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Section: Original Research

Article Title: Longitudinal Changes in Body Composition Assessed Using DXA and Surface Anthropometry Show Good Agreement in Elite Rugby Union Athletes

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Longitudinal changes in body composition assessed using DXA and surface anthropometry show good agreement in elite rugby union athletes

Submission type: Original research

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Abstract

Rugby union athletes have divergent body composition based on the demands of their on-field playing position and ethnicity. With an established association between physique traits and positional requirements, body composition assessment is routinely undertaken. Surface anthropometry and dual-energy X-ray absorptiometry (DXA) are the most common assessment techniques utilised, often undertaken synchronously. This study aims to investigate the association between DXA and surface anthropometry when assessing longitudinal changes in fat free mass (FFM) and fat mass (FM) in rugby union athletes. Thirty-nine elite male rugby union athletes (age 25.7 ± 3.1 years; stature 187.6 ± 7.7 cm; mass 104.1 ± 12.2 kg) underwent assessment via DXA and surface anthropometry multiple times over three consecutive international seasons. Changes in the lean mass index (LMI), an empirical measure to assess proportional variation in FFM, showed large agreement with changes in DXA FFM (r=0.54, SEE=1.5%, P<0.001); the strength of association stronger amongst forwards (r=0.63) compared with backs (r=0.38). Changes in the sum of 7 skinfolds (S7SF) showed very large agreement with changes in DXA FM (r=0.73, SEE=5.8%, P<0.001), with meaningful differences observed regardless of ethnicity (Caucasians r=0.75; Polynesians r=0.62). The LMI and S7SF were able to predict the direction of change in FFM and FM, respectively, 86% and 91% of the time when DXA change was >1kg. Surface anthropology measures provide a robust indication of the direction of change in FFM and FM, although caution may need to be applied when interpreting magnitude of change, particularly with FM.

Keywords: fat mass, fat free mass, body fat, skinfolds.
Introduction

Rugby union is an internationally-competitive field-based team sport, in which athletes from a wide variety of ethnic backgrounds participate. Given the unique and divergent physiological demands of the positional packs (Austin et al., 2011; Duthie et al., 2003; Quarrie & Wilson, 2000), distinct differences in body composition exist. Forwards have consistently been shown to be heavier, taller, and possess more fat free mass (FFM) and fat mass (FM), whilst backs display proportionally lower body fat (Lees et al., 2017; Zemski et al., 2015). Optimal body composition assists athletes in executing the distinctive on-field requirements associated with their specific positions (Carlson et al., 1994; Fontana et al., 2015). Given this, the monitoring of physique traits in rugby union has become routine.

Anecdotally, there is an increasing proportion of rugby union participants at the elite level of Polynesian descent. Polynesians have been shown to possess greater relative FFM and less FM compared to Caucasians (Craig et al., 2003; Rush et al., 2004; Swinburn et al., 1996), physique traits that predispose them to morphological optimisation in rugby. Polynesians also display differences in regional adiposity, a trait common to non-athletic individuals (Rush et al., 2009) as well as elite rugby athletes (Zemski et al., 2015). The impact these differences in regional physique distribution have on the selection and interpretation of different body composition assessment techniques has not previously been explored.

Anthropometry is the scientific procedure of acquiring surface anatomical dimensional measurements, including skinfolds, and is an easily accessible, inexpensive, mobile and robust method of body composition assessment utilised in rugby union (Ackland et al., 2012; Duthie et al., 2003). It is minimally impacted by client presentation when International Society for the Advancement of Kinanthropometry (ISAK) protocols are followed (Kerr et al., 2017). Recommended practice is to assess changes in FM via variations in skinfolds, including sites from both the upper and lower body (Reilly et al., 1996). Changes in FFM can be indicated via
fluctuations in the lean mass index (LMI), which assesses within-athlete proportional changes in body mass adjusted for changes in the sum of seven skinfold thickness (S7SF; Slater et al., 2006). However, surface anthropometry measures are unable to accurately quantify absolute (Doran et al., 2014; Reilly et al., 2009; Zemski et al., 2018), or changes in, FFM and FM (Silva et al., 2009). Given this limitation, anthropometric data is increasingly being complemented by other measures.

