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Development of anthropometric characteristics in professional rugby league players: Is there too much emphasis on the pre-season period?

JAMES C. MOREHEN[1], JON CLARKE[2], JAKE BATSFORD[2], JAMIE HIGHTON[4], ROBERT M. ERSKINE[1,3], JAMES P. MORTON[1] & GRAEME L. CLOSE[1]

[1]Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, Liverpool, UK; [2]Warrington Wolves Rugby League Club, The Halliwell Jones Stadium, Mike Gregory Way, Warrington, UK; [3]Institute of Sport, Exercise & Health, University College London, London, UK, [4]Department of Sport and Exercise Sciences, University of Chester, UK.

Address for correspondence:

Professor Graeme L. Close,

Research Institute for Sport and Exercise Sciences,

Liverpool John Moores University,

Tom Reilly Building,

Bryom St Campus,

Liverpool,

L3 3AF, UK

g.l.close@ljmu.ac.uk

Abstract

Rugby League is a team sport requiring players to experience large impact collisions, thus requiring high amounts of muscle mass. Many players (academy and senior) strive to increase muscle mass during the pre-season, however, quantification of changes during this period have not been thoroughly investigated. We therefore assessed changes in body-composition using Dual X-Ray Absorptiometry (DXA) in eleven academy players over three successive pre-seasons and ninety-three senior players from four different European Super League clubs prior to, and at the end of, a pre-season training period. There was no meaningful change in lean mass of the academy players during any of the pre-season periods (year 1 = 72.3 ± 7.1 to 73.2 ± 7.2kg; ES 0.05, year 2 = 74.4 ± 6.9 to 75.5 ± 6.9kg; ES 0.07, year 3 = 75.9 ± 6.7 to 76.8 ± 6.6kg; ES 0.06) with *small* changes only occurring over the three-year study period (72.3 to 75.9kg; ES = 0.22). Senior players showed *trivial* changes in all characteristics during the pre-season period (total mass = 95.1 to 95.0kg; ES -0.01, lean mass = 74.6 to 75.1kg; ES 0.07, fat mass = 13.6 to 12.9kg; ES -0.17, body fat percentage = 14.8 to 14.1%; ES -0.19). These data suggest that academy players need time to develop towards profiles congruent with senior players. Moreover, once players reach senior level, body-composition changes are *trivial* during the pre-season and therefore teams may need to individualise training for players striving to gain muscle mass by reducing other training loads.

Key Words: *Team sport, training, nutrition, DXA, physiology*

Introduction

Rugby League (RL) is an intermittent team sport requiring players to experience large impact collisions with opposing players whilst performing repeated bouts of high-intensity activity, including high-speed running and sprinting (Austin & Kelly, 2014; Gabbett, Polley, Dwyer, Kearney, & Corvo, 2014; Twist et al., 2014). It is therefore crucial that academy (15-19 years old) RL players increase their muscle mass to that of senior players in order to withstand the impacts of these physical collisions (Jones et al., 2015; Morehen, Routledge, Twist, Morton, & Close, 2015) and to improve forward momentum from greater sprint speeds which has been attributed to possessing higher muscle mass (Dobbin, Highton, Moss, & Twist, 2019a; Scott et al., 2017). Indeed, at senior level, success has been attributed to players who possess greater muscular strength and power (Baker & Newton, 2008; de Lacey, Brughelli, McGuigan, & Hansen, 2014), although the validity of standardised testing procedures and its ability to differentiate anthropometric and physical characteristics between academy and senior players has been questioned (Dobbin, Highton, Moss, & Twist, 2019b). As would be expected, within the elite player performance pathway, body mass increases with age, with masses of 13, 14 and 15 year old players being reported as 63.9 ± 9.8, 71.1 ± 9.6 and 77.6 ± 9.8 kg respectively (Till, Cobley, O'Hara, Chapman, & Cooke, 2013). These masses continue to increase as players progress through the pathway with 15, 16 and 17 years old reporting at 79.6, 81.4 and 86.3 kg (Till, Jones, & Geeson-Brown, 2016; Waldron, Worsfold, Twist, & Lamb, 2014). Once players become senior, there are also differences in total mass reported between sub-elite players (88.0 kg) and elite players (99.1 kg), highlighting the importance of lean muscle mass (Gabbett, Kelly, & Pezet, 2008; Harley, Hind, & O'Hara, 2011; Jones et al., 2018; Till, Jones, O'Hara, et al., 2016). Given that academy and senior RL players strive to achieve position specific body compositions (Morehen et al., 2015) it is crucial that body composition is accurately tracked at several key time points during the season as players progress through the development pathway.

To allow lean muscle mass to be tracked, body composition must be assessed alongside total mass. Sum of skinfolds has been previously used to track changes in academy players (Dobbin et al., 2019a; Till et al., 2013; Till, Jones, Darrall-Jones, Emmonds, & Cooke, 2015; Waldron et al., 2014). However, with well-known limitations of using skinfold predictive equations (Doran et al., 2013), such observations are often presented with large measurement errors whilst only providing an estimate of fat mass, neglecting the opportunity to assess lean mass. In comparison to skinfold assessments, a more valid and reliable method of body composition is the use of Duel Energy X-Ray Absorptiometry (DXA). DXA scanning has gained acceptance as a reference method for body composition analysis (Nana, Slater, Hopkins, & Burke, 2012) and has previously been used to measure body composition in elite RL players (Georgeson, Weeks, McLellan, & Beck, 2012; Harley et al., 2011; Morehen et al., 2015). The use of DXA provides an accurate assessment of total and regional body composition measurements (Barlow et al., 2015) and would therefore be useful for sport science support staff to identify whole body lean mass, fat mass and body fat percentage changes in both academy and senior RL players. However, studies using DXA to identify changes in body composition during the pre-season period currently are yet to be performed.

Muscular strength and power are critical components that contribute to success in RL (Baker & Newton, 2008; Comfort, Graham-Smith, Matthews, & Bamber, 2011) and therefore, once academy players reach the first team there is often still a desire to increase muscle mass. Considering the in-season period includes weekly matches, and during certain periods of the year, multiple matches per week (Twist, Highton, Daniels, Mill, & Close, 2017) many teams limit their in-season resistance training to one to three sessions per week (Baker, 2001). Therefore, the pre-season is regarded as the optimum time period for players to increase their training volume (Dobbin, Gardner, Daniels, & Twist, 2018) to make meaningful changes in body composition (Weaving, Jones, Marshall, Till, & Abt, 2017). Despite the importance of the pre-season period, to date there are no data quantifying the changes in body composition over this period in both academy and senior players. Such data are essential to guide support staff with regards to realistic targets during the pre-season period and help to reduce the pressure that may be placed on youth players to gain mass too quickly, which in turn may result in unfavourable fat mass gain, negatively interfering with the development of other key physical qualities (Dobbin et al., 2019a) or in fact may result in young players to dope (Till, Jones, McKenna, Whitaker, & Backhouse, 2016). Finally, in senior players, if meaningful changes are not made during the pre-season period, perhaps time could be better spent developing other key areas of success in RL players, for example, rugby specific skills and/or physical training to reduce injury risk.

