increase in total body mass during heavy training loads. Players with higher skinfolds often exhibit a decrease in body mass during training, and those who have the average level of skinfold thickness maintain a relatively stable body mass.¹⁷ Despite these contrasting changes, both forwards and backs recorded trivial increases in the proportion of lean mass. Collectively, measurement of body mass and skinfolds, and the calculation of a LMI, provides a framework for managing the body composition of individual players irrespective of their initial shape.

We observed $\sim 1.5\%$ decreases in lean mass during the initial season in the programme for both forwards and backs which was due to a decrease in mass and an increase in skinfold thickness. There was evidence of a reversal of this trend with a trivial $\sim 0.5\%$ increase in LMI in the third year in

the programme. The negative changes in lean mass across years appear to occur primarily in the club season phase of the year. Players should ideally maintain lean mass (as indicated by the LMI) leading into the following preseason to facilitate further improvements, rather than an annual cycling of fluctuations in body composition. Positive changes over consecutive seasons would result in long term improvement in body composition.

Another key issue is the trend for changes in body composition over consecutive years in elite rugby players recruited to the programme (between subject, years in the programme changes). In contrast with previous trends,⁴ we found a between subject $\sim 2\%$ decrease in body mass of recruited players between 1999 and 2003. This decrease, accompanied by a slight increase in skinfolds ($\sim 1\%$ per year), resulted in a clear decrease in the LMI between 1999 and 2003 for the forwards (-2.2% , 90% confidence limits $\pm 2.1\%$ per year) and backs (-1.2% , 90% confidence limits $\pm 1.4\%$ per year). It is important to recognise that, although the players may have had poorer body composition in recent years, body composition is only one of many factors that contribute to performance. For example, the players may have expressed greater skill in recent years.

We have provided a case study of an elite player to illustrate the utility of the LMI for quantifying proportional changes in lean mass. The player exhibited a reduction in LMI during a five month break because of injury before regaining previously attained levels with an intensive rehabilitation programme. Overall the player's LMI increased by 0.2% over a four year period in contrast with the typical decrease of 1.5% over three years for individual backs seen in the main analysis. Such positive changes are a result of a consistent strength and conditioning training performed over several years.

In this study, we used a mean value of the exponent x to investigate mean effects on the LMI. However, variation in the value of x between athletes (here represented by the standard deviation of 0.04 for forwards and 0.06 for backs) can result in considerable error in the change in the LMI for an individual player, when fluctuations in skinfolds occur. For example, using a value of the exponent one standard deviation above or below the mean results respectively in over-estimation or under-estimation of the change in LMI by a factor of 1.33, when there is a change only in skinfolds. Ideally a value of x should be established for individual

What is already known on this topic

- There are a range of investigations on the anthropometric characteristics of rugby union players by playing level and positional group
- Most previous investigations have provided a cross sectional analysis of players' body mass, stature, and various assessments of fat mass

What this study adds

- This study provides a longitudinal assessment of the body composition of a group of elite rugby union players
- The study presents a novel method of examining an individual player's level of lean mass, and details within and between season changes in the lean mass of Super 12 rugby players

players, but an adequate history of a player's body composition will not usually be available when a player enters a programme. Meanwhile, use of a single value of x for players within a sport can produce an estimate of lean mass that has validity comparable to that of other indirect measures of lean mass.¹³ A mean value of x is required for the given sport and for playing levels and positions within the sport, when there are substantial differences in body build between levels and positions. It may be possible to increase the accuracy of the LMI by including other anthropometric measures, such as height, to account for the effects of variation in body build between sports and between individuals within sports.

CONCLUSIONS

The LMI has direct application in the monitoring of specific training programmes and dietary interventions in rugby players. Given that the development of lean mass is an important factor in the training of elite rugby players, the LMI appears to be a useful assessment tool in an elite athletic programme where practical and efficient measurements need to be conducted. Future studies are required to determine the value of the LMI exponent for rugby players of different levels.

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