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Body composition differences by age and playing standard in male rugby union and rugby league: A systematic review and meta-analysis

Tom Geeson-Brown[1,2], Ben Jones[1,2,4,5,6], Kevin Till[1,2], Sarah Chantler[1,3], Kevin Deighton[1]

[1]Leeds Beckett University, Carnegie Applied Rugby Research (CARR) centre, Institute for Sport, Physical Activity and Leisure, Leeds, United Kingdom

[2]Leeds Rhinos Rugby League club, Leeds, United Kingdom

[3]Yorkshire Carnegie Rugby Union club, Leeds, United Kingdom

[4]England Performance Unit, The Rugby Football League, Leeds, United Kingdom

[5]School of Science and Technology, University of New England, Armidale, NSW, Australia.

[6]Division of Exercise Science and Sports Medicine, Department of Human Biology, Faculty of Health Sciences, the University of Cape Town and the Sports Science Institute of South Africa, Cape Town, South Africa

Address for correspondence
Tom Geeson-Brown,
Carnegie Applied Rugby Research (CARR) centre, Institute for Sport, Physical Activity and Leisure,
Headingley Campus, Leeds Beckett University, West Yorkshire, LS6 3QS
Email: t.w.geeson-brown@leedsbeckett.ac.uk

Body composition differences by age and playing standard in male rugby union and rugby league: A systematic review and meta-analysis

Abstract

Objective

This systematic review and meta-analysis aimed to determine differences in body composition between playing standard and age in male rugby union and rugby league athletes.

Eligibility criteria

The MOOSE (Meta-analysis of Observational Studies in Epidemiology) guidelines for design, implementation, and reporting were followed. Studies were required to be in male rugby union or league and have body composition as the primary or secondary outcome. Data was required to be presented separately for positional groups and body composition presented as whole-body.

Data sources

PubMed, Cochrane Library, MEDLINE, SPORTDiscus, and CINHAHL via EBSCOhost.

Risk of bias

The methodological quality of the included studies was evaluated using a modified assessment scale

Results

58 studies were included for meta-analysis. Results highlighted significantly higher fat-free mass in senior elite than senior sub-elite or junior elite athletes for all RU and RL forwards. Small and non-significant differences were found in fat mass between rugby union playing standards and age categories. Rugby league senior elite forwards had less fat mass than junior elite forwards.

Conclusions

Practitioners should prioritise training and nutritional strategies that maximise fat-free mass development, especially in junior elite cohorts.

Key Words: Body composition; Muscle; Team Sports; Nutrition; Fat-free mass

Body composition differences by age and playing standard in male rugby union and rugby league: A systematic review and meta-analysis

1 Introduction

Rugby league (RL) and rugby union (RU) are intermittent, contact-skill-based evasion team sports [1, 2]. Rugby league has fewer on-field players (13 vs 15) and only permitted 6 tackles before the ball is handed to the opposition, whereas in RU, the phases of play are unlimited. Despite distinct differences in tactical and technical match play, they're both played over 80 minutes at senior level and contain the same fundamental movements (i.e. tackling, passing, and kicking). Subsequently, both RL and RU match play and training requires players to perform frequent bouts of high intensity activity (e.g., sprinting, side stepping, collisions & jumping) alongside periods of lower intensity work (e.g., standing, walking or jogging) [3-5].

Such high intensity activities involve well developed physical qualities which are closely associated with players' body composition. Players require well developed muscular strength, speed and power [6, 7], which can be improved by increasing fat free mass (FFM, often used as a proxy measure of lean mass) [8, 9]. Alternatively, high amounts of fat mass (FM) can negatively affect power to weight ratio and reduce acceleration ability [10], which may impair performance. Due to their strenuous training, rugby players are thought to have greater bone mineral density (BMD) than the general population [11], which is likely advantageous in preventing skeletal injuries.

Rugby players are typically classified into two positional groups; forwards and backs [12, 13]. For both RL and RU, backs typically undertake more running than forwards, and forwards are exposed to more collisions than backs during a match [14, 15, 5]. The difference in match demands is likely indicative of the specific body composition profiles of players. For example, both RL and RU forwards have greater FFM and FM than backs [16, 17], likely due to a higher frequency of collisions and lower running demands [14].

Previous research investigating the body composition of rugby players is often limited by small sample sizes or the inclusion of only a single club for data analysis. Findings suggest that differences in body composition may exist between senior and junior players [18], and between elite and sub-elite players [19, 20]. However, the consistency and magnitude of these observations has not been evaluated. Understanding these differences can provide insights into the physical characteristics of rugby players and may guide the development of specific body composition goals, as players aim to transition between junior and senior elite squads, and between sub-elite and elite standards. It is important for applied practitioners to be able to adopt an evidence-based approach when working with athletes to be confident in optimising the body composition of players.

This systematic review and meta-analysis provides the first quantitative synthesis of body composition outcomes in rugby research and evaluates the differences between age (junior *vs.* senior) and playing standard (elite *vs.* sub-elite). These findings can help guide practitioners who have a focus on supporting the physical development of rugby players.

2 Methods

This systematic review and meta-analysis was conducted in accordance with the recommendations outlined in the ‘Meta-analysis of observational studies in epidemiology’ [21].

2.1 Literature Search

A systematic search of the following databases: PubMed and the Cochrane Library as well as MEDLINE, SPORTDiscus, and CINHAHL via EBSCOhost took place. All published studies up to October 2019 were included. No publication year or language restrictions were applied during the searches. Reference lists of eligible studies and review articles were also searched. The combinations of key words and specific search parameters can be found in Supplementary document 1. If only the abstract or partial data were published, then the author was contacted for the full data set.

