Ethnic-specific body mass index cut-off points for overweight and obesity in girls

J Scott Duncan, Elizabeth K Duncan, Grant Schofield

Abstract

Aim To develop ethnic-specific body mass index (BMI) cut-off points for overweight and obesity in girls from New Zealand’s five major ethnic groups.

Methods A total of 1676 girls (41% European, 21% Pacific Island, 15% East Asian, 13% Māori, and 11% South Asian) aged 5–16 years participated in this study. BMI was determined from height and weight, and body fat percentage (%BF) was obtained from hand-to-foot bioelectrical impedance measurements. Using stepwise multiple regression, a series of ethnic-specific BMI cut-off points were developed that corresponded to the equivalent %BF of European girls at the BMI reference values provided by the International Obesity TaskForce (IOTF).

Results The adjusted cut-off points for overweight and obesity ranged from an average of 3.3 and 3.8 kg.m\(^{-2}\) (respectively) lower than the IOTF standards in South Asian girls to 1.5 and 1.9 kg.m\(^{-2}\) higher in Pacific Island girls.

Conclusion We conclude that the ethnic-specific BMI cut-off points developed in this study are more appropriate than universal definitions of overweight and obesity for predicting excess adiposity in New Zealand girls.

Rapid and widespread increases in childhood overweight and obesity are a serious public health concern for many countries. To facilitate the comparison of prevalence estimates between populations, the International Obesity TaskForce released a series of body mass index (BMI) cut-off points defining overweight and obesity in young people that adjust for natural differences between sexes and across age groups.\(^1\) However, there is a growing body of evidence indicating that universal BMI thresholds often correspond to different body fat levels in children from diverse ethnic backgrounds.\(^2-8\) Indeed, several studies have concluded that ethnic-specific BMI cut-off points would provide a more appropriate representation of overweight and obesity in multiethnic populations.\(^2-4,9,10\)

Previously, we have shown that adjusting universal BMI standards for ethnicity improves diagnostic accuracy when screening for overweight in Māori, Pacific Island, East Asian, and South Asian girls.\(^4\) A logical progression is the formulation of ethnic-specific cut-off points that correspond to the equivalent level of body fat in all ethnicities, thereby standardising BMI-based estimates of overweight and obesity. Rush et al.\(^8\) used regression analysis to demonstrate the increase in BMI required for Māori and Pacific Island girls to match the same body fat percentage (%BF) as European girls at a range of BMI values. To our knowledge, no studies have derived ethnic-specific BMI cut-off points from the existing IOTF standards. The purpose of the present study was to propose adjusted BMI-for-age curves in Māori, Pacific
Island, East Asian, and South Asian girls that correspond to the observed %BF of European girls at the IOTF cut-off points for overweight and obesity.

Methods

The participant recruitment and body composition methodology has been described in detail elsewhere, and consequently only a brief description is given here. A total of 1676 participants aged 5-16 y (school years 1-10) were randomly selected from 39 primary, intermediate, and secondary schools in Auckland, New Zealand. The ethnic composition of this sample was 680 European (40.6%), 355 Pacific Island (21.2%), 216 Māori (12.9%), 243 East Asian (14.5%), and 182 South Asian (10.9%).

BMI was calculated as weight (kg) divided by squared height (m$^2$). Fat-free mass measurements were obtained using a hand-to-foot bioelectrical impedance analyzer (Model BIM4, Impedimed, Capalaba, Australia) and prediction equations previously validated in all ethnic groups within the present study. Fat mass was derived as the difference between fat-free mass and body weight, and %BF was calculated as $100 \times \frac{\text{fat mass}}{\text{weight}}$. Ethical approval for this study was obtained from the Auckland University of Technology Ethics Committee. Written informed consent was provided by each participant and her legal guardian.