To this end, the aim of this study was twofold. 1) To track, for the first time using DXA, the changes in body composition during three consecutive pre-season periods in elite academy players from two different European Super League clubs and 2) assess for the first time changes in body composition in elite senior players from three different European Super League clubs at the beginning and end of a single pre-season period.

Methods

Participants and Overall Study Design

Part One

Eleven male academy players (age 18 ± 1 years at the start of the study) from two European Super League academy teams volunteered for this study. At the beginning of the study, all players were competing regularly at academy level, with all players signing professional senior contracts at the same club by the end of the three-year study period. Testing took place within the opening week and final week of the teams' respective pre-seasons. All players completed the pre-season training phase of 10-12 weeks (105 ± 13 sessions), which consisted of typical strength and conditioning training (Table 1), fitness and skills (Dobbin et al., 2018) and included a minimum of 6 weeks blocked hypertrophy training utilising high set ranges at 70% of 1RM (Argus, Gill, Keogh, Hopkins, &

Beaven, 2010). At the start and end of the pre-season, players visited the laboratory for body composition assessment, using a DXA scanner, along with basic anthropometrical analysis. This process was repeated for three consecutive seasons generating six assessment points for analysis.

Part Two

Ninety-three male first team senior professional RL players (age 25 ± 6 years) from three different European Super League teams, (two teams which are the same as in part 1), including forty-four current/former Internationals volunteered for this study. Players were categorised into six positional groups based on their predominant match-day position and asked to self-select their position if they played in multiple. In total, players were split as follows: Fullbacks and Wingers (18), Centres (11), Halfbacks (6), Hookers (11), Props (19) and Back Row Forwards (28). Testing took place within the opening week and final week of the teams' respective pre-seasons. All players completed the pre-season training phase of 12-14 weeks (124 ± 16 sessions), which consisted of typical strength and conditioning training (Table 1), fitness and skills (Dobbin et al., 2018). At the start and end of the pre-season, players visited the laboratory for body composition assessment, using a DXA scanner, along with basic anthropometrical analysis. Ethics approval, for Parts 1 and 2, was granted from the National Research Ethics Service (17/WM/0014).

TABLE 1 ABOUT HERE

DXA and Anthropometric Assessment (Parts 1 and 2)

A whole-body fan beam DXA measurement scan (Hologic QDR Series, Discovery A, Bedford, MA, USA) was performed using QDR for Windows software version 12:4:3 for the assessment of total mass, total body lean soft tissue mass, fat mass and body fat percentage (Erlandson, Lorbergs, Mathur, & Cheung, 2016). In accordance with best practice guidance (Nana et al., 2016), all players attended the laboratory between 07:00-09:30 h with the bladder voided, in a fasted condition having refrained from exercise in the previous 18 h. All jewellery and metal objects were removed prior to each scan and calibration was performed using an anthropometric spine and step phantom with a subsequent radiographic uniformity scan following the manufactures best practice guidelines. Scans were performed and analysed by the same trained operator with the effective radiation dose reported at 0.01 mSv per person. The scans were analysed automatically by the software with the trained operator subsequently confirming regions of interest. In the present study lean mass and fat mass is reported as sub-total, i.e. whole body minus the head to provide stronger associations and reduced measurement error than with DXA defined total whole body mass, as previously described (Doran et al., 2013). The coefficient of variation (CV) during the testing period for this study was 0.37 % which is in line with previously reported data on the same machine (Morehen et al., 2015) and therefore, a meaningful change in body composition characteristic is anything above twice the CV error of the DXA scanner machine, as previously suggested (Colyer et al., 2016), during the testing period (CV of whole body fat = 1.9 % and 0.37 kg; lean mass = 1.0 % and 0.44 kg and percent body fat 1.9 % and 0.41 %). Players were weighed using a dual height and body mass stadiometer (SECA, Birmingham, UK) to the nearest 0.1 kg and 0.5 cm, respectively, wearing shorts only. Mean CV for height and body mass was 0.23 % and 0.00 %, respectively.

Statistical Analysis (Parts 1 and 2)

Individual changes and means are presented for academy players and mean (±SD) [range] for the senior players. Magnitude-based inferences (MBI) statistics were employed to provide information on the size of the difference, allowing a more practical and meaningful explanation of the data. A custom-made spreadsheet (Hopkins, 2006) was used to determine MBI for all differences, with inferences based on standardised thresholds for *trivial* < 0.2, *small* 0.21-0.60, *moderate* 0.61-1.20, *large* 1.21-1.99 and *very large* ≥ 2.0 with effect sizes calculated as the difference between the means divided by the pooled standard deviation (Batterham & Hopkins, 2006). Threshold probabilities for a meaningful effect based on the 90% confidence limits (CL) were < 0.5 % *most unlikely*, 0.5-5 %

very unlikely, 5-25 % *unlikely*, 25-75 % *possibly*, 75-95 % *likely*, 95-99.5 % *very likely*, > 99.5 % *most likely*. We classified the magnitude of effects mechanistically, whereby if the 90 % CL overlapped the thresholds for the smallest worthwhile positive and negative effects, the effect was deemed unclear (Hopkins, Marshall, Batterham, & Hanin, 2009). In all instances, the smallest worthwhile effect was calculated as 0.2 x the pooled SD of the measurements.

Results

Part 1 – Academy Players

The total mass, lean mass, fat mass and percentage body fat of the academy players can be seen in Figures 1A, 1B, 2A, 2B respectively. There was a trivial change in the height of the academy players from the start of the pre-season in year 1 to the end of pre-season in year 3 (183.6 ± 5.9 vs 185.5 ± 6.0 cm; 0.8%, ES 0.03 ± 0.01, *most likely*) and therefore these data are not graphically reported.

Total Mass (kg)

There was a trivial change in the total mass from the start of the pre-season to the end of the pre-season in either year 1, 2 or 3 (year 1: -1.6 %, ES 0.11 ± 0.13, *most likely*; year 2: 0.7 %, ES 0.06 ± 0.06 *most likely* and year 3: 0.1 %, ES 0.00 ± 0.09, *most likely*). There was a trivial change in total mass between the start of pre-season in year 1 compared with the start of pre-season in year 2 (1.6 %, ES 0.11 ± 0.13, *most likely*). Similarly, there were trivial changes in total mass from the start of pre-season in year 2 compared with the start of pre-season in year 3 (1.2 %, ES 0.09 ± 0.11, *most likely*). Collectively, this resulted in a *small* 2.7 % increase in total mass from 91.7 kg in year 1 to 94.4 kg in year 3 (2.7 %, ES 0.22 ± 0.15, *most likely*). Total mass is shown in Figure 1A.

