Body size, body composition, and fat distribution: a comparison of young New Zealand men of European, Pacific Island, and Asian Indian ethnicities

Elaine Rush, Lindsay Plank, Vishnu Chandu, Manaia Laulu, David Simmons, Boyd Swinburn, Chittaranjan Yajnik

Abstract

Aims To investigate body size and body fat relationships and fat distribution in young healthy men drawn from New Zealand European, Pacific Island, and Asian Indian populations.

Method A total of 114 healthy men (64 European, 31 Pacific Island, 19 Asian Indian) aged 17–30 years underwent measurements of height, weight, and body composition by total body dual-energy X-ray absorptiometry (DXA). Body mass index (BMI) was then calculated. Percent body fat (%BF), fat-free mass, bone mineral content, bone mineral density, abdominal fat, thigh fat, and appendicular skeletal muscle mass (ASMM) were obtained from the DXA scans.

Results For the same BMI, %BF for Pacific Island men was 4% points lower and for Asian Indian men was 7–8% points higher compared to Europeans. Compared to European men for the same %BF, BMI was 2–3 units higher for Pacific Island, and 3–6 units lower for Asian Indian. The ratio of abdominal fat to thigh fat, adjusted for height, weight, and %BF, was significantly higher for Asian Indian men than European (p=0.022) and Pacific Island (p=0.002) men. ASMM, adjusted for height and weight, was highest in Pacific Island and lowest in Asian Indian men.

Conclusions The relationship between %BF and BMI is different for European, Pacific Island, and Asian Indian men which may, at least in part, be due to differences in muscularity. Asian Indians have more abdominal fat deposition than their European and Pacific Island counterparts. Use of universal BMI cut-off points are not appropriate for comparison of obesity prevalence between these ethnic groups.
prevalence of Type 2 diabetes in Asian Indian peoples is more than four-fold and in 
Pacific Island peoples more than two-fold higher than in Europeans.\textsuperscript{8} These 
observations are of particular concern because of the increasing size of the resident 
Asian Indian and Pacific Island populations in this country. The 2001 census 
indicated that there are now more people of Asian than Pacific Island ethnicity 
resident in NZ. The Asian Indian subgroup comprises approximately 26\% of the 
New Zealand Asian population.\textsuperscript{9}

Ethnic differences in body build, fat patterning, and muscularisation may all 
contribute to differences in the relationship between BMI and body fat between ethnic 
groups. Asian Indians have a more central distribution of body fat than Europeans,\textsuperscript{2} 
which is associated with increased risk of diabetes Type 2 and ischaemic heart 
disease.\textsuperscript{10,11} Polynesians have higher bone mass and muscle mass than Europeans.\textsuperscript{12–14} 
The WHO has recognised the deficiencies of a universal cut-off for overweight and 
obesity\textsuperscript{15,16} and in a recently published report\textsuperscript{17} suggested that further body 
composition studies of Asian and Pacific Island populations are needed to determine 
equivalent fatness levels and the relation of BMI to body size.

Dual-energy X-ray absorptiometry (DXA) is widely accepted as a valuable technique 
for the assessment of body composition and, in particular, fat distribution, muscle 
mass and bone mass. While not without drawbacks as a reference method,\textsuperscript{18} it has 
clear advantages over the traditional anthropometric approaches such as skinfold 
thicknesses, girths, and BMI. A significant drawback is that individuals with very 
high BMI are not easily accommodated.

On the other hand, the technology provides a more direct assessment of total body fat 
than anthropometric methods and offers regional composition analysis. We are not 
aware of any comparative analysis of the body composition of European, Asian 
Indian, and Pacific Island subjects using this technique.

We sought in the current study of a group of young healthy males who underwent 
DXA to identify ethnic differences in:

(1) The relationships between body fatness and body size,
(2) Fat distribution,
(3) Muscularity, and
(4) Bone mineral density and mass.

\textbf{Methods}

Data from healthy male volunteers aged 17–30 years, who participated in cross-sectional studies of 
body composition conducted in the Department of Surgery, University of Auckland, were examined. 
All studies were approved by the local ethics committees and all participants provided written informed 
consent. Recruitment for these studies, principally from the urban Auckland area, was by personal 
contact, advertisement, or through existing networks of the recruiters.