2.2 Inclusion and exclusion criteria

For inclusion, studies were required to be human studies that measured the body composition of rugby players as the primary or secondary outcome of the study (i.e., clearly outlined assessment protocol and not solely as the descriptive characteristics of study participants). Body composition data were required to be presented separately for positional groups to be included (i.e., forwards and backs). Studies were included if they were published in peer-review journals or were available as published conference proceedings, theses or dissertations, to minimise the effect of any potential publication bias. Baseline data from intervention studies were included, as well as data from cross-sectional research. Studies were excluded if: (i) only segmental, not whole-body composition was measured, (ii) participants were competing in parasports, (iii) female, (iv) not rugby union or league (e.g. rugby sevens), (v) data was not split into positional groups (i.e. presented as ‘all’).

Two researchers independently screened the titles and abstracts of studies to assess eligibility for inclusion. Any disagreements over inclusion or exclusion were settled by a third reviewer. Potential studies that were not excluded based on their title or abstract were retrieved in full-text and reviewed against the inclusion/exclusion criteria independently by two researchers. Any disagreements over inclusion or exclusion were settled by a third reviewer. In total, 58 studies met the inclusion criteria and were included in this meta-analysis (supplementary document 3). For a body composition variable (fat free mass [FFM], fat mass [FM], percentage fat mass [%FM], bone mineral content [BMC], or skinfold anthropometry [SF]) to be included in the meta-analysis a minimum of three studies across all subgroups, measuring the respective variable, were required to meet the inclusion criteria. The individual study characteristics and outcome variables for all studies which met the inclusion criteria (including those that did not have sufficient comparisons to be meta-analysed) are presented in Supplementary document 2.

2.3 Data abstraction

Data were extracted by one researcher into a standardised spreadsheet and then cross checked by another reviewer. Any disagreements were settled by a third author. Data for the following variables were extracted: study information, population (sample size, rugby code, age, sex, standard, and position), body composition assessment method (skinfold anthropometry [SF], Dual-energy X-ray absorptiometry [DXA], Bioelectrical impedance (BIA)), and body composition data for each body composition variable (FFM, FM, %FM, BMC, SF) assessed. Plot digitizer was used to obtain data when the outcome measure was only present in graphic form.

2.4 Sub-group classification

Participants in an under-19-year-old (U19) squad and below were classified as junior, while all others were senior. Participants in a top tier international squad or who were professionally contracted as a senior or academy player were classified as elite, while all others were classified as sub-elite [22].

2.5 Assessment of Risk of Bias in included studies

The methodological quality of the included studies was evaluated using a modified assessment scale [23] by two authors. A third reviewer was consulted when disagreements occurred. The scale was modified to assess 10 (numbers 1-4, 6, 7, 11, 12, 16, 20) of the initial 27 criteria. This was due to the irrelevance of some questions as no intervention data was used from the included studies in this review. Question 20 was adjusted to assess if papers clearly outlined and referenced their body composition assessment methodology. The average score of included studies was 8 out of 10. No studies were eliminated on the basis of methodological quality.

2.6 Statistical analysis

If outcome values were reported as median and range then they were converted to mean and standard deviation (SD) [24]. If reported as confidence intervals (CIs) or standard error of the mean (SEM) then they were converted to mean and SD [25]. Data were analysed separately for rugby codes and positional groups (i.e., forwards and backs) due to the differences in match demands and physical characteristics between these groups. Statistical comparisons (using subgroup analyses) were made between age groups (senior and junior) and playing standards (elite and sub-elite).

If studies provided body composition data on individual playing positions (e.g., scrum-half) then means and standard deviations were pooled into positional groups (i.e., forwards and backs) [26]. All analyses were conducted using Comprehensive Meta-analysis Software (version 3, Biostat, Englewood, NJ, USA). A random effects model was employed for all analyses based on the assumption that heterogeneity would exist between included studies due to the variability between teams [27]. Heterogeneity between studies was assessed using the I^2 statistic, Cochrane's Q statistic and Tau-squared statistic. The magnitude of heterogeneity was classified using the I^2 value, where > 75% indicates high heterogeneity, 25-75% indicates moderate heterogeneity, <25% indicates low heterogeneity [28]. To assess whether any between group effects were dependant on a single study, sensitivity analysis was used for each variable by repeating the analysis with each study omitted in turn.

3 Results

Overview

Supplementary document 3 outlines the flow chart of study selection. Of the 169 papers included at full text review, 57 studies were included for meta-analysis. Within the 57 included studies, 41 were in RU and 16 were in RL players. In RU, 36 studies included senior players of which 16 studies included elite players [29-37, 19, 17, 38-42] and 21 included sub-elite players [34, 43-62]. Five studies were in junior RU players, of which three studies included elite players [63-65] and two included sub-elite players [66, 67]. In RL, 12 studies included senior players of which seven studies included elite players [68, 6, 69, 16, 18, 70, 20] and five included sub-elite players [71-74, 20]. Seven studies included junior RL players, of which six studies included elite players [68, 75, 18, 76-78] and only one study included sub-elite players [79]. Some studies included more than one playing standard or age group.

Meta-analysis

Individual study characteristics and results for each variable can be found in supplementary document 2. The summary effects for each variable and subgroup are provided in supplementary document 4.

3.1 Rugby Union

3.1.1 Fat free mass

Backs

Senior elite backs (79.2 kg, 95% CI: 76.9 to 81.4 kg, $n = 10$) had a significantly higher FFM than sub-elite backs (66.8 kg, 95% CI: 62.9 to 70.5 kg, $n = 8$) ($p < 0.001$). FFM was also higher in senior elite backs than junior elite backs (63.7 kg, 95% CI: 62.3 to 65.1 kg, $n = 1$) ($p <0.001$). The FFM of junior sub-elite backs was not assessed in any of the included studies. Sensitivity analysis revealed minor changes only, and these changes did not substantially alter the overall mean difference.