Dual-energy X-ray absorptiometry (DXA) is able to quantify whole body and regional bone mass, FFM, and FM, and is becoming more accessible and popular as a technique to monitor body composition in athletic populations (Meyer et al., 2013; Nana et al., 2015). However, DXA does have some limitations for application in an elite sport environment, including the logistical issues associated with following best practice protocols, equipment availability, cost, and the limits on assessment frequency to minimize radiation exposure (Nana et al., 2015; Orchard et al., 2005). As such, it is common practice for DXA to be utilised in conjunction with surface anthropometry to monitor body composition. A recent study found LMI was good at estimating DXA derived FFM changes in a relatively homogenous population of rugby league athletes (Delaney et al., 2016). However, the ability of anthropometric measures to infer absolute body composition changes in elite populations of athletes with widely varying physique traits remains relatively untested. Specifically, it is unclear whether changes in skinfolds are equally reflective of whole body changes in FFM and FM in both Caucasian and Polynesian athletes given the different regional FM patterning observed (Zemski et al., 2015). Moreover, as DXA has been shown to underestimate FM in some leaner populations (Prior et al., 2001; Toombs et al., 2012; Van Der Pleog et al., 2003; Williams et al., 2006), it is uncertain as to whether anthropometric changes are equally as reflective of DXA changes across the different positional groups, given the relative leanness of backs in comparison to forwards.
As DXA and surface anthropometry are often both used over the course of a season and/or an athlete’s career, an understanding of the interrelationship between the two assessment techniques is imperative when attempting to interpret body composition change longitudinally. The aim of this study is to investigate the association between DXA and surface anthropometry when measuring changes in FFM and FM in elite rugby union athletes, and to explore whether differences exist due to the physique traits of the athlete based on ethnicity and position.

**Methods**

**Participants**

Thirty-nine elite rugby union athletes were recruited via their involvement in the Australian national squad, the Wallabies. All participants provided informed consent to participate in the study, and the research was approved by the Human Research Ethics Committee at the University of the Sunshine Coast (EC00297, S/12/424).

At the time of consent, participants were requested to provide researchers with the ethnicity of their grandparents via open ended questions. It was made clear that this was optional and would not impact their involvement in the research or the national squad. As this study investigated the role of phenotype expression, grandparental heritage was chosen as in previous research (Zemski et al., 2015; Zemski et al., 2018). Participants were ascribed a specific ethnicity if three or more of their grandparents were of the same ethnicity.

**Experimental design**

Participants undertook routine body composition assessment via DXA and surface anthropometry over three consecutive international seasons. Participants were assessed between two and five times over this period with the variability due to selection, injury, and availability for international representation. Anthropometry and DXA measurements were generally undertaken within 48 hours of each other at each time point. Where this was not
logistically possible, the time frame between anthropology and DXA measurement never exceeded seven days. A repeated-measures approach was used to establish the parallel validity of DXA and surface anthropology measures.

**Surface anthropology**

An ISAK level 3 accredited anthropometrist with a technical error of measurement of 1.7% for S7SF took all measurements. Body mass was assessed using electronic scales (A&D Mercury, Adelaide, Australia) to 0.1 kg accuracy upon waking after an overnight fast with bladder voided. Stature was self reported to the nearest 1 cm. Skinfolds were assessed using Harpenden calipers (British Indicators, Hertfordshire, UK) to 0.1 mm accuracy on the same day waking body mass was assessed. All anthropometric equipment was calibrated as recommended by the manufacturers.