Exclusion criteria were: total joint replacement, lifting weights more than once per week, major 
medical conditions (such as diabetes or cancer), and medication which could possibly affect body 
composition (such as oral steroids). Only one member of a family was measured. In addition, one 
subject was subsequently excluded from analysis because of a large difference (>3 kg) between 
recorded scale weight and DXA weight (sum of fat mass, fat-free soft tissue and bone mineral content). 
Of 114 volunteers, 64 self-identified as European, 31 as Pacific Island, and 19 as Asian Indian.
Height and weight were measured with participants wearing light clothing or standard hospital gown and no shoes. An estimated clothing weight was subtracted. Body composition (fat, fat-free soft tissue, and bone mineral content) and whole-body bone mineral density measurements were made using a single DXA machine (model DPX+ with software version 3.6y, Lunar Radiation Corp., Madison, WI). Fat-free mass (FFM) was calculated as the sum of the values for fat-free soft tissue and bone mineral content. Percent body fat was calculated as 100 x fat mass/(fat mass+FFM).

For assessing regional fat distribution, the whole-body DXA scans were analysed. Abdominal and thigh regions of interest were defined by the criteria of Ley et al.\textsuperscript{19} Abdominal fat was obtained from analysis of a region of interest positioned with the lower horizontal border on top of the iliac crest and the upper border approximately parallel with the junction of the T12 and L1 vertebrae. The sides of this region were adjusted to include the maximum amount of abdominal tissue. A region of interest of identical height placed over the thighs (with the upper horizontal border positioned immediately below the ischial tuberosities) was used to obtain fat content of the thighs. The lateral margins were adjusted to follow the shape of the thighs.

Appendicular skeletal muscle mass (ASMM) was derived from the DXA scans as total limb mass minus the sum of limb fat mass and wet bone mass, estimated as bone mineral content divided by 0.55.\textsuperscript{20} In this model, mass of the skin and associated dermal tissues is assumed to be negligible relative to the skeletal muscle component.

Results are presented as means ± SD. Between-group differences in subject characteristics were tested using one-way ANOVA followed by pairwise comparisons if a significant F test was obtained. Analysis of covariance was used to adjust body composition results for comparison across ethnic groups. Before carrying out analysis of covariance, similarity of regression slopes among the ethnic groups was verified by examining the significance of the interaction between the covariate(s) and the group variable. Data were analysed using SAS software, version 6.12 (SAS Institute Inc., Cary, NC). Results with p values <0.05 were considered significant.

Results

The subject characteristics are summarised in Table 1. Pacific Island men in this study were heavier with higher BMI than Europeans and Asian Indians. Asian Indians were shorter than Pacific Islanders and significantly fatter than Europeans and Pacific Islanders.

As a proportion of total body fat, abdominal fat was significantly higher for Asian Indians than Europeans (p<0.0001) or Pacific Islanders (p<0.0001), while thigh fat was significantly lower than Europeans (p=0.037) or Pacific Islanders (p=0.015) (Table 1). After adjustment for weight, height, and %BF, the ratio of abdominal to thigh fat was significantly higher for Asian Indians than Europeans (p=0.022) and Pacific Islanders (p=0.002).

ASMM for Pacific Islanders was significantly higher than Europeans (p<0.0001); and for Europeans, ASMM was significantly higher than Asian Indians (p=0.0021) (Table 1). This pattern remained after adjustment of ASMM for height and weight, with Pacific Islanders having significantly higher ASMM than Europeans (p<0.0001), and Europeans having significantly higher ASMM than Asian Indians (p=0.0012).

After adjustment for height and weight, bone mineral density was significantly higher in Pacific Islanders than European (p=0.0009) and Asian Indian (p=0.0014). Adjusted bone mineral density for European was similar to that for Asian Indian (p=0.46). When adjusted for height and weight bone mineral content was significantly higher in Pacific Islanders than European (p=0.0021) and higher in European than Asian Indian (p=0.0008).
Table 1. Characteristics of 64 New Zealand European, 31 Pacific Island, and 19 Asian Indian men aged 17–30 years