Forwards

FFM was significantly higher in senior elite forwards (91.1 kg, 95% CI: 88.6 to 93.5 kg, $n = 10$) than sub-elite forwards (76.3 kg, 95% CI: 71.5 to 81.1 kg, $n = 8$) ($p < 0.001$). Senior elite forwards also had a significantly higher FFM than junior elite forwards (68.3 kg 95% CI: 66.7 to 69.8 kg, $n = 1$) ($p < 0.001$). The FFM of junior sub-elite forwards was not assessed in any of the included studies. Sensitivity analysis revealed minor changes only, and these changes did not substantially alter the overall mean difference

Insert Figure 1

Figure 1: Forest plot of study means and sub-group summaries (means ± 95% confidence intervals [CIs]) for studies evaluating FFM (kg) in rugby union. The black circle represents the summary (mean ± 95% CI) for each sub-group. The heterogeneity of each sub-group was senior elite backs ($I^2 = 93.9\%$, $Q = 147.6$, $\tau^2 = 11.8$, df = 9), senior elite forwards ($I^2 = 95.3\%$, $Q = 191.1$, $\tau^2 = 13.1$, df = 9), senior sub-elite backs ($I^2 = 95.9\%$, $Q = 172.7$, $\tau^2 = 27.3$, df = 7), and senior sub-elite forwards ($I^2 = 96.2\%$, $Q = 185.6$, $\tau^2 = 42.8$, df = 7).

3.1.2 Absolute fat mass

Backs

There was no significant difference in absolute FM between senior elite backs (11.4 kg, 95% CI: 10.2 to 12.6 kg, $n = 7$) and senior sub-elite backs (13.5 kg, 95% CI: 8.5 to 18.4 kg, $n = 3$) ($p = 0.274$). There was also no significant difference between senior elite backs and junior elite backs (10.2 kg, 95% CI: 9.6 to 10.8 kg, $n = 1$) ($p = 0.351$). The absolute FM of junior sub-elite backs was not assessed in any of the included studies. Sensitivity analysis revealed that the removal of Bell (1979) from senior sub-elite backs (15.7 kg, 95% CI: 14.2 to 17.2 kg, $n = 2$) caused the comparison with senior elite backs to become significant ($p < 0.001$).

Forwards

There was no significant difference in absolute FM between senior elite forwards (16.9 kg, 95% CI: 15.7 to 18.1 kg, $n = 7$) and sub-elite forwards (21.7 kg, 95% CI: 15.0 to 28.4 kg, $n = 3$) ($p = 0.171$). There was no significant difference found between senior elite forwards and junior elite forwards (15.2 kg, 95% CI: 13.7 to 16.7 kg, $n = 1$) ($p = 0.080$). The absolute FM of junior sub-elite forwards was not assessed in any of the included studies. The removal of Bell (1979) made the absolute FM of senior sub-elite forwards (24.7 kg, 95% CI: 22.4 to 27.1 kg, $n = 2$) significantly higher than senior elite forwards ($p < 0.001$).

Insert Figure 2

Figure 2: Forest plot of study means and sub-group summaries (means ± 95% confidence intervals [CIs]) for studies evaluating FM (kg) in rugby union. The black circle represents the summary (mean ± 95% CI) for each sub-group. The heterogeneity of each sub-group was senior elite backs ($I^2 = 74.0\%$, $Q = 23.0$, $\tau^2 = 0.8$, df = 6), senior elite forwards ($I^2 = 71.0\%$, $Q = 20.6$, $\tau^2 = 1.7$, df = 6), senior sub-elite backs ($I^2 = 96.5\%$, $Q = 57.2$, $\tau^2 = 18.3$, df = 2), and senior sub-elite forwards ($I^2 = 95\%$, $Q = 40.3$, $\tau^2 = 33.2$, df = 2).

3.1.3 Percentage fat mass

Backs

%FM was significantly lower in senior elite backs (11.4%, 95% CI: 10.5 to 12.3%, $n = 9$) than senior sub-elite backs (13.4%, 95% CI: 12.0 to 14.9%, $n = 14$) ($p = 0.015$). Senior elite backs also had significantly lower %FM than junior elite backs (14.0%, 95% CI: 13.4 to 14.7%, $n = 2$) ($p < 0.001$). There was no significant difference in

%FM between junior elite backs and junior sub-elite backs (13.9%, 95% CI: 8.8 to 19.0%, *n* = 2) (*p* = 0.957). There was no significant difference between senior sub-elite and junior sub-elite backs (*p* = 0.789). Sensitivity analysis revealed minor changes only, and these changes did not substantially alter the overall mean difference.

Forwards

%FM was significantly lower in senior elite forwards (15.3%, 95% CI: 14.1 to 16.5%, *n* = 9) than senior sub-elite forwards (17.7%, 95% CI: 16.2 to 19.2%, *n* = 14) (*p* = 0.018). Senior elite forwards had significantly lower %FM than junior elite forwards (18.6%, 95% CI: 17.7 to 19.6%, *n* = 2) (*p* < 0.001). There was no significant difference in %FM between junior elite and sub-elite forwards (18.2%, 95% CI: 10.5 to 25.9%, *n* = 2) (*p* = 0.901). There was no significant difference between senior sub-elite forwards and junior sub-elite forwards (*p* = 0.927).

Insert Figure 3

Figure 3: Forest plot of study means and sub-group summaries (means ± 95% confidence intervals [CIs]) for studies evaluating %FM in rugby union. The black circle represents the summary (mean ± 95% CI) for each sub-group. The heterogeneity of each sub-group was senior elite backs (I^2 = 92.4%, Q = 105.7, τ^2 = 1.4, df = 8), senior elite forwards (I^2 = 95.4%, Q = 174.4, τ^2 = 3.2, df = 8), senior sub-elite backs (I^2 = 93.0%, Q = 185.3, τ^2 = 6.5, df = 13), senior sub-elite forwards (I^2 = 90.3%, Q = 134.3, τ^2 = 7.1, df = 13), junior elite backs (I^2 = 27.5%, Q = 1.4, τ^2 = 0.1, df = 1), junior elite forwards (I^2 = <0.5%, Q = 0.1, τ^2 = <0.5, df = 1), junior sub-elite backs (I^2 = 98.5%, Q = 68.5, τ^2 = 13.3, df = 1), and junior sub-elite forwards (I^2 = 88.0%, Q = 8.4, τ^2 = 27.5, df = 1).