FIGURE 1 ABOUT HERE

Lean Mass (kg)

There was a trivial change in lean mass from the start of pre-season to the end of pre-season in year 1, 2 or 3 (year 1: 1.1 %, ES 0.05 ± 0.05, *most likely*; year 2: 1.2 %, ES 0.07 ± 0.03, *most likely* and year 3: 1.1 %, ES 0.06 ± 0.05, *most likely*). There was a trivial change in lean mass from the start of pre-season in year 1 to the start of pre-season in year 2 (2.6 %, ES 0.13 ± 0.11, *very likely*) and the start of pre-season in year 2 compared to the start of pre-season in year 3 (1.7 %, ES 0.09 ± 0.08, *very likely*). Collectively, this resulted in a *small* increase of lean mass from 72.3 kg in year 1 to 75.9 kg in year 3 (4.3 %, ES 0.22 ± 0.08, *possibly small*). Lean mass is shown in Figure 1B.

Absolute Fat Mass (kg)

There was a trivial change in fat mass from the start of pre-season to the end of pre-season in year 1, 2 or 3 (year 1: 1.0 %, ES 0.01 ± 0.06, *very likely*; year 2: 1.6 %, ES 0.02 ± 0.05, *very likely* and year 3: 3.1 %, ES 0.03 ± 0.03, *very likely*). There was a trivial change in fat mass from the start of pre-season in year 1 to the start of pre-season in year 2 (17.6 %, ES 0.15 ± 0.13, *likely*) and from the start of pre-season in year 2 compared to the start of pre-season in year 3 (2.8 %, ES 0.03 ± 0.05, *very likely*). Collectively, there was a *trivial* increase from 12.1 kg in year 1 to 14.4 kg in year 3 (20.9 %, ES 0.18 ± 0.12, *likely*). Absolute fat mass is shown in Figure 2A.

FIGURE 2 ABOUT HERE

Percentage Body Fat (%)

There was a trivial change in body fat percentage from the start of pre-season to the end of pre-season in year 1, 2 or 3 respectively (year 1: 0.2 %, ES 0.01 ± 0.23, *unclear*; year 2: -0.2 %, ES -0.01 ± 0.31, *unclear* and year 3: 1.5 %, ES 0.02 ± 0.03, *very likely)*. Similarly, trivial changes in body fat percentage was seen from the start of pre-season in year 1 to the start of pre-season in year 2 (13.0 %, ES 0.12 ± 0.10, *likely*) or the start of pre-season in year 2 to the start of pre-season in year 3 (0.1 %, ES 0.00 ± 0.04, *most likely*). Collectively, there was a trivial change in body fat percentage from the start of pre-season in year 1 to the start of pre-season in year 3 (13.1 %, ES 0.13 ± 0.10, *likely*). Percentage body fat is shown in Figure 2B.

Part 2 – Senior players (Table 2)

There were trivial changes in total mass from the start of pre-season to the end of pre-season in all players (-0.2 %, ES -0.01 ± 0.03, *most likely*) and all positional groups (Full Back and Winger: 0.6 %, ES 0.05 ± 0.09, *very likely*; Centre: 0.2 %, ES 0.03 ± 0.15, *most likely*; Halfback: -0.1 %, ES -0.01 ± 0.10, *most likely*; Hooker: -0.3 %, ES -0.05 ± 0.19, *most likely*; Prop: -0.7 %, ES -0.11 ± 0.11, *very likely* and Back Row Forward: -0.3 %, ES -0.04 ± 0.08, *most likely*).

There were trivial changes in lean mass from the start of pre-season to the end of pre-season in all players (0.7 %, ES 0.07 ± 0.03, *very likely*) and all positional groups (Full Back and Winger: 1.5 %, ES 0.09 ± 0.05, *very likely*; Centre: 0.3 %, ES 0.02 ± 0.04, *most likely*; Halfback: 0.4 %, ES 0.01 ± 0.06, *most likely*; Hooker: 0.8 %, ES 0.04 ± 0.05, *very likely*; Prop: 0.3 %, ES 0.03 ± 0.05, *most likely* and Back Row Forward: 0.5 %, ES 0.04 ± 0.06, *most likely*).

There were trivial changes in fat mass from the start of pre-season to the end of pre-season in all players (-5.4 %, ES -0.17 ± 0.05, *very likely*) and all positional groups (Full Back and Winger: -3.5 %, ES -0.04 ± 0.04, *very likely*; Centre: -4.4 %, ES -0.04 ± 0.04, *very likely*; Halfback: -3.2 %, ES -0.02 ± 0.03, *very likely*; Hooker: -6.2 %, ES -0.06 ± 0.06, *likely*; Prop: -3.8 %, ES -0.05 ± 0.05, *very likely* and Back Row Forward: -5.1 %, ES -0.07 ± 0.04, *likely*).

There were trivial changes in body fat percentage from the start of pre-season to the end of pre-season in all players (-5.3 %, -0.19 ± 0.06, *likely*) and all positional groups (Full Back and Winger: -4.4 %, ES -0.05 ± 0.04, *very likely*; Centre: -3.9 %, ES -0.04 ± 0.04, *very likely*; Halfback: -3.1 %, ES -0.02

± 0.04, *very likely*; Hooker: -6.1 %, ES -0.06 ± 0.06, *likely*; Prop: -3.4 %, ES -0.05 ± 0.05, *very likely* and Back Row Forward: -4.9 %, ES -0.07 ± 0.03, *very likely*).

** TABLE 2 ABOUT HERE**

Discussion

The aim of the present study was to assess the changes in body composition (total mass, lean mass, fat mass, and body fat percentage) in professional RL players with a specific focus on what changes can be made during the crucial pre-season period. To this end, using DXA, we tracked eleven academy players over three successive pre-seasons, and we assessed ninety-nine senior players prior to and following a single pre-season training programme. Surprisingly, we report for the first time in academy players (17-19 years old) *trivial* anthropometric differences throughout the pre-season periods with *trivial* to *small* differences observed following three-years' worth of pre-season training. Similarly, in senior players we also report *trivial* changes across all body composition characteristics, in all positional groups, measured prior to and following a pre-season training period. Collectively, these data contradict the assumption that significant gains in lean mass are made during a RL pre-season and highlights the importance of looking at changes in body composition over the entire season, along with the need for player specific training and nutrition strategies to maximise training adaptations.