<table>
<thead>
<tr>
<th>Variable</th>
<th>European Mean (SD)</th>
<th>Pacific Island Mean (SD)</th>
<th>Asian Indian Mean (SD)</th>
<th>p value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>23.8 (3.7)</td>
<td>22.7 (2.6)</td>
<td>24.2 (3.4)</td>
<td>0.24</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>177.5 (6.2)</td>
<td>179.1 (7.3)</td>
<td>174.0 (6.1)p</td>
<td>0.030</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>79.1 (10.7)p</td>
<td>94.7 (17.5)</td>
<td>79.6 (14.9)p</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>25.2 (3.4)p</td>
<td>29.6 (5.3)</td>
<td>26.3 (4.8)p</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Fat-free mass (kg)</td>
<td>63.2 (5.9)p</td>
<td>72.0 (8.9)</td>
<td>55.9 (7.2)pe</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Total body fat (kg)</td>
<td>15.9 (8.7)</td>
<td>22.7 (12.6)</td>
<td>23.7 (10.2)pe</td>
<td>0.001</td>
</tr>
<tr>
<td>Total body fat (%)</td>
<td>19.4 (8.2)p</td>
<td>22.7 (9.5)</td>
<td>28.8 (8.0)e</td>
<td>0.002</td>
</tr>
<tr>
<td>Abdominal fat (kg)</td>
<td>1.23 (0.86)p</td>
<td>1.73 (1.09)</td>
<td>2.11 (0.99)e</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Abdominal fat (% of total fat)</td>
<td>7.3 (1.2)</td>
<td>7.3 (1.3)</td>
<td>8.8 (1.2)e</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Thigh fat (kg)</td>
<td>1.47 (0.70)p</td>
<td>2.14 (1.11)</td>
<td>2.07 (0.86)e</td>
<td>0.0005</td>
</tr>
<tr>
<td>Thigh fat (% of total fat)</td>
<td>9.5 (1.1)</td>
<td>9.7 (1.1)</td>
<td>8.9 (1.3)e</td>
<td>0.045</td>
</tr>
<tr>
<td>Abdominal-to-thigh fat ratio</td>
<td>0.79 (0.20)</td>
<td>0.77 (0.19)</td>
<td>1.02 (0.24)e</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>ASMM (kg)</td>
<td>26.9 (2.8)p</td>
<td>31.7 (2.4)</td>
<td>24.1 (3.4)e</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>ASMM (%)</td>
<td>34.3 (4.0)</td>
<td>34.0 (4.3)</td>
<td>30.7 (4.0)e</td>
<td>0.004</td>
</tr>
<tr>
<td>Bone mineral content (kg)</td>
<td>3.33 (0.42)p</td>
<td>3.81 (0.45)</td>
<td>2.92 (0.44)e</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Bone mineral density (g/cm²)</td>
<td>1.24 (0.08)p</td>
<td>1.34 (0.09)</td>
<td>1.22 (0.10)p</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

ASMM=appendicular skeletal muscle mass; *analysis of variance; p<0.05 vs European, p<0.05 vs Pacific Island

Curvilinear relationships between %BF and BMI for each ethnic group were linearised by logarithmically transforming BMI (Figure 1). No significant difference was found between the slopes of the regressions of %BF on the logarithm of BMI for the three ethnic groups, but covariance analysis showed their elevations to be significantly different (p<0.0001).

The common slope regression equation for predicting %BF from BMI for the three ethnic groups was:

- %BF = 105.79 log_{10}(BMI) – 128.42 – 3.77 group1 + 7.60 group2
- (SEE (standard error of estimate) = 4.89%, R² = 0.72)

where group1 is coded as 0 for European, 1 for Pacific Islanders, 0 for Asian Indians—and group2 is coded as 0, 0, 1 for these respective ethnic groups. Hence, for fixed BMI, compared with Europeans, Pacific Islanders had lower %BF by 3.8% (95% confidence interval: 1.4%–6.1%) and Asian Indians had higher %BF by 7.6% (5.0%–10.2%). At a BMI of 30 for Europeans the predicted %BF (28%) equates to a BMI of 33 for the Pacific Islanders and 25 for the Asian Indians (Table 2).
Table 2. Comparison of European body mass index (BMI) and corresponding percent body fat with estimated BMI equivalents for Pacific and Asian Indians derived from equations relating BMI to percent body fat

<table>
<thead>
<tr>
<th>BMI (kg/m²)</th>
<th>European Body fat (%)</th>
<th>Pacific Island Approximate BMI equivalent (kg/m²)</th>
<th>Asian Indian Approximate BMI equivalent (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>9</td>
<td>22</td>
<td>17</td>
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<tr>
<td>25</td>
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<td>27</td>
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<td>40</td>
<td>41</td>
<td>43</td>
<td>34</td>
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</tbody>
</table>

Figure 1. Relation between percentage body fat (%BF) and BMI for 64 European (closed circles), 31 Pacific Island (open circles), and 19 Asian Indian (triangles) men. The common slope linear regressions are given by %BF = 105.8 log_{10}(BMI) – intercept, where intercept=128.4 for the European (solid line), 132.2 for the Pacific Island (dashed line), and 120.8 for the Asian Indian men (dotted line)
Discussion

In a group of young European, Pacific Island and Asian Indian young men, we have shown that the relationship between percent body fat and BMI is ethnicity specific.