3.1.4 Sum of seven-site skinfolds

Backs

Sum of seven-site skinfolds (7SF) was significantly lower in senior elite backs (56.4 mm, 95% CI: 51.5 to 61.3 mm, *n* = 5) than senior sub-elite backs (68.3 mm, 95% CI: 61.7 to 74.8 mm, *n* = 1) (*p* = 0.004). The sum of SF7 of junior backs was not assessed in any of the included studies. Sensitivity analysis revealed minor changes only, and these changes did not substantially alter the overall mean difference.

Forwards

SF7 was significantly lower in senior elite forwards (78.7 mm, 95% CI: 72.3 to 85.1 mm, *n* = 5) than senior sub-elite forwards (99.3 mm, 95% CI: 87.9 to 110.7 mm, *n* = 1) (*p* = 0.002). The sum of SF7 of junior forwards was not assessed in any of the included studies. Sensitivity analysis revealed minor changes only, and these changes did not substantially alter the overall mean difference.

Insert Figure 4

Figure 4: Forest plot of study means and sub-group summaries (means ± 95% confidence intervals [CIs]) for studies evaluating SF7 (mm) in rugby union. The black circle represents the summary (mean ± 95% CI) for each sub-group. The heterogeneity of each sub-group was senior elite backs ($I^2 = 85.5\%$, Q = 27.6, $\tau^2 = 25.3$, df = 4) and senior elite forwards ($I^2 = 73.2\%$, Q = 14.9, $\tau^2 = 37.8$, df = 4).

3.1.5 Sum of four-site skinfolds

Backs

Sum of four-site skinfolds (4SF) was significantly lower in senior elite backs (26.4 mm, 95% CI: 24.4 to 28.4 mm, *n* = 1) than senior sub-elite backs (44.1 mm, 95% CI: 40.2 to 47.9 mm, *n* = 2) (*p* = <0.001). The 4SF of junior backs was not assessed in any of the included studies. Sensitivity analysis revealed minor changes only, and these changes did not substantially alter the overall mean difference.

Forwards

4SF was significantly lower in senior elite forwards (36.2 mm, 95% CI: 31.3 to 41.1 mm, *n* = 1) than senior sub-elite forwards (62.5 mm, 95% CI: 57.2 to 67.8 mm, *n* = 2) (*p* = <0.001). The sum of 4SF of junior forwards was not assessed in any of the included studies. Sensitivity analysis revealed minor changes only, and these changes did not substantially alter the overall mean difference.

Insert Figure 5

Figure 5: Forest plot of study means and sub-group summaries (means ± 95% confidence intervals [CIs]) for studies evaluating SF4 (mm) in rugby union. The black circle represents the summary (mean ± 95% CI) for each sub-group. The heterogeneity of each sub-group was senior sub-elite backs ($I^2 = <0.05\%$, Q = 0.4, $\tau^2 = <0.05$, df = 1) and senior sub-elite forwards ($I^2 = 17.9\%$, Q = 1.2, $\tau^2 = 3.3$, df = 1).

3.1.6 Sum of eight-site skinfolds

Backs

Eight-site skinfolds (8SF) was significantly lower in senior elite backs (72.5 mm, 95% CI: 67.2 to 77.7 mm, *n* = 2) than senior sub-elite backs (90.9 mm, 95% CI: 80.3 to 101.5 mm, *n* = 2) (*p* = 0.002). No difference was observed between senior elite backs and junior elite backs (71.0 mm, 95% CI: 63.1 to 78.9 mm, *n* = 1) (*p* = 0.766). The sum of 8SF of junior sub-elite backs was not assessed in any of the included studies.

Forwards

8SF was significantly lower in senior elite forwards (102.1 mm, 95% CI: 94.3 to 109.9 mm, *n* = 2) than senior sub-elite forwards (126.9 mm, 95% CI: 112.7 to 141.0 mm, *n* = 2) (*p* = 0.003). No difference was observed between senior elite forwards and junior elite forwards (106.0 mm, 95% CI: 93.7 to 118.4 mm, *n* = 1) (*p* = 0.599). The sum of 8SF of junior sub-elite forwards was not assessed in any of the included studies.

Insert Figure 6

Figure 6: Forest plot of study means and sub-group summaries (means ± 95% confidence intervals [CIs]) for studies evaluating SF8 (mm) in rugby union. The black circle represents the summary (mean ± 95% CI) for each sub-group. The heterogeneity of each sub-group was senior elite backs ($I^2 < 0.05\%$, Q = 0.8, $\tau^2 < 0.01$, df = 1), senior elite forwards ($I^2 < 0.05\%$, Q = 0.7, $\tau^2 < 0.001$, df = 1), senior sub-elite backs ($I^2 < 0.05\%$, Q = 0.2, $\tau^2 < 0.01$, df = 1), and senior sub-elite forwards ($I^2 = 24.58\%$, Q = 1.3, $\tau^2 = 26.6$, df = 1).

3.1.7 Bone mineral content

Backs

There was no significant difference in BMC between senior elite backs (3732 g, 95% CI: 3277 to 4189 g, *n* = 5) and senior sub-elite backs (3401 g, 95% CI: 3138 to 3662 g, *n* = 3) (*p* = 0.215). The BMC of junior elite or sub-elite backs was not assessed in any of the included studies. Sensitivity analysis revealed that the removal of Higham et al. (2014) from senior elite backs (3982 g, 95% CI: 3663 to 4301 g, *n* = 4) caused the comparison with senior sub-elite backs to become significant (*p* = 0.006).