As expected, previous research in academy players aged 13-17 has shown incremental increases in total mass as players mature (Till et al., 2013; Waldron et al., 2014). We confirm and extend this by showing increases in total mass (year 1; 91.6 kg, year 2; 93.6 kg, year 3; 94.5 kg) over three consecutive years in academy players. The range of total mass changes within a single pre-season period was between 0 and 3.6 kg, whilst over the three-year study period this increased between 0.6 and 7.4 kg. Interestingly, minimal changes in lean mass were reported during the pre-season period in academy players with *small* changes only occurring from one pre-season period to the next. For example, within a single pre-season period, the amount of lean mass gained between players ranged between 0 to 3.3 kg with larger increases of 1.3 to 9.3 kg built over three consecutive years of data collection (year 1; 72.7 kg, year 2; 74.5 kg; year 3; 76.4 kg). This may reflect that, during the pre-season period, players are also subjected to increased training loads (Dobbin et al., 2018) in terms of on-field running as well as increased gym work (Coutts et al., 2008; Argus, Gill, Keogh, Hopkins, & Beaven, 2010) and consequently gains in lean mass may be difficult to achieve due to inadequate nutrient intake (Howarth et al., 2010) combined with the opposing demands of concurrent training (Coffey & Hawley, 2016). Of interest however, to confirm the aims of the pre-season period, we asked the head of strength and conditioning of each club if they were attempting to gain muscle mass during the season and in each case the answer was positive for both academy and senior players, with a minimum of 6 weeks of the training plan dedicated to hypertrophy, utilising high set ranges at 70% 1RM. Another potential reason for the minimal change in lean mass could relate to previous data that shows daily energy expenditures of some players during a normal training week reporting as high as 5374 Kcal (Morehen et al., 2016) with further increases in energy expenditure relating to collision activity sustained in training (Costello, Deighton, et al., 2018). With approximately an additional 500 Kcal per day being required to increase muscle mass, this would require a daily intake of 5874 Kcal which is substantially more than has been documented in elite rugby players (Bradley et al., 2015; Morehen et al., 2016). It may therefore be prudent for coaches to consider reducing the training load of players whose main priority is to gain muscle mass to facilitate this growth along with age-specific nutrition support given during this crucial period. Indeed, using contemporary behaviour change science to help better design and implement more effective nutritional interventions has been shown to be effective with increasing daily energy intake, and therefore total body mass, in rugby players (Costello, McKenna, Sutton, Deighton, & Jones, 2018).

Fat mass increased in the academy players over the three-year study period, something that none of the strength and conditioning coaches working with the players at the time were striving to achieve.

This increase in body fat may be detrimental to performance and is likely to be an unwanted consequence of attempting to gain lean muscle mass too quickly with the aim of reaching a specific body mass target. Coaches should now use these data to help plan more appropriate and timely increases in lean muscle mass appreciating that for some players, meaningful changes in lean mass (twice the CV error of the DXA machine) can take one to three years to achieve. It should be noted, however, that these data are only on eleven academy players given that we attempted to track players from two different academies through to first team, and future studies may wish to evaluate such suggestions using a larger group of players.

The senior players in the present study also demonstrated no meaningful changes in any anthropometric characteristic, from the start to the end of pre-season. These data confirm and extend previous research, which has used skinfold thickness and DXA scan technology showing either non-meaningful or *trivial* changes in body composition in RL players (Dobbin et al., 2018; Georgeson et al., 2012; Harley et al., 2011). Although the mean gain in lean mass was only 0.7 kg, the maximum gain in lean mass over the pre-season was approximately 3 kg which, whilst certainly meaningful, is lower than what some coaches may believe possible during this period, especially given it is possible that 1-2 kg of this lean mass could be attributable to changes in hydration status, muscle glycogen concentration and creatine (Bone et al., 2017). Therefore, despite many clubs confirming that they use the pre-season period to try and make significant changes in body composition (Weaving et al., 2017), a longer time period may be required (Georgeson et al., 2012). Alternatively, coaches may wish to consider revising the structure of the pre-season period to give more time to gain muscle mass if this is the priority of a given player.

It is also worthy of consideration that, rather than the pre-season being used for senior players to continually increase muscle mass, this period may be better used to develop technical skills and resilience given that meaningful changes in body composition are rarely achieved. Studies suggest that both technical and tactical differences combined with minimal errors when in possession of the ball clearly distinguish between successful and less successful teams (Hulin, Gabbett, Kearney, & Corvo, 2015; Kempton, Kennedy, & Coutts, 2016; Kempton, Sirotic, & Coutts, 2017). Research should now assess what would be a minimal effective dose of resistance training to maintain muscle mass and improve strength/power whilst allowing more time in the pre-season to be spent on technical skills along with exercise-based interventions for injury prevention. For example, both active stretching and water based activities are shown to improve mobility, agility and psychological stress in rugby players (Herman, Barton, Malliaras, & Morrissey, 2012; Suzuki et al., 2004), which may help to prevent injuries, and therefore result in increased player availability to train during the pre-season. During the pre-season period, coaches may therefore choose to allocate more time on these activities over hypertrophy, strength or power-based gym work.

In academy players, after the first pre-season, we report average total mass and lean mass values that were lower than senior grade players. Whilst we report no meaningful changes in lean mass over a single pre-season, the lean mass of the academy players by the end of the third pre-season was in line with that expected of a senior player (Morehen et al., 2015). Taken together, these data support the notion that academy players need time to develop and achieve body compositions required to withstand the physicality of the modern game, rather than unrealistic expectations for youth players to achieve significant body composition changes in an individual pre-season period.

Practical Applications

The present study has several practical applications, which have immediate translational potential. Firstly, contrary to popular belief, in both academy and senior players, meaningful changes in lean mass are rarely seen during the pre-season period. Although the precise reason for this was not tested, this likely reflects the increased metabolic conditioning and skills training loads during this period, including extensive high-speed running. If gains in muscle mass are essential, the pre-season training period should be tailored to the individual ensuring sufficient time is given for growth and repair. Secondly, it should be noted that in academy players, it took almost three-years for players to achieve a body composition commensurate with senior players and therefore players must be given sufficient time to develop. Finally, given that meaningful changes in body composition are rarely achieved during the pre-season in senior players, it could therefore be questioned if this crucial time period could be used more effectively. To this end, it would be interesting to investigate if teams that dedicate greater attention to the fitness and skill components of RL during the pre-season period, rather than striving to achieve increased muscle mass, go on to achieve greater success during the competitive season.

Conclusion

In conclusion, the present study has for the first time assessed the body composition of academy European Super League players over three successive seasons using the gold standard DXA scan technology. We report *trivial* changes during an individual pre-season with *trivial* to *small* changes in body composition over the three-year period. We also show, for the first time in a large group of senior European Super League players using DXA scan technology, *trivial* changes in body composition during a single pre-season period. Given the heterogeneous sample of players from a variety of different clubs (with different coaches) these data question the assumption that meaningful changes can be made in body composition during the pre-season period.