The most commonly used measure of obesity is BMI, and we found that, for a fixed BMI, Pacific Island men had significantly less body fat while Asian Indian men had significantly more body fat than their European counterparts. At a fixed %BF, BMI in Pacific Island men was 2–3 units higher and in Asian Indian men was 3–6 units lower than in European men. The BMI differences are smallest at low %BF and diverge with increasing %BF. This effect is seen in Table 2 and also is evident in Figure 1 when allowance is made for the logarithmic transformation of BMI. The results for Pacific Island men confirm our previous observations. Ethn

Ethnic differences in the BMI-body fat relationships may be explained, at least in part, by differences in body build, particularly muscularity. We have shown that, compared with European men of similar weight and height, Asian Indian men have significantly less skeletal muscle in the limbs while Pacific Island men have significantly more. (Appendicular skeletal muscle is approximately 75% of total body skeletal muscle mass.)

We have also shown, by examination of the distribution of fat in our subjects, that Asian Indian men have a more central fat deposition pattern than European or Pacific Island men. The propensity for abdominal adiposity found in Asian Indians had been inferred from measurements of waist-to-hip girth ratios in a number of studies. Central obesity is closely associated with risk for cardiovascular disease and Type 2 diabetes.

The greater bone mineral mass and bone density that we observed in Pacific Island men (relative to Europeans) may also contribute to differences in the body fat-BMI relationship for these ethnic groups. While bone mineral mass was lower in Asian Indians than Europeans, their bone mineral density was similar after adjustment for body size. Others have shown that both bone mineral density and bone mineral content in Asian men (predominantly Chinese) were similar to European men after controlling for weight, height, and age. Age was not a significant covariate for our restricted-age range data.

A limitation of the present study is the comparatively small Asian Indian group and our results need to be confirmed with a larger sample from this ethnic group. In addition, our study does not address the other Asian subgroups which make up the majority of Asians in New Zealand.

The WHO BMI classifications of overweight (≥25 kg/m²) and obesity (≥30 kg/m²), although intended for international use, are based on the relationship between BMI and cardiovascular morbidity in Western populations. Based on percent body fat levels a BMI of 26 kg/m² has been suggested as an obesity cut-off point in Asian Indians equivalent to that for Europeans, and revised cut-off values to define overweight (23 kg/m²) and obesity (25 kg/m²) in Asian Indians have been proposed by the WHO. Current New Zealand Ministry of Health cut-offs for ‘overweight’ and ‘obesity’ are 26 and 32 kg/m², respectively in both Maori and Pacific Island adults. Studies are required to define the BMI range that may be considered ‘healthy’ in Asian Indian
and Pacific Island people on the basis of risk for obesity-related diseases. A consistent finding among migrant Asian Indian populations is hyperinsulinaemia and insulin resistance, characteristics which may be important in the development of type 2 diabetes and cardiovascular disease.

Simmons et al have reported that young Asian Indians are relatively hyperinsulinaemic compared to their European counterparts with the same BMI. Vikram et al have shown that Asian Indians with ‘normal’ BMI (<25 kg/m²) have high cardiovascular disease risk. Pacific Islanders in New Zealand, by contrast, are not hyperinsulinaemic relative to Europeans of the same BMI and whilst they have a high prevalence of type 2 diabetes, they are believed to have a lower rate of cardiovascular disease.

Our results demonstrate the marked differences in body build, body composition, and fat distribution that characterise male New Zealanders of European, Asian Indian and Pacific Island ancestry. We speculate that these may be related to differences in risk for cardiovascular disease and different pathways to Type 2 diabetes among these ethnic groups. The results emphasise the inadequacy of universal BMI cut-off points for determination of percentage body fat and obesity and the need to consider ethnic-specific weight targets.

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