Skinfold measurements were made on the right side of the body using ISAK techniques previously described (Norton et al., 2006), with a S7SF calculated from measures of the triceps, subscapular, biceps, supraspinale, abdominal, mid-thigh, and medial calf skinfold sites. All measurements were undertaken in duplicate to establish within-day retest reliability. If the difference between the duplicate measures exceeded 4% for an individual skinfold, a third measurement was taken after all other measurements were completed. The mean of duplicate or median of triplicate measurements were used for all subsequent analysis. LMI was calculated using methods previously described (Duthie et al., 2006) using the equation below, with the exponent x set at 0.14 for forwards, and 0.13 for backs:

\[
LMI = \frac{\text{body mass (kg)}}{\text{sum of seven skinfolds}^x (\text{mm})}
\]

**Dual-energy X-ray absorptiometry (DXA)**

Measures were taken using a fan-beam DXA scanner (Hologic Discovery A, Hologic, Bedford, MA), with analysis performed using Apex 12.7.3 software (Hologic, Bedford, MA).
The scanner was calibrated daily using a phantom as per manufacturer guidelines for quality control purposes. All the scans were undertaken using the array mode.

Scanning protocols were implemented as per techniques previously described to maximise technical reliability and minimise error (Nana et al., 2015). Specifically, participants were scanned first thing in the morning prior to food, fluid, or exercise. Participants were requested to remove all metal items from their person, and lay supine on the scanning bed as still as possible for the duration of the scan. Participants were scanned wearing sports shorts, and those taller than the 196 cm area of the scanning bed (7 participants) undertook multiple scans (Evans et al., 2005). For positioning consistency, the same experienced and qualified technician performed all measurements using the NHANES positioning protocol previously described (Hangartner et al., 2013; NHANES, 2011), with the participants leg positioning standardised using a set width foot strap that was placed over both feet anterior to the lateral malleolus.

**Statistical methods**

All statistical procedures were performed with SPSS 22 (SPSS Inc., Chicago, Illinois, USA). Descriptive statistics were calculated and reported as mean ± standard deviation (SD) with a 95% confidence interval (95% CI). All measures used in the study were checked for normality, and as they were not normally distributed, subsequently log-transformed before analysis. For change scores, Spearman’s correlations (r) for nonparametric data were calculated, and the line of best fit was forced through the origin. As a result, the slope of this line represents the scaling factor for predicting percentage change in DXA FFM using surface anthropometry estimates, and the standard error of the estimate (SEE) was the prediction error. For correlations, coefficients were qualitatively ranked by magnitude (Hopkins, 2006), with the strength of correlation coefficients defined as trivial, $r < 0.1$; small, $0.1 \leq r < 0.3$; moderate,
0.3 ≤ r < 0.5; large, 0.5 ≤ r < 0.7; very large, 0.7 ≤ r < 0.9; almost perfect, 0.9 ≤ r < 1.0; and perfect, r = 1.0. Since not all players were present at all testing occasions, change scores were calculated for each available pairing of two unique time points for each participant.

**Results**

All 39 participants (age 25.7 ± 3.1 years; stature 187.6 ± 7.7 cm; mass 104.1 ± 12.2 kg) were able to be ascribed an ethnicity, with 26 identifying as Caucasian (17 forwards, 9 backs), and 13 (6 forwards, 7 backs) as Polynesian. A flow diagram describing the configuration of participants investigated is shown in Figure 1, with descriptive characteristics corresponding to the time point at which each individual presented with their highest LMI value presented in Table 1. The highest LMI value was used for consistency, as theoretically this was when the participants were in their peak physical condition. Significant differences were seen in all body composition characteristics between forwards and backs (P<0.001), whilst no differences were observed based on ethnicity. No differences were noted in any analyses undertaken based on whether the athletes undertook single versus multiple scans due to their stature exceeding the boundaries of the scanning bed.

Changes in DXA FFM and LMI showed a moderate to large agreement (Table 2, Figure 2), with minimal influence from ethnicity (Caucasians r=0.55; Polynesians r=0.51). However, the strength of association was stronger amongst forwards (r=0.63) compared to backs (r=0.38). The SEE for the prediction of change in DXA FFM ranged between 1.3–1.6% (Table 2). The LMI was able to predict the direction of change (increase or decrease) 74% of the time in all cases, and 86% of the time when the DXA FFM identified change was >1kg.