References

Argus, C. K., Gill, N., Keogh, J., Hopkins, W. G., & Beaven, C. M. (2010). Effects of a short-term pre-season training programme on the body composition and anaerobic performance of professional rugby union players. *Journal of Sports Sciences*, *28*(6), 679–686. https://doi.org/10.1080/02640411003645695

Austin, D. J., & Kelly, S. J. (2014). Professional Rugby League Positional Match-Play Analysis Through the Use of Global Positioning System. *Journal of Strength and Conditioning Research*, *28*(1), 187–193. https://doi.org/10.1519/JSC.0b013e318295d324

Baker, D. (2001). The Effects of an In-Season of Concurrent Training on the Maintenance of Maximal Strength and Power in Professional and College-Aged Rugby League Football Players. *The Journal of Strength and Conditioning Research*, *15*(2), 172. https://doi.org/10.1519/1533-4287(2001)015<0172:TEOAIS>2.0.CO;2

Baker, D. G., & Newton, R. U. (2008). Comparison of Lower Body Strength, Power, Acceleration, Speed, Agility, and Sprint Momentum to Describe and Compare Playing Rank among Professional Rugby League Players. *Journal of Strength and Conditioning Research*, *22*(1), 153–158. https://doi.org/10.1519/JSC.0b013e31815f9519

Barlow, M. J., Oldroyd, B., Smith, D., Lees, M. J., Brightmore, A., Till, K., … Hind, K. (2015). Precision Error in Dual-Energy X-Ray Absorptiometry Body Composition Measurements in Elite Male Rugby League Players. *Journal of Clinical Densitometry*. https://doi.org/10.1016/j.jocd.2015.04.008

Batterham, A. M., & Hopkins, W. G. (2006). Making meaningful inferences about magnitudes. *Int J Sports Physiol Perform*, *1*(1), 50–57. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/19114737

Bone, J. L., Ross, M. L., Tomcik, K. A., Jeacocke, N. A., Hopkins, W. G., & Burke, L. M. (2017). Manipulation of Muscle Creatine and Glycogen Changes Dual X-ray Absorptiometry

Estimates of Body Composition. *Medicine and Science in Sports and Exercise*. https://doi.org/10.1249/MSS.0000000000001174

Bradley, W. J., Cavanagh, B. P., Douglas, W., Donovan, T. F., Morton, J. P., & Close, G. L. (2015). Quantification of training load, energy intake, and physiological adaptations during a rugby preseason: a case study from an elite European rugby union squad. *J Strength Cond Res*, *29*(2), 534–544. https://doi.org/10.1519/JSC.0000000000000631

Coffey, V. G., & Hawley, J. A. (2016). Concurrent exercise training: Do opposites distract? *J Physiol*. https://doi.org/10.1113/JP272270

Colyer, S. L., Roberts, S. P., Robinson, J. B., Thompson, D., Stokes, K. A., Bilzon, J. L. J., & Salo, A. I. T. (2016). Detecting meaningful body composition changes in athletes using dual-energy x-ray absorptiometry. *Physiological Measurement*. https://doi.org/10.1088/0967-3334/37/4/596

Comfort, P., Graham-Smith, P., Matthews, M. J., & Bamber, C. (2011). Strength and power characteristics in English elite rugby league players. *Journal of Strength and Conditioning Research*. https://doi.org/10.1519/JSC.0b013e3181d687f5

Costello, N., Deighton, K., Preston, T., Matu, J., Rowe, J., Sawczuk, T., … Jones, B. (2018). Collision activity during training increases total energy expenditure measured via doubly labelled water. *European Journal of Applied Physiology*. https://doi.org/10.1007/s00421-018-3846-7

Costello, N., McKenna, J., Sutton, L., Deighton, K., & Jones, B. (2018). Using contemporary behavior change science to design and implement an effective nutritional intervention within professional rugby league. *International Journal of Sport Nutrition and Exercise Metabolism*. https://doi.org/10.1123/ijsnem.2017-0298

Coutts, A., Sirotic, A. C., Catterick, C., & Knowles, H. (2008). Monitoring training loads in professional rugby league. *Science and Football VI,* pp 272.

de Lacey, J., Brughelli, M. E., McGuigan, M. R., & Hansen, K. T. (2014). Strength, Speed and

Power Characteristics of Elite Rugby League Players. *Journal of Strength and Conditioning Research*, *28*(8), 2372–2375. https://doi.org/10.1519/JSC.0000000000000397

Dobbin, N., Gardner, A., Daniels, M., & Twist, C. (2018). The influence of` preseason training phase and training load on body composition and its relationship with physical qualities in professional junior rugby league players. *Journal of Sports Sciences*. https://doi.org/10.1080/02640414.2018.1473993

Dobbin, N., Highton, J., Moss, S. L., & Twist, C. (2019a). Factors Affecting the Anthropometric and Physical Characteristics of Elite Academy Rugby League Players: A Multi-Club Study. *International Journal of Sports Physiology and Performance*. https://doi.org/10.1123/ijspp.2018-0631

Dobbin, N., Highton, J., Moss, S. L., & Twist, C. (2019b). The Discriminant Validity of Standardised Testing Battery and Its Ability to Differentiate Anthropometric and Physical Characteristics Between Youth, Academy and Senior Professional Rugby League Players. *International Journal of Sports Physiology and Performance*. https://doi.org/10.1123/ijspp.2018-0519

Doran, D., Mc Geever, S., Collins, K., Quinn, C., McElhone, R., & Scott, M. (2013). The Validity of Commonly Used Adipose Tissue Body Composition Equations Relative to Dual Energy X-ray Absorptiometry (DXA) in Gaelic Games Players. *International Journal of Sports Medicine*, *35*(02), 95–100. https://doi.org/10.1055/s-0033-1333693

Erlandson, M. C., Lorbergs, A. L., Mathur, S., & Cheung, A. M. (2016). Muscle analysis using pQCT, DXA and MRI. *European Journal of Radiology*. https://doi.org/10.1016/j.ejrad.2016.03.001

Gabbett, T. J., Polley, C., Dwyer, D. B., Kearney, S., & Corvo, A. (2014). Influence of field position and phase of play on the physical demands of match-play in professional rugby league forwards. *J Sci Med Sport*, *17*(5), 556–561. https://doi.org/10.1016/j.jsams.2013.08.002

Gabbett, T., Kelly, J., & Pezet, T. (2008). A comparison of fitness and skill among playing positions in sub-elite rugby league players. *Journal of Science and Medicine in Sport*, *11*(6), 585–592. https://doi.org/10.1016/j.jsams.2007.07.004

Georgeson, E. C., Weeks, B. K., McLellan, C., & Beck, B. R. (2012). Seasonal change in bone, muscle and fat in professional rugby league players and its relationship to injury: a cohort study. *BMJ Open*, *2*(6). https://doi.org/10.1136/bmjopen-2012-001400