Forwards

There was no significant difference in BMC between senior elite forwards (4283 g, 95% CI: 3903 to 4664 g, *n* = 5) and senior sub-elite forwards (3998 g, 95% CI: 3774 to 4223 g, *n* = 3) (*p* = 0.204). The BMC of junior elite or sub-elite forwards was not assessed in any of the included studies. Sensitivity analysis revealed the removal of Higham et al. (2014) from senior elite forwards (4422 g, 95% CI: 4310 to 4534 g, *n* = 4) caused the comparison with senior sub-elite forwards to become significant (*p* = 0.001).

Insert Figure 7

Figure 7: Forest plot of study means and sub-group summaries (means ± 95% confidence intervals [CIs]) for studies evaluating BMC (g) in rugby union. The black circle represents the summary (mean ± 95% CI) for each sub-group. The heterogeneity of each sub-group was senior elite backs ($I^2 = 97.7\%$, Q = 175.0, $\tau^2 = 263044.0$, df = 4), senior elite forwards ($I^2 = 96.5\%$, Q = 114.5, $\tau^2 = 180062$, df = 4), senior sub-elite backs ($I^2 = 93.5\%$, Q = 30.6, $\tau^2 = 49506.9$, df = 2), and senior sub-elite forwards ($I^2 = 90.4\%$, Q = 20.8, $\tau^2 = 35065.5$, df = 2).

3.2 Rugby league

3.2.1 Fat Free Mass

Backs

FFM was significantly higher in senior elite backs (71.5 kg, 95% CI: 70.6 to 72.4 kg, $n = 3$) than senior sub-elite backs (67.8 kg, 95% CI: 66.2 to 69.5 kg, $n = 2$) ($p < 0.001$). There was no significant difference between senior elite backs and junior elite backs (70.3 kg, 95% CI: 68.7 to 71.9 kg, $n = 1$) ($p = 0.200$). The FFM of junior sub-elite backs was not assessed in any of the included studies. Sensitivity analysis revealed minor changes only, and these changes did not substantially alter the overall mean difference.

Forwards

FFM was significantly higher in senior elite forwards (77.2 kg, 95% CI: 76.4 to 78.0 kg, $n = 3$) than senior sub-elite forwards (74.7 kg, 95% CI: 72.8 to 76.5 kg, $n = 2$) ($p = 0.010$). Senior elite forwards also had a significantly greater FFM than junior elite forwards (73.3 kg, 95% CI: 71.8 to 74.8 kg, $n = 1$) ($p < 0.001$). The FFM of junior sub-elite forwards was not assessed in any of the included studies. Sensitivity analysis revealed minor changes only, and these changes did not substantially alter the overall mean difference.

Insert Figure 8

Figure 8: Forest plot of study means and sub-group summaries (means ± 95% confidence intervals [CIs]) for studies evaluating FFM (kg) in rugby league. The black circle represents the summary (mean ± 95% CI) for each sub-group. The heterogeneity of each sub-group was senior elite backs ($I^2 = 75.4\%$, $Q = 18.1$ $\tau^2 = 4.7$, df = 2), senior elite forwards ($I^2 = = 40.6\%$, $Q = 3.3$, $\tau^2 = 0.6$, df = 2), senior sub-elite backs ($I^2 = <0.05\%$, $Q = 0.7$, $\tau^2 = <0.05$, df = 1), and senior sub-elite forwards ($I^2 = <0.05\%$, $Q = 0.5$, $\tau^2 = <0.05$, df = 1).

3.2.2 Absolute fat mass

Backs

Absolute FM was significantly lower in senior elite backs (12.0 kg, 95% CI: 10.6 to 13.3 kg, $n = 3$) than senior sub-elite backs (18.2 kg, 95% CI: 16.2 to 20.2 kg, $n = 1$) ($p < 0.001$). There was no significant difference in absolute FM between senior elite backs and junior elite backs (13.7 kg, 95% CI: 12.1 to 15.3 kg, $n = 1$) ($p = 0.110$). The absolute FM of junior sub-elite backs was not assessed in any of the included studies. Sensitivity analysis revealed minor changes only, and these changes did not substantially alter the overall mean difference

Forwards

Absolute FM was significantly lower in senior elite forwards (15.6 kg, 95% CI: 14.4 to 16.7 kg, *n* = 3) than senior sub-elite forwards (20.1 kg, 95% CI: 18.4 to 21.8 kg, *n* = 1) (*p* < 0.001). Senior elite forwards also had significantly lower absolute FM than junior elite forwards (19.3 kg, 95% CI: 17.7 to 20.9 kg, *n* = 1) (*p* <0.001). The absolute FM of junior sub-elite forwards was not assessed in any of the included studies. Sensitivity analysis revealed minor changes only, and these changes did not substantially alter the overall mean difference

Insert Figure 9

Figure 9: Forest plot of study means and sub-group summaries (means ± 95% confidence intervals [CIs]) for studies evaluating FM (kg) in rugby league. The black circle represents the summary (mean ± 95% CI) for each sub-group. The heterogeneity of each sub-group was senior elite backs ($I^2 = 87.2\%$, Q = 15.6, $\tau^2 = 1.9$, df = 2) and senior elite forwards ($I^2 = 72.8\%$, Q = 7.4, $\tau^2 = 1.1$, df = 2).

3.2.3 Percentage fat mass

Backs

%FM was significantly lower in senior elite backs (13.4%, 95% CI: 11.6 to 15.1%, *n* = 4) than senior sub-elite backs (17.5%, 95% CI: 14.6 to 20.4%, *n* = 3) (*p* = 0.020). No significant difference was observed between senior elite backs and junior elite backs (13.7%, 95% CI: 9.8 to 17.7%, *n* = 2) (*p* = 0.860). The %FM of junior sub-elite backs was not assessed in any of the included studies. Sensitivity analysis revealed that the removal of Jones et al. (2015) from senior sub-elite backs caused the relationship with senior elite backs to become non-significant (*p* = 0.116).