Changes in DXA FM and S7SF showed large to very large agreement (Table 3 and Figure 3). The difference in correlation based on position was minor (forwards r=0.72; backs r=0.76), whilst the difference based on ethnicity was more noteworthy (Caucasians r=0.75;
Polynesians r=0.62). The SEE for the prediction of change in DXA FM in all sub-categories ranged between 4.6–7.0%. The S7SF was able to predict the direction of change (increase or decrease) 83% of the time in all cases, and 91% of the time when the DXA FM identified change was >1kg.

Discussion

The primary finding of this study was that in elite rugby union athletes, surface anthropology derived measures appear suitable to track changes in DXA measures of FFM and FM. Specifically, LMI was suitable for both identifying the direction of change and tracking proportional changes in FFM, whilst S7SF was able to correctly identify the direction of change, but less accurately able to quantify the magnitude of change in FM. Additionally, the LMI was better able to predict proportional changes in FM amongst forwards compared to backs independent of ethnicity, whilst S7SF was better able to predict proportional change in FM amongst Caucasians in comparison to Polynesians.

The ability of the LMI to track proportional FFM change has varied in the literature, perhaps being impacted by the population under investigation. In an elite rugby league group, a higher correlation (r=0.69) was found than that in the present study (r=0.54) despite similar assessment techniques being used (Delaney et al., 2016). The unique heterogeneity of rugby union athletes based on size and ethnicity compared to their rugby league counterparts may explain the slightly lower agreement observed in the current study. Differences were identified between forwards (r=0.63, P<0.001) and backs (r=0.38, P=0.029) in regards to the ability of LMI to track longitudinal changes in DXA FFM. Although the association found in backs was low compared to forwards, it was similar to that previously reported in a group of elite rugby union athletes not differentiated by position (r=0.37; Slater et al., 2006). Given the relative leaniness of backs in comparison to forwards, the propensity of DXA overestimate FFM in
leaner populations (Prior et al., 2001; Toombs et al., 2012; Van Der Pleog et al., 2003; Williams et al., 2006) may explain this variation in agreement. In a study investigating the validity of a skinfold-based estimate of FFM changes in a steroid-enhanced population, the relationship reported was significantly higher than in this or the above mentioned studies (r=0.88) (van Marken Lichtenbelt et al., 2004). However, it is most likely a result of the comparatively large increase in FFM resulting from the intervention. In the present study, longitudinal variation of FFM according to LMI and DXA was found to be similar between ethnicities. The findings suggest that the LMI may not be able to detect small changes in FFM (<1.6% or ~1.5 kg in this population), and may be slightly less reliable for backs. However, in the majority of cases (83%) the LMI was able to indicate the change in direction of DXA FFM when changes were >1 kg, which is approximately the threshold for least significant change for DXA previously proposed in rugby union athletes (Barlow et al., 2015).