Harley, J. A., Hind, K., & O'Hara, J. P. (2011). Three-Compartment Body Composition Changes in elite Rugby League Players During a Super League Season, Measured by Dual-Energy X-ray Absorptiometry. *Journal of Strength and Conditioning Research*, *25*(4), 1024–1029. https://doi.org/10.1519/JSC.0b013e3181cc21fb

Herman, K., Barton, C., Malliaras, P., & Morrissey, D. (2012). The effectiveness of neuromuscular warm-up strategies, that require no additional equipment, for preventing lower limb injuries during sports participation: a systematic review. *BMC Medicine*. https://doi.org/10.1186/1741-7015-10-75

Hopkins, W. (2006). Spreadsheets for analysis of controlled trials, with adjustment for a subject characteristic. *Sportscience*. https://doi.org/10.1021/acsnano.5b00376

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc*, *41*(1), 3–13. https://doi.org/10.1249/MSS.0b013e31818cb278

Howarth, K. R., Phillips, S. M., MacDonald, M. J., Richards, D., Moreau, N. A., & Gibala, M. J. (2010). Effect of glycogen availability on human skeletal muscle protein turnover during exercise and recovery. *Journal of Applied Physiology*, *109*(2), 431–438. https://doi.org/10.1152/japplphysiol.00108.2009

Hulin, B. T., Gabbett, T. J., Kearney, S., & Corvo, A. (2015). Physical Demands of Match Play in Successful and Less-Successful Elite Rugby League Teams. *International Journal of Sports Physiology and Performance*, *10*(6), 703–710. https://doi.org/10.1123/ijspp.2014-0080

Jones, B., Till, K., Barlow, M., Lees, M., O'Hara, J. P., & Hind, K. (2015). Anthropometric and

Three-Compartment Body Composition Differences between Super League and Championship Rugby League Players: Considerations for the 2015 Season and Beyond. *PLOS ONE*, *10*(7), e0133188. https://doi.org/10.1371/journal.pone.0133188

Jones, B., Till, K., Roe, G., O'Hara, J., Lees, M., Barlow, M. J., & Hind, K. (2018). Six-year body composition change in male elite senior rugby league players. *Journal of Sports Sciences*, *36*(3), 266–271. https://doi.org/10.1080/02640414.2017.1300313

Kempton, T, Kennedy, N., & Coutts, A. J. (2016). The expected value of possession in professional rugby league match-play. *J Sports Sci*, *34*(7), 645–650. https://doi.org/10.1080/02640414.2015.1066511

Kempton, Thomas, Sirotic, A. C., & Coutts, A. J. (2017). A comparison of physical and technical performance profiles between successful and less-successful professional rugby league teams. *International Journal of Sports Physiology and Performance*. https://doi.org/10.1123/ijspp.2016-0003

Morehen, J C, Bradley, W. J., Clarke, J., Twist, C., Hambly, C., Speakman, J. R., … Close, G. L. (2016). The Assessment of Total Energy Expenditure During a 14-Day In-Season Period of Professional Rugby League Players Using the Doubly Labelled Water Method. *Int J Sport Nutr Exerc Metab*, *26*(5), 464–472. https://doi.org/10.1123/ijsnem.2015-0335

Morehen, J C, Routledge, H. E., Twist, C., Morton, J. P., & Close, G. L. (2015). Position specific differences in the anthropometric characteristics of elite European Super League rugby players. *Eur J Sport Sci*, *15*(6), 523–529. https://doi.org/10.1080/17461391.2014.997802

Morehen, James C, Routledge, H. E., Twist, C., Morton, J. P., & Close, G. L. (2015). Position specific differences in the anthropometric characteristics of elite European Super League rugby players. *European Journal of Sport Science*, *15*(6), 523–529. https://doi.org/10.1080/17461391.2014.997802

Nana, A., Slater, G. J., Hopkins, W. G., & Burke, L. M. (2012). Effects of daily activities on dual-energy X-ray absorptiometry measurements of body composition in active people. *Medicine* and Science in Sports and Exercise*. https://doi.org/10.1249/MSS.0b013e318228b60e

Nana, A., Slater, G. J., Hopkins, W. G., Halson, S. L., Martin, D. T., West, N. P., & Burke, L. M. (2016). Importance of standardized DXA protocol for assessing physique changes in athletes. *International Journal of Sport Nutrition and Exercise Metabolism*. https://doi.org/10.1123/ijsnem.2013-0111

Scott, T. J., Dascombe, B. J., Delaney, J. A., Sanctuary, C. E., Scott, M. T. U., Hickmans, J. A., & Duthie, G. M. (2017). Running momentum: a new method to quantify prolonged high-intensity intermittent running performance in collision sports. *Science and Medicine in Football*. https://doi.org/10.1080/24733938.2017.1331044

Suzuki, M., Umeda, T., Nakaji, S., Shimoyama, T., Mashiko, T., & Sugawara, K. (2004). Effect of incorporating low intensity exercise into the recovery period after a rugby match. *British Journal of Sports Medicine*. https://doi.org/10.1136/bjsm.2002.004309

Till, K., Jones, B., McKenna, J., Whitaker, L., & Backhouse, S. H. (2016). The search for size: a doping risk factor in adolescent rugby'. *British Journal of Sports Medicine*, *50*(4), 203–204. https://doi.org/10.1136/bjsports-2015-094737

Till, K., Cobley, S., O'Hara, J., Chapman, C., & Cooke, C. (2013). A longitudinal evaluation of anthropometric and fitness characteristics in junior rugby league players considering playing position and selection level. *Journal of Science and Medicine in Sport*, *16*(5), 438–443. https://doi.org/10.1016/j.jsams.2012.09.002

Till, K., Jones, B., Darrall-Jones, J., Emmonds, S., & Cooke, C. (2015). Longitudinal Development of Anthropometric and Physical Characteristics Within Academy Rugby League Players. *Journal of Strength and Conditioning Research*, *29*(6), 1713–1722. https://doi.org/10.1519/JSC.0000000000000792

Till, K., Jones, B., & Geeson-Brown, T. (2016). Do physical qualities influence the attainment of professional status within elite 16–19 year old rugby league players? *Journal of Science and Medicine in Sport*, *19*(7), 585–589. https://doi.org/10.1016/j.jsams.2015.07.001

Till, K., Jones, B., O'Hara, J., Barlow, M., Brightmore, A., Lees, M., & Hind, K. (2016). Three-Compartment Body Composition in Academy and Senior Rugby League Players. *International Journal of Sports Physiology and Performance*, *11*(2), 191–196. https://doi.org/10.1123/ijspp.2015-0048

Twist, C, Highton, J., Waldron, M., Edwards, E., Austin, D., & Gabbett, T. J. (2014). Movement demands of elite rugby league players during Australian National Rugby League and European Super League matches. *Int J Sports Physiol Perform*, *9*(6), 925–930. https://doi.org/10.1123/ijspp.2013-0270