Forwards

%FM was significantly lower in senior elite forwards (15.8%, 95% CI: 14.0% to 17.6%, *n* = 4) than senior sub-elite forwards (20.0%, 95% CI: 18.8 to 21.3%, *n* = 3) (*p* = <0.001). There was no significant difference in %FM between senior elite forwards and junior elite forwards (17.9%, 95% CI: 14.3 to 21.6%, *n* = 2) (*p* = 0.310). The %FM of junior sub-elite forwards was not assessed in any of the included studies. Sensitivity analysis revealed minor changes only, and these changes did not substantially alter the overall mean difference.

Insert Figure 10

Figure 10: Forest plot of study means and sub-group summaries (means ± 95% confidence intervals [CIs]) for studies evaluating %FM in rugby league. The black circle represents the summary (mean ± 95% CI) for each sub-group. The heterogeneity of each sub-group was senior elite backs ($I^2 = 91.3\%$, Q = 51.5, $\tau^2 = 2.9$, df = 3), senior sub-elite forwards ($I^2 = 92.5\%$, Q = 39.8, $\tau^2 = 3.2$, df = 3), senior sub-elite backs ($I^2 = 93.3\%$, Q = 30.0, $\tau^2 = 6.0$, df = 2), senior sub-elite forwards ($I^2 = 93.5\%$, Q = 15.4, $\tau^2 = 6.4$, df = 2), junior elite backs ($I^2 = 94.9\%$, Q = 19.4, $\tau^2 = 7.6$, df = 1), and junior elite forwards ($I^2 = 59.0\%$, Q = 15.4, $\tau^2 = 6.4$, df = 1).

3.2.4 Sum of four-site skinfolds

Backs

Sum of four-site skinfolds (4SF) were not significantly different between senior elite backs (40.3 mm, 95% CI: 37.9 to 42.7 mm, $n = 2$) and senior sub-elite backs (40.3 mm, 95% CI: 34.4 to 46.3 mm, $n =3$) ($p = 0.980$). Senior elite backs had higher 4SF than junior elite backs (33.4 mm, 95% CI: 30.3 to 36.5 mm, $n = 3$) ($p = 0.001$). There was no significant difference between junior elite backs and junior sub-elite backs (34.2 mm, 95% CI: 32.6 to 35.8 mm, $n =1$) ($p = 0.660$). Sensitivity analysis revealed minor changes only, and these changes did not substantially alter the overall mean difference

Forwards

4SF were not significantly different between senior elite forwards (58.4 mm, 95% CI: 48.6 to 68.3 mm, $n = 2$) and senior sub-elite forwards (50.6 mm, 95% CI: 47.8 to 53.4 mm, $n = 3$) ($p = 0.130$). Senior elite forwards had higher 4SF than junior elite forwards (39.7 mm, 95% CI: 32.2 to 47.1 mm, $n = 3$) ($p = 0.003$). Junior elite forwards had significantly lower 4SF than junior sub-elite forwards (48.4 mm, 95% CI, 45.7 to 51.2 mm, $n = 1$) ($p = 0.030$). Sensitivity analysis revealed minor changes only, and these changes did not substantially alter the overall mean difference.

Insert Figure 11

Figure 11: Forest plot of study means and sub-group summaries (means ± 95% confidence intervals [CIs]) for studies evaluating SF4 (mm) in rugby league. The black circle represents the summary (mean ± 95% CI) for each sub-group. The heterogeneity of each sub-group was senior elite backs ($I^2 = 14.0\%$, $Q = 1.2$, $\tau^2 = 0.6$, df = 1), senior elite forwards ($I^2 = 73.9\%$, $Q = 3.8$, $\tau^2 = 38.0$, df = 1), senior sub-elite backs ($I^2 = 96.1\%$, $Q = 25.9$, $\tau^2 = 29.6$, df = 2), senior sub-elite forwards ($I^2 = 81.9\%$, $Q = 11.1$, $\tau^2 = 4.8$, df = 2), junior elite backs ($I^2 = 87.3\%$, $Q = 15.7$, $\tau^2 = 5.1$, df = 2), and junior elite forwards ($I^2 = 90.7\%$, $Q = 21.5$, $\tau^2 = 35.8$, df = 2).

3.2.5 Sum of seven-site skinfolds

Backs

Sum of seven-site skinfolds (7SF) were not significantly different between senior elite backs (54.0 mm, 95% CI: 51.1 to 57.0 mm, $n = 2$) and junior elite backs (57.1 mm, 95% CI: 54.2 to 59.9 mm, $n = 2$) ($p = 0.535$). The 7SF of senior and junior sub-elite backs was not assessed in any of the included studies.

Forwards

7SF were not significantly different between senior elite forwards (62.8 mm, 95% CI: 60.1 to 65.4 mm, *n* = 2) and junior elite forwards (75.7 mm, 95% CI: 44.7 to 106.6 mm, *n* = 2) (*p* = 0.495). The 7SF of senior and junior sub-elite backs was not assessed in any of the included studies.

Insert Figure 12

Figure 12: Forest plot of study means and sub-group summaries (means ± 95% confidence intervals [CIs]) for studies evaluating SF7 (mm) in rugby league. The black circle represents the summary (mean ± 95% CI) for each sub-group. The heterogeneity of each sub-group was senior elite backs (I^2 = 60.9%, Q = 2.6, τ^2 = 7.3, df = 1), senior elite forwards (I^2 = 92.9%, Q = 14.0, τ^2 = 51.97, df = 1), junior elite backs (I^2 = 96.1%, Q = 25.8, τ^2 = 114.2, df = 1), and junior elite forwards (I^2 = 97.7%, Q = 44.3, τ^2 = 488.0, df = 1).