It is well established that skinfold based regression equations are not an effective way of estimating absolute body composition in rugby union (Zemski et al., 2018) or other sports (Doran et al., 2014; Reilly et al 2009), nor changes in body composition amongst athletes (Silva et al., 2009). For this reason, anthropometry regression equations were not used to assess change, instead utilising the S7SF as a comparison measure. This study found strong linear associations between the methodologies when assessing change in FM, with the S7SF able to predict the direction of change 83% of the time, or 91% when DXA FM change >1kg, which is approximately the threshold for least significant change previously reported in a similar population (Barlow et al., 2015). Despite this, the relative changes estimated by S7SF will be 4.6–7.0% different in magnitude from those measured by DXA, potentially due to questions raised about the reliability of DXA for assessing FM, particularly in lean individuals (Prior et al., 2001; Toombs et al., 2012; Van Der Pleog et al., 2003; Williams et al., 2006). A recent study found a typical error of 3.2% in DXA-estimated FM in resistance trained individuals.
with a body mass index (BMI; mass (kg) divided by stature (m) squared) >25 kg/m² (Kerr et al., 2017). Furthermore, poor validity (r=0.67, 90% CI=0.39–0.84) and reliability (CV%=17.2%, 90% CI=13.4 – 24.6) of DXA for quantifying FM in comparison to a whole-body phantom has been reported (Bilsborough et al., 2014). However, it is important to note the phantom used in this study had significantly lower proportions of FM in comparison to the athletes tested in that particular investigation. Interestingly, the agreement between skinfolds and DXA when assessing changes in body fat were lower for Polynesians (r=0.62) in comparison to Caucasians (r=0.75). This may be a result of the different regional body fat distribution Polynesian athletes display. In analysis previously undertaken by this group comparing specific DXA regions with skinfolds, it has been shown that Polynesians have higher relative measures from the trunk skinfold sites, yet lower relative DXA derived FM in the trunk region compared to Caucasians (Zemski et al., 2015). As such, it appears differences in ethnicity dictates the way region specific subcutaneous adiposity is distributed, and thus changes in specific skinfold sites may not equally reflect DXA regional change for Caucasians and Polynesians. Furthermore, ethnic differences in fat patterning may be impacted by the fact that surface anthropometry only quantifies subcutaneous adipose tissue (SAT), while DXA quantifies both SAT and visceral adipose tissue (VAT). Indeed, ethnicity has been shown to influence SAT to VAT ratios (Camhi et al., 2011; Carrol et al., 2008; Katzmarzyk et al., 2010), however; this has not been explored in Polynesian populations. In either case, changes in skinfold measurement may not as accurately reflect changes in whole body or regional FM for Polynesians, given the correlation value was found to be lower in this group compared to the Caucasians. This is an important consideration for sport science practitioners when interpreting changes in anthropometry. The findings suggest that although skinfolds are an excellent proxy for detecting the direction of changes in FM in comparison to DXA, they may not be able to accurately estimate the magnitude of changes.
As DXA is able to quantify regional and whole body tissue it has a number of benefits in sport science practice, including estimating nutritional requirements and tracking injury rehabilitation (Ackland et al., 2012). However, given the best practice recommendations for DXA, frequent scans are often logistically not feasible in elite athlete scheduling. Furthermore, the small amount of radiation exposure needs to be considered within the context of other imaging assessments undertaken by the athletes in this sport given the high incidence of injury (Fuller et al., 2008). As such, it is recommended that the frequency of DXA assessment is determined according to the likelihood that any change exceeds the measurement error (Nana et al., 2015), and if the results are likely to influence athlete management (Orchard et al., 2005). Therefore, being able to gain more timely information regarding longitudinal changes in body composition via surface anthropometry is of value, especially when this information is used to further refine interventions.

A limitation of this study was that although best practice guidelines for both DXA and surface anthropometry were followed at each assessment, due to the availability of the athletes and facilities it was not always possible to assess both DXA and surface anthropometry on the same day. On the majority of occasions (84 out of 106) anthropometric and DXA measures were taken within 48 hours, however; due to logistical complexities a small number of assessments were taken up to 7 days apart (22 out of 106). As all testing was undertaken between the months of July and November, which in Australia is during the international season, no meaningful changes in body composition would be expected over a week given relatively minor in-season adaptations have been observed over significantly longer periods (Lees et al., 2017). To confirm this, data collected >48 hours apart was compared with data collected <48 hours apart. Statistical analysis revealed relatively small differences in the Spearman’s correlation coefficient values when the data from >48 hours was compared to the data collected <48 hours for both FFM (r=0.50, p=0.008 vs r=0.56, p<0.001) and FM (r=0.79,
p<0.001 vs r=0.70, p<0.001). As only minor differences were noted between the two subsets of data, and in both cases the analysis fell within the same qualitative ranking band, it was deemed appropriate to use the extended data set to add more statistical power to the ethnicity and position group analysis.