Data were analysed using SPSS for Windows v12.0.1 software, (SPSS Inc., Chicago, IL). The relationship between BMI and %BF was assessed using stepwise multiple regression, with age (rounded to nearest half-year) and ethnicity as independent variables ($P_{in} > 0.05$, $P_{out} > 0.10$). BMI was log transformed due to the curvilinear relationship between BMI and %BF. To minimise collinearity complications, the log$_{10}$BMI variable was centered about the mean by subtracting 1.31 (mean log$_{10}$BMI) from each value. The variables for ethnicity were dummy coded $E_1$-$E_4$. For South Asian $E_1 = 1$, $E_2 = 0$, $E_3 = 0$, $E_4 = 0$; for Pacific Island $E_1 = 0$, $E_2 = 1$, $E_3 = 0$, $E_4 = 0$; for East Asian $E_1 = 0$, $E_2 = 0$, $E_3 = 1$, $E_4 = 0$; and for Māori $E_1 = 0$, $E_2 = 0$, $E_3 = 0$, $E_4 = 1$.

Results

Table 1 presents the coefficients of the stepwise multiple regression in the order the independent variables were entered into the equation. The final regression equation was as follows: $\%BF = [59.5 \times (\log_{10}\text{BMI} – 1.31)] + [4.50 \times E_1] – [1.84 \times E_2] + [1.39 \times E_3] – [0.164 \times \text{age}] – [0.731 \times E_4] + 28.9$; with an $R^2$ of 0.669 and a SEE of 3.73%. Hence, at a fixed BMI and age, South Asian ($E_1 = 1$) and East Asian ($E_3 = 1$) girls averaged 4.50% (95% CI: 3.89-5.11%) and 1.39% (0.841-1.94%) more body fat (respectively) than European girls, while Pacific Island ($E_2 = 1$) and Māori ($E_4 = 1$) girls averaged 1.84% (1.32-2.35%) and 0.731% (-0.014-1.31%) less body fat.

The variance in %BF explained by each term in the equation was as follows: log$_{10}$BMI – 1.31, 58.3%; $E_1$, 11.1%; $E_2$, 2.8% ; $E_3$, 1.5%; age, 1.0%; and $E_4$, 0.4%. Significant ($P < 0.05$) interactions between age and log$_{10}$BMI, and between age and $E_3$, were excluded as they resulted in only minor improvements to the regression equation. There were no significant interactions between log$_{10}$BMI and any of the dummy variables, indicating that there were no differences in the regression slopes between the ethnic groups. In other words, ethnic differences in the association between BMI and %BF were similar across the entire BMI distribution.
To demonstrate the ethnic variation in BMI thresholds for overweight and obesity, the expected %BF at each IOTF age and sex specific cut-off point was first calculated using the regression equation in European participants. Body fat levels increased steadily with age before reaching a plateau in older girls (range: overweight, 25.2% [5 years] to 36.1% [16 years]; obese, 28.1% to 41.0%). These %BF data were entered into the reversed equation to determine the BMI levels for Pacific Island, Māori, East Asian, and South Asian participants that correspond to the IOTF cut-off points for overweight and obesity in European children (Table 2).

Table 1. Stepwise multiple regression with %BF as the dependent variable

| Log10(BMI) | E₁ | E₂ | E₃ | Age | E₄ | Intercept | β   | SE  | β   | SE  | β   | SE  | β   | SE  | β   | SE  | r²  | SEE (%)
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<tbody>
<tr>
<td>51.5</td>
<td>1.02</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>27.2</td>
<td>0.100</td>
<td>0.602</td>
<td>4.09</td>
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<tr>
<td>53.5</td>
<td>0.967</td>
<td>4.60</td>
<td>0.304</td>
<td>–</td>
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<td>–</td>
<td>26.7</td>
<td>0.099</td>
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<td>55.9</td>
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<td>4.29</td>
<td>0.302</td>
<td>–</td>
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<td>–</td>
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<td>0.660</td>
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<td>56.2</td>
<td>1.00</td>
<td>4.60</td>
<td>0.306</td>
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<td>0.247</td>
<td>0.272</td>
<td>26.8</td>
<td>0.126</td>
<td>0.666</td>
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<tr>
<td>58.9</td>
<td>1.21</td>
<td>4.66</td>
<td>0.305</td>
<td>–</td>
<td>0.248</td>
<td>1.55</td>
<td>0.153</td>
<td>0.0394</td>
<td>–</td>
<td>28.6</td>
<td>0.476</td>
<td>0.668</td>
<td>3.73</td>
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<td>59.5</td>
<td>1.23</td>
<td>4.50</td>
<td>0.311</td>
<td>–</td>
<td>0.263</td>
<td>1.39</td>
<td>0.164</td>
<td>0.0395</td>
<td>0.731</td>
<td>0.297</td>
<td>28.9</td>
<td>0.490</td>
<td>0.669</td>
<td>3.73</td>
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E₁ = 1 for South Asian, E₂ = 1 for Pacific, E₃ = 1 for East Asian, E₄ = 1 for Māori.
SE standard error, SEE standard error of estimate, r² = explained variance.
β = unstandardised coefficients.