3.2.6 Bone mineral content

Backs

BMC was significantly higher in senior elite backs (4160 g, 95% CI: 4076 to 4245 g, *n* = 2) than senior sub-elite backs (3971 g, 95% CI: 3848 to 4094 g, *n* = 1) (*p* = 0.010). There was no difference between senior elite backs and junior elite backs (4009 g, 95% CI: 3870 to 4147 g, *n* = 1) (*p* = 0.070). The BMC of junior sub-elite backs was not assessed in any of the included studies. Sensitivity analysis revealed minor changes only, and these changes did not substantially alter the overall mean difference

Forwards

There was a trend towards BMC being higher in senior elite forwards (4469 g, 95% CI: 4381 to 4557 g, *n* = 2) than senior sub-elite forwards (4302 g, 95% CI: 4151 to 4453 g, *n* = 1) (*p* = 0.060). Senior elite forwards had significantly greater BMC than junior elite forwards (4157 g, 95% CI: 4004 to 4310 g, *n* = 1) (*p* <0.001). The BMC of junior sub-elite forwards was not assessed in any of the included studies. Sensitivity analysis revealed minor changes only, and these changes did not substantially alter the overall mean difference

Insert Figure 13

Figure 13: Forest plot of study means and sub-group summaries (means ± 95% confidence intervals [CIs]) for studies evaluating BMC (g) in rugby league. The black circle represents the summary (mean ± 95% CI) for each sub-group. The heterogeneity of each sub-group was senior elite backs (I^2 = <0.05%, Q = 0.6, τ^2 = <0.05, df = 1) and senior elite forwards (I^2 = 7.1, Q = 0.3, τ^2 = < 0.05, df = 1)

4 Discussion

4.1 Overview of the meta-analysis

The purpose of this meta-analysis was to provide a comprehensive overview of body composition across RU and RL and to investigate differences between age groups and playing standards. The primary outcomes of the study revealed that FFM is higher in senior than junior players (age), and elite than non-elite (standard) in RU players and RL forwards. No difference in FFM was found in RL elite backs (senior *vs.* junior). The findings for FM were less clear, with no differences found between age or standard in either RU positional group. In RL, senior elite players had lower FM than sub-elite, with no difference found between senior and junior elite backs, but senior forwards had lower FM than junior elite forwards. Increases in FFM and negligible differences in FM, resulted in senior elite players of both rugby codes and positional groups having reduced %FM. No differences were found between senior elite or sub-elite players for BMC, apart from RL backs where senior elite had higher BMC than sub-elite players. Consequently, FFM accrual may be a key distinguishing factor between age and playing standard in RU and RL as opposed to other body composition measures (FM, BMC, or %FM).

4.2 Fat-free mass

The findings of this meta-analysis suggest that RU senior elite forwards and backs have significantly higher FFM than senior sub-elite and junior elite forwards and backs. Similarly, rugby league senior elite forwards had significantly higher FFM than senior sub-elite and junior elite forwards, while RL senior elite backs had significantly higher amounts of FFM than senior sub-elite, but not junior elite backs. The explanation for the reported differences in FFM is likely due to elite senior players being full-time professionals, whereas sub-elite players are more likely to be part-time [80]. This allows elite players to dedicate a greater amount of time to training, nutrition and other lifestyle factors which are likely to benefit FFM accrual [20]. Furthermore, access to full time club practitioners (strength and conditioning coaches / nutritionists) is more likely within a professional environment [74]. Alternatively, it must be acknowledged that elite senior players may possess a genetic advantage for the accrual of FFM, which has enabled them to gain elite status. The cross-sectional nature of the data included in this study means that direct causal relationships cannot be established, but it is most likely to be due to a combination of both genetic advantage and advanced training regimes.

The higher FFM in elite senior RL and RU forwards is expected to provide an advantage during match play. Forwards in both codes are required to undertake a large number of collisions per game [14, 81], in which they are required be dominant and advance by as many metres as possible. Consequently, higher amounts of FFM should allow players to exert greater forces [9], particularly when static (scrummaging) or wrestling (in a ruck or tackle). In non-static exertions of force, linear momentum, the product of mass and velocity, also has logical benefits upon collisions [33, 8]. An increase in FFM and subsequent increase in overall mass, would increase momentum on the condition that velocity remains constant. This is suggested to improve ball carrying at the gain line, increasing the ability to overcome opposing defenders, and greater impact forces in tackles [82]. It is logical to assume that an increase in FFM as opposed to FM, would not negatively affect velocity [8], however, this remains speculative without knowing a players acceleration ability [20].

Senior elite RU players and RL forwards had significantly higher amounts of FFM than junior elite players of the same position. A key role of professional rugby academies is to facilitate the transition of players to the senior elite squads. It is essential to physically prepare academy players for increased training and match demands at senior level [83, 84]. The lower levels of FFM in junior elite players may be due to musculoskeletal immaturity, minimal time within the academy, or low relative training age [76]. However, it is also likely to be hampered by uniquely high energy requirements [85-87], which are the result of numerous training sessions and matches per week [88], combined with growth and other life demands (full-time education etc.). Collisions within games and training may further hinder FFM accrual due to elevations in resting metabolic rate for up to 72 hours after collision-based activity, thereby challenging the attainment of a positive energy balance [89]. Hypertrophy is multifaceted but an appropriate stimulus from resistance training is undoubtedly required [90], yet, this is often restricted due to time and facilities for adolescent rugby players [88]. Accordingly, it is imperative that practitioners and coaches are aware of the unique energetic demands placed upon professional young collision-sport athletes during intensified training periods in order to provide an appropriate stimulus and nutritional plan for FFM development.

4.3 Fat mass

Absolute FM did not differ between age or standard in RU for either positional group. These findings suggest that the higher body mass of senior elite players [91] are likely to be the result of greater FFM, rather than differences in FM. Consequently, coaches and practitioners may benefit most from a focus on FFM accrual, rather than FM reductions. This is an important consideration based on the frequent use of body fat targets for players and previous concerns over the effects of FM on acceleration and energetic cost of movement [92, 93].