The results from this study provide sport scientists and coaches with valuable information to assist with the planning and interpretation of longitudinal body composition assessment. Whilst surface anthropometry measures provide a robust indication of the direction of change in FFM and FM, caution may need to be applied when interpreting magnitude of change, particularly with FM. Given the usefulness of DXA in regards to whole body and regional quantification of absolute tissue mass, and the practicality of surface anthropometry in regards to frequent and robust assessment, where resources allow it may be of value to use both techniques concurrently. This would facilitate an opportunity to assess changes acutely, whilst also being able to more accurately quantify absolute changes over longer periods of time. Furthermore, this would ensure the use of DXA is appropriate to both minimise radiation exposure, and allow time to ensure meaningful change that exceeds the measurement error.
Acknowledgements, authorships, declarations of funding sources, and conflicts of interest

The study was designed by AJZ, GJS and EMB; data were collected and analyzed by AJZ, GJS and SEK; data interpretation and manuscript preparation were undertaken by AJZ, EMB, SEK and GJS. All authors approved the final version of the paper.

Declarations of funding sources

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Conflicts of interest

Nil
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References


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Figure 1: Flow diagram of the study population.
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Figure 2: Relationship between relative changes in dual-energy X-ray absorptiometry (DXA) measures of fat free mass and changes in lean mass index (LMI).
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**Figure 3:** Relationship between relative changes in dual-energy X-ray absorptiometry (DXA) measure of fat mass and changes in sum of seven skinfolds.
Table 1: Body composition characteristics of the elite rugby union athletes by position and ethnicity

<table>
<thead>
<tr>
<th></th>
<th>All n = 39</th>
<th>Position</th>
<th>Ethnicity</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Forwards n = 23</td>
<td>Backs n = 16</td>
<td>Caucasians n = 26</td>
</tr>
<tr>
<td>Age (years)</td>
<td>25.7 ± 3.1 (24.8 – 26.7)</td>
<td>26.5 ± 3.4 (25.1 – 27.9)</td>
<td>24.7 ± 2.3 (23.6 – 25.8)</td>
<td>25.5 ± 2.7 (24.5 – 26.5)</td>
</tr>
<tr>
<td>Stature (cm)</td>
<td>187.6 ± 7.7 (185.2 – 190.0)</td>
<td>191.2 ± 7.1 (188.3 – 194.1)</td>
<td>182.4 ± 5.4* (179.8 – 185.1)</td>
<td>188.0 ± 7.7 (185.0 – 191.0)</td>
</tr>
<tr>
<td>Scale Mass (kg)</td>
<td>104.1 ± 12.2 (100.2 – 107.9)</td>
<td>112.4 ± 7.3 (109.4 – 115.3)</td>
<td>92.2 ± 6.6* (88.9 – 95.4)</td>
<td>103.2 ± 11.6 (98.7 – 107.6)</td>
</tr>
<tr>
<td>Sum of 7 Skinfolds (mm)</td>
<td>69.4 ± 23.2 (62.1 – 76.7)</td>
<td>80.6 ± 22.1 (71.6 – 89.7)</td>
<td>53.2 ± 13.4* (46.7 – 59.8)</td>
<td>69.1 ± 22.7 (60.4 – 77.8)</td>
</tr>
<tr>
<td>LMI</td>
<td>58.6 ± 4.9 (56.0 – 59.5)</td>
<td>61.1 ± 4.1 (59.4 – 62.7)</td>
<td>54.8 ± 4.0* (51.1 – 54.9)</td>
<td>58.0 ± 4.5 (55.3 – 59.3)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>29.5 ± 2.6 (28.7 – 30.3)</td>
<td>30.8 ± 2.5 (29.8 – 31.8)</td>
<td>27.7 ± 1.3* (27.0 – 28.3)</td>
<td>29.1 ± 2.3 (28.3 – 30.0)</td>
</tr>
<tr>
<td>DXA Fat Free Mass (kg)</td>
<td>90.9 ± 9.2 (88.0 – 93.8)</td>
<td>96.5 ± 6.3 (93.9 – 99.1)</td>
<td>82.8 ± 5.9* (79.9 – 85.7)</td>
<td>90.1 ± 8.5 (86.8 – 93.4)</td>
</tr>
<tr>
<td>DXA Fat Mass (kg)</td>
<td>14.7 ± 4.7 (13.2 – 16.1)</td>
<td>17.4 ± 4.0 (15.8 – 19.0)</td>
<td>10.8 ± 2.2* (9.7 – 11.8)</td>
<td>14.5 ± 4.8 (12.6 – 16.3)</td>
</tr>
</tbody>
</table>