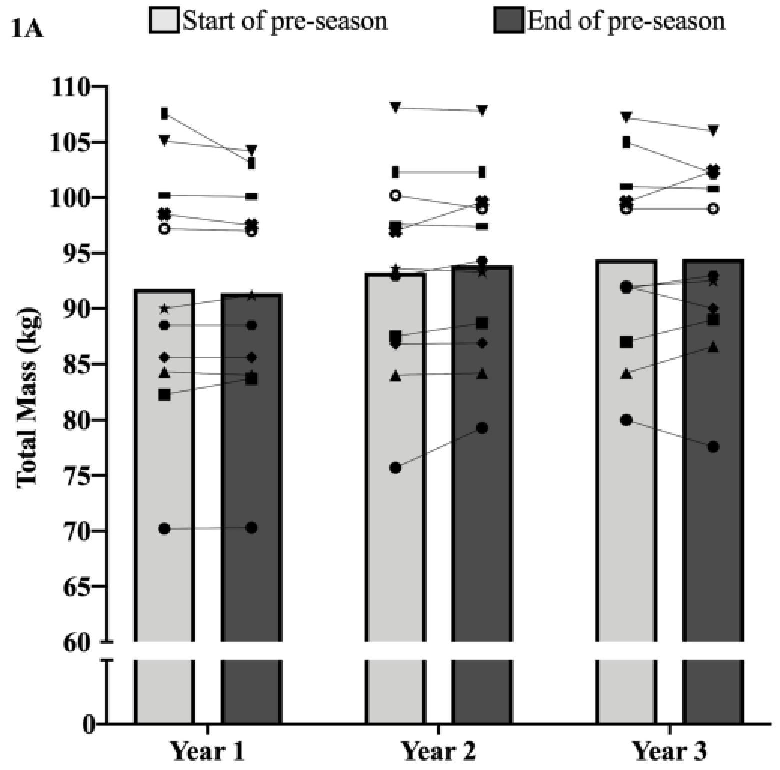
Twist, Craig, Highton, J., Daniels, M., Mill, N., & Close, G. (2017). Player Responses to Match and Training Demands During an Intensified Fixture Schedule in Professional Rugby League: A Case Study. *International Journal of Sports Physiology and Performance*, *12*(8), 1093–1099. https://doi.org/10.1123/ijspp.2016-0390

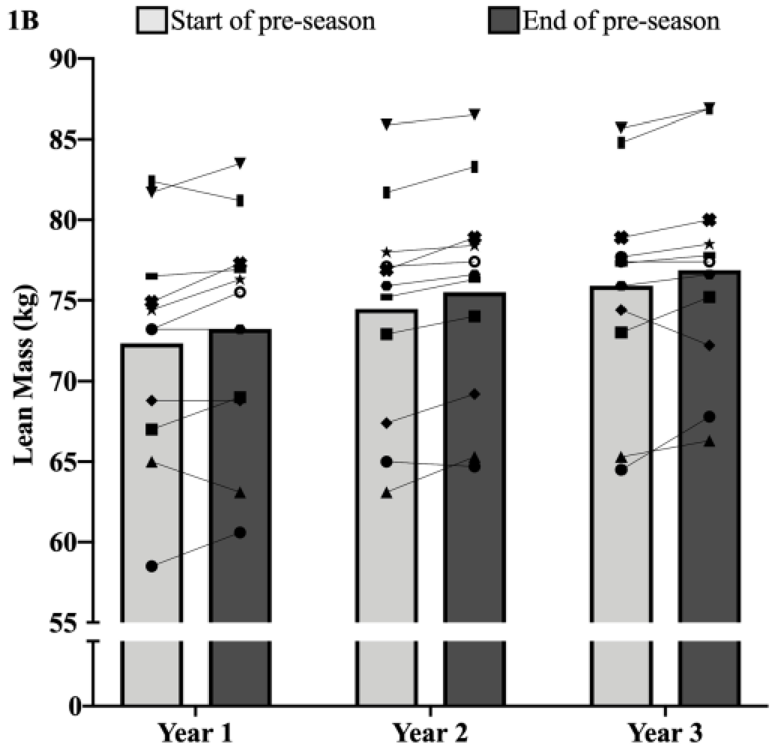
Waldron, M., Worsfold, P., Twist, C., & Lamb, K. (2014). Changes in anthropometry and performance, and their interrelationships, across three seasons in elite youth rugby league players. *J Strength Cond Res*, *28*(11), 3128–3136. https://doi.org/10.1519/JSC.0000000000000445

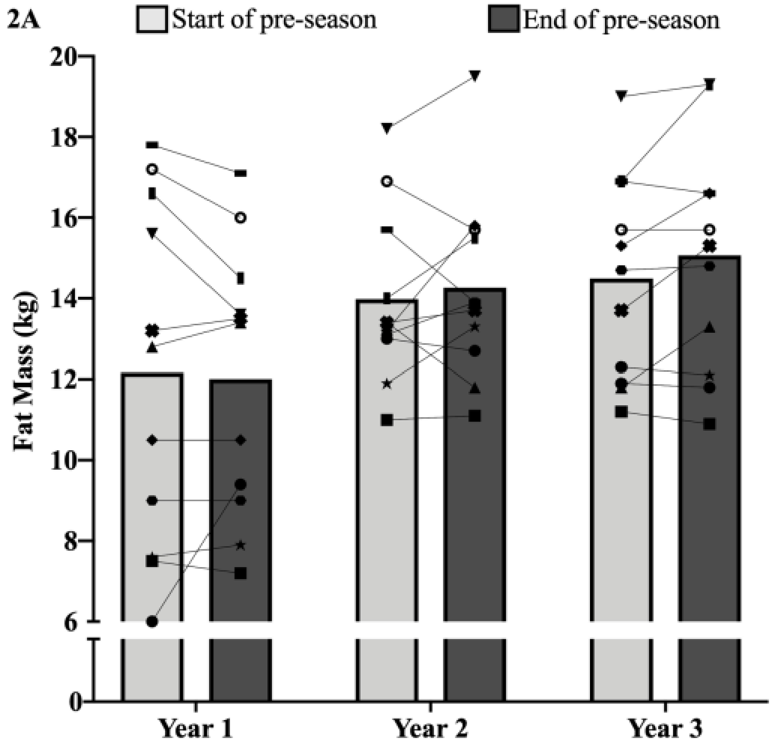
Weaving, D., Jones, B., Marshall, P., Till, K., & Abt, G. (2017). Multiple Measures are Needed to Quantify Training Loads in Professional Rugby League. *International Journal of Sports Medicine*, *38*(10), 735–740. https://doi.org/10.1055/s-0043-114007

Figure 1. Change in total mass (1A) and lean mass (1B) from the start of pre-season to the end of pre-season over three consecutive rugby league seasons. Individual shapes represent each player. Light grey bars represent start of pre-season average whilst dark grey bars represent end of pre-season average.