In RL, senior elite backs and forwards had lower FM than senior sub-elite players, and senior elite forwards had lower FM than junior elite forwards. A greater overall body mass may have potential benefits in collisions due to an increased linear momentum, however, increased FM may also negatively affect velocity and acceleration, causing detrimental effects upon momentum [33, 95]. Given the high intensity activities and locomotor demands of RL match play [96], a higher amount of FM may negatively affect other match demands. Junior RL forwards had an increased amount of FM compared to senior elite forwards, which may have desirable consequences on momentum and successful collisions in the absence of sufficient FFM development [18] [33, 82]. However, an increase in match demands from academy to professional RL [97] as well as continued development of FFM [18] may result in the increased FM becoming detrimental as players progress from junior elite (academy) to senior elite (professional), thus the shift to lower levels of FM.

Senior elite players had greater 4SF than junior elite players for both positional groups, and junior elite forwards had lower 4SF than junior sub-elite forwards. However, no difference was found in 7SF between senior playing standards or elite playing standards for either positional group. Skinfold anthropometry is often used as an applied measure of body composition due to the low cost and speed of measurement [98]. Typically, within RL research 4SF is used, as a measure of subcutaneous fat at four specific points and often a proxy of FM [99]. Results from this meta-analysis suggest that FM decreases from senior sub-elite to elite playing standard, however, this is contrary to the findings of 4SF. Furthermore, FM decreases from junior to senior elite forwards, also contrary to the findings of 4SF and 7SF. Therefore, this may suggest that 4SF and 7SF may not be an appropriate measure of body composition in RL. The accuracy of skinfold anthropometry is inherently linked to the skill and experience of the practitioner[100], which may also explain the poor relationship between SF and FM.

In RU, senior elite players had significantly less 8SF, 7SF, and 4SF than senior sub-elite of both positional groups. Results from this meta-analysis observed no difference in absolute FM between RU senior elite and sub-elite. Subsequently, this would suggest skinfolds are not an appropriate measure of absolute FM in senior RU players. Skinfold anthropometry does offer an applied measure of monitoring body composition [98], however, practitioners should appreciate that the sum of skinfold measures may not act as an accurate assessment of absolute FM in senior RU players.

4.4 Percentage fat mass

In RU, senior elite players had lower %FM than junior elite and senior sub-elite players. Despite having negligible differences in absolute FM between age and playing standard, an increased amount of FFM in senior elite cause a reduced percentage of FM to overall mass. In RL, %FM was significantly lower in senior elite than sub-elite players. No difference was found between junior or senior elite in either backs or forwards. Although not significant, %FM did display a trend towards being lower in senior over junior elite forwards. Percentage FM is often used within an applied rugby environment [101] as it can be calculated from via skinfold equations [102]. However, the ability of skinfold equations to accurately estimate %FM within a rugby population has been questioned [103]. Subsequently, practitioners are encouraged to determine absolute measures of body composition and, where possible, prioritise the assessment of FFM. Ideally, this would be through criterion assessment methods (DXA) ensuring best practise protocol of assessment [104].

4.5 Bone mineral content

Bone mineral content was only assessed in a small number of included studies due to the required assessment technique (DXA). No clear differences were found in BMC between senior standards in either RU positional group. RL senior elite backs had greater amount of BMC than senior sub-elite backs, and senior elite forwards had greater amounts of BMC than junior elite forwards. A high BMC is desirable as it is likely to restrict the possibility of skeletal fractures [105]. Increased FFM is associated with greater BMC due to greater torque being acted upon the bone [11]. Although senior elite players had considerably greater FFM than sub-elite players, it would appear that a ceiling may exist to the amount FFM and rugby training that can influence BMC. Negligible differences within senior populations (excluding RL backs) is also likely due to both groups having reached skeletal maturity [106]. This would suggest that rugby training assists in the development of BMC. Given that limited studies exist within junior RU and RL that measure BMC, this represents a direction for future research.

5 Limitations

This is the first systematic review and meta-analysis to comprehensively analyse body composition within both rugby codes, however, some limitations should be acknowledged. Research into body composition in rugby is an emerging field and gaps within the literature still exist, particularly within junior players. This meta-analysis aims to counteract this by combining papers for analysis, however, the statistical power of the analysis must be considered when interpreting the results. As few as one study were included in some subgroups for analysis, and therefore may be underpowered. Included studies used varying methods to assess body composition, despite the potential for variance between methods, a meta-analysis would not have been possible without the combination of them. It must be assumed that necessary steps were taken to ensure methodological rigor in each included paper. Studies were excluded if data were not split by position, due to the known differences between backs and forwards. This potentially excluded some literature within the area of study. Finally, despite an extensive search returning 3,542 records, it cannot be guaranteed that the search was completely exhaustive of the relevant literature, however, reference lists from relevant reviews were also assessed for missing papers.

6 Conclusion

This meta-analysis examined the differences in body composition by age and playing standard in both rugby codes. FFM was found to be significantly higher in senior elite cohorts than senior sub-elite or junior elite cohorts for both codes and playing positions, except RL backs. In RU, insignificant differences were found in FM for all groups between age and playing standard. In RL, senior elite forwards had reduced FM compared to senior sub-elite and junior elite forwards. In parallel with these findings, increased FFM in senior elite groups caused a reduced %FM in comparisons to sub-elite or junior elite groups. This review highlights the importance of FFM as the main distinguishing factor in body composition between age groups and playing standard in both codes. Consequently, the accretion of FFM should be prioritised by practitioners and coaches working with athletes who wish to transition to senior elite playing standards.

7 Practical recommendations

1. Fat free mass appears to be a key body composition variable in distinguishing between playing level and age groups in RU and RL. This is likely due to the relationship between body composition, physical qualities and the match demands of both rugby codes.
2. Practitioners and coaches should be mindful around the importance of FFM and conscious that FM may be less important.
3. Dieticians & Sports Nutritionists should consider how best to augment FFM development. Considering the increased metabolic costs of a collision sport and how to maximise nutritional intake through behavioural & nutritional strategies.

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