Mean ± SD, 95% confidence intervals in parentheses LMI = Lean Mass Index (kg/sum 7 skinfolds\(^x\) (mm); \(x = 0.13\) backs; \(x = 0.14\) forwards); BMI = Body Mass Index

*Significant difference found between forwards and backs (\(P<0.001\))
Table 2: Correlation between changes in dual-energy X-ray absorptiometry fat free mass and surface anthropometric lean mass index measures

<table>
<thead>
<tr>
<th></th>
<th>r</th>
<th>SEE (%)</th>
<th>P</th>
<th>Ranking</th>
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<tbody>
<tr>
<td>All (n = 106)</td>
<td>0.54</td>
<td>1.5</td>
<td>&lt;0.001</td>
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<td>Position</td>
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<td></td>
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<tr>
<td>Forwards (n = 72)</td>
<td>0.63</td>
<td>1.4</td>
<td>&lt;0.001</td>
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<td>Backs (n = 34)</td>
<td>0.38</td>
<td>1.6</td>
<td>0.029</td>
<td>Moderate</td>
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<tr>
<td>Ethnicity</td>
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<td></td>
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<tr>
<td>Caucasian (n = 85)</td>
<td>0.55</td>
<td>1.5</td>
<td>&lt;0.001</td>
<td>Large</td>
</tr>
<tr>
<td>Polynesians (n = 21)</td>
<td>0.51</td>
<td>1.3</td>
<td>0.019</td>
<td>Large</td>
</tr>
</tbody>
</table>

Qualitative ranking of correlation defined as trivial, $r < 0.1$; small, $0.1 \leq r < 0.3$; moderate, $0.3 \leq r < 0.5$; large, $0.5 \leq r < 0.7$; very large, $0.7 \leq r < 0.9$; almost perfect, $0.9 \leq r < 1.0$; perfect, $r = 1.0$.

$r =$ Spearman’s correlation coefficient; SEE = standard error of the estimate; P = significance.
Table 3: Correlation between changes in dual-energy X-ray absorptiometry fat mass and surface anthropometric sum of 7 skinfold measures

<table>
<thead>
<tr>
<th>Position</th>
<th>r</th>
<th>SEE (%)</th>
<th>P</th>
<th>Ranking</th>
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<tbody>
<tr>
<td>All (n = 106)</td>
<td>0.73</td>
<td>5.8</td>
<td>&lt;0.001</td>
<td>Very Large</td>
</tr>
<tr>
<td>Forwards (n = 72)</td>
<td>0.72</td>
<td>4.8</td>
<td>&lt;0.001</td>
<td>Very Large</td>
</tr>
<tr>
<td>Backs (n = 34)</td>
<td>0.76</td>
<td>7.0</td>
<td>&lt;0.001</td>
<td>Very Large</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian (n = 85)</td>
<td>0.75</td>
<td>5.9</td>
<td>&lt;0.001</td>
<td>Very Large</td>
</tr>
<tr>
<td>Polynesians (n = 21)</td>
<td>0.62</td>
<td>4.6</td>
<td>0.003</td>
<td>Large</td>
</tr>
</tbody>
</table>

Qualitative ranking of correlation defined as trivial, r < 0.1; small, 0.1 ≤ r < 0.3; moderate, 0.3 ≤ r < 0.5; large, 0.5 ≤ r < 0.7; very large, 0.7 ≤ r < 0.9; almost perfect, 0.9 ≤ r < 1.0; perfect, r = 1.0.

r = Spearman’s correlation coefficient; SEE = standard error of the estimate; P = significance