Figure 2. Change in fat mass (2A) and body fat percentage (2B) from the start of pre-season to the end of pre-season over three consecutive rugby league seasons. Individual shapes represent each player. Light grey bars represent start of pre-season average whilst dark grey bars represent end of pre-season average.


1A
Start of pre-season
End of pre-season
Total Mass (kg)
110
105
100
95
90
85
80
75
70
65
60
0
Year 1
Year 2
Year 3


1B
Start of pre-season
End of pre-season
Lean Mass (kg)
90
85
80
75
70
65
60
55
0
Year 1
Year 2
Year 3


2A
Start of pre-season
End of pre-season
Fat Mass (kg)
20
18
16
14
12
10
8
6
0
Year 1
Year 2
Year 3

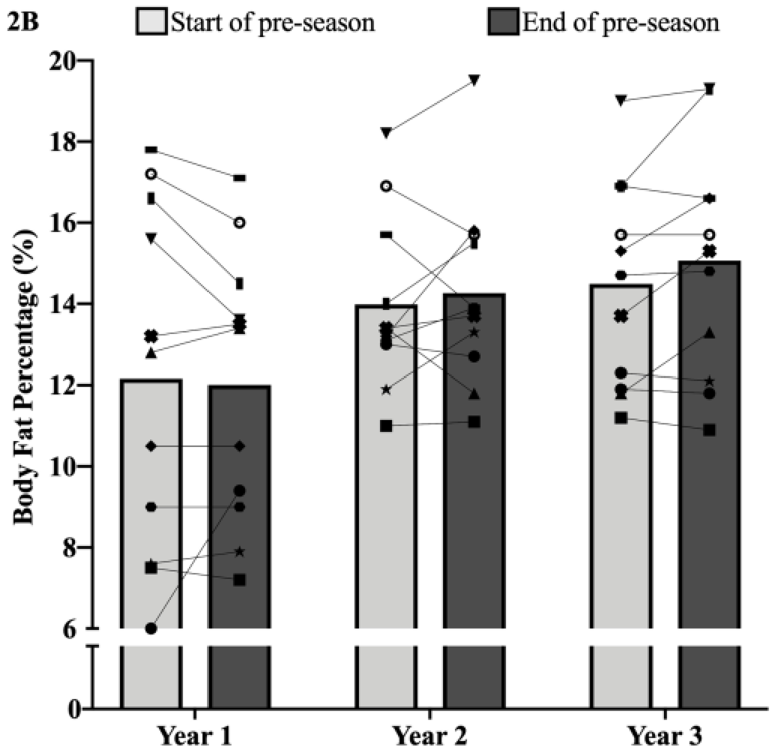

2B
Start of pre-season
End of pre-season
Body Fat Percentage (%)
20
18
16
14
12
10
8
6
0
Year 1
Year 2
Year 3

Table 1. A typical pre-season training week. Training days are shown as days per week. Number in parentheses () indicates the duration of the particular activity and number in parentheses [] indicates the sRPE. Swimming was performed off site whilst all other activities were performed on site at the respective rugby club.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
AM	UB Weights (60) [360]	Conditioning (90) [720]	Swim (60) [180]	Skills (60) [360]	Rest	LB Strength (60) [360]	Rest
Mid-AM	Skills (30) [180]	Rest	Rest	Rest	Conditioning (90) [720]	Rest	Rest
PM	Rest	LB Weights (60) [480]	Rest	UB Strength (60) [360]	Wrestle (60) [480]	Rest	Rest
Mid-PM	Skills (120) [720]	Gymnastics (60) [480]	Rest	Video	Rest	Rest	Rest

Table 2. Mean (±SD) [range] total mass, lean mass, fat mass and body fat percentage values of senior Rugby League players by positional groups from the start of pre-season and the end of pre-season period.

Position	**Full Back and Winger (*n* = 18)**		**Centre (*n* = 11)**		**Halfback (*n* = 6)**		**Hooker (*n* = 11)**		**Prop (*n* = 19)**		**Back Row Forward (*n* = 28)**		**All Players Together (*n* = 93)**	
Pre-season Period	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End
Total Mass (kg)	90.6 (±8.3) [79-108]	91.1 (±8.4) [80-110]	91.6 (±3.7) [87-99]	91.8 (±4.3) [87-100]	86.5 (±7.2) [80-100]	86.4 (±7.1) [80-100]	87.2 (±4.9) [81-96]	86.9 (±4.0) [81-94]	107.2 (±5.0) [97-115]	106.5 (±5.0) [97-115]	98.8 (±6.0) [87-115]	98.5 (±5.5) [87-113]	95.1 (±9.6) [75-115]	95.0 (±9.2) [78-115]
Change (kg)	0.5		0.2		-0.1		-0.3		-0.7		-0.3		-0.1	
Fat Free Mass (kg)	71.2 (±5.3) [64-82]	72.4 (±5.7) [65-83]	73.5 (±3.1) [70-79]	73.8 (±4.0) [68-80]	67.9 (±5.2) [61-77]	68.2 (±6.7) [62-77]	68.9 (±3.8) [63-75]	70.0 (±3.7) [64-76]	82.2 (±4.0) [73-90]	82.5 (±4.0) [75-90]	77.7 (±5.1) [66-93]	78.1 (±4.7) [67-93]	74.6 (±6.8) [61-93]	75.1 (±6.7) [62-93]
Change (kg)	0.8		0.3		0.3		1.1		0.3		0.4		0.5	
Fat Mass (kg)	12.5 (±3.5) [8-19]	12.0 (±3.6) [7-20]	11.4 (±1.4) [9-14]	11.0 (±1.8) [8-14]	12.6 (±3.3) [9-18]	12.1 (±3.3) [8-17]	11.8 (±2.0) [8-15]	10.8 (±1.0) [9-12]	17.8 (±2.8) [14-25]	17.1 (±2.9) [13-23]	14.0 (±2.7) [9-20]	13.3 (±2.8) [8-20]	13.6 (±3.5) [7-24]	13.0 (±3.5) [7-23]
Change (kg)	-0.5		-0.4		-0.5		-1.0		-0.7		-0.7		-0.6	
Body Fat (%)	14.2 (±2.9) [9-19]	13.6 (±3.0) [9-19]	13.0 (±1.6) [10-16]	12.5 (±2.0) [9-17]	15.0 (±3.1) [10-18]	14.4 (±3.3) [10-18]	14.2 (±2.0) [11-17]	13.1 (±1.2) [11-15]	17.2 (±2.3) [14-23]	16.6 (±2.4) [13-22]	14.8 (±2.5) [10-20]	14.0 (±2.7) [8-20]	14.8 (±2.7) [9-23]	14.1 (±2.8) [8-22]
Change (kg)	-0.6		-0.5		-0.6		-1.1		-0.6		-0.8		0.7	