Table 2. Ethnic-specific BMI cut-off points equivalent to the predicted %BF of European children at the IOTF BMI cut-off points for overweight and obesity

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>IOTF</th>
<th>Pacific Island</th>
<th>South Asian</th>
<th>East Asian</th>
<th>Māori</th>
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<tbody>
<tr>
<td></td>
<td>Overweight</td>
<td>Obesity</td>
<td>Overweight</td>
<td>Obesity</td>
<td>Overweight</td>
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<tr>
<td>5</td>
<td>17.15</td>
<td>19.17</td>
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<td>20.58</td>
<td>14.41</td>
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<tr>
<td>5.5</td>
<td>17.20</td>
<td>19.34</td>
<td>18.47</td>
<td>20.77</td>
<td>14.45</td>
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<td>17.34</td>
<td>19.65</td>
<td>18.62</td>
<td>21.10</td>
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</tr>
<tr>
<td>6.5</td>
<td>17.53</td>
<td>20.08</td>
<td>18.82</td>
<td>21.56</td>
<td>14.73</td>
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<td>7</td>
<td>17.75</td>
<td>20.51</td>
<td>19.06</td>
<td>22.02</td>
<td>14.91</td>
</tr>
<tr>
<td>7.5</td>
<td>18.03</td>
<td>21.01</td>
<td>19.36</td>
<td>22.56</td>
<td>15.15</td>
</tr>
<tr>
<td>8</td>
<td>18.35</td>
<td>21.57</td>
<td>19.70</td>
<td>23.16</td>
<td>15.42</td>
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<tr>
<td>8.5</td>
<td>18.69</td>
<td>22.18</td>
<td>20.07</td>
<td>23.82</td>
<td>15.70</td>
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<tr>
<td>10</td>
<td>19.86</td>
<td>24.11</td>
<td>21.33</td>
<td>25.89</td>
<td>16.69</td>
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<tr>
<td>10.5</td>
<td>20.29</td>
<td>24.77</td>
<td>21.79</td>
<td>26.60</td>
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</table>
Pacific Island girls averaged the highest BMI cut-off points for overweight and obesity, equivalent to 1.5 and 1.8 kg.m\(^{-2}\) greater than the IOTF recommendations, respectively. In contrast, the South Asian cut-off points were lowest at an average of 3.3 and 3.9 kg.m\(^{-2}\) below the IOTF criteria. Figure 1 shows the ethnic-specific BMI cut-off points for overweight and obesity in each group alongside the established IOTF standards.

Figure 1. IOTF and ethnic-specific BMI curves for overweight and obesity in girls aged 5–16 years
Discussion

This study provides the first ethnic-specific BMI criteria for standardising youth overweight and obesity in a multiethnic population. The diverse ethnic composition of the sample enabled a wide range of body types to be compared: Pacific Island and Māori phenotypes are defined by a relatively low fat-to-fat-free mass ratio, whereas Asian individuals tend to display the opposite characteristics. In agreement with these observations, our results indicated that Māori and Pacific Island BMI thresholds need to be raised to match the equivalent body fatness of European girls at the IOTF BMI cut-off points, while East and South Asian thresholds need to be lowered. The adjusted BMI-for-age curves for South Asian girls, in particular, were over 3 kg.m$^{-2}$ lower than the existing IOTF definitions of overweight and obesity. Thus, it is likely that a significant proportion of overweight or obese South Asian girls are currently classified as normal weight by the IOTF criteria. This underestimation may prohibit health services from identifying those most at need, and may reduce the probability that ‘at risk’ individuals will initiate the lifestyle changes necessary to prevent fat accretion.

Although Pacific Island girls are also liable to be misclassified, it could be argued that overestimation of overweight/obesity status is preferable to overlooking those with excess adiposity. Nevertheless, labelling a young person as overweight raises the possibility of adverse psychosocial effects, and consequently every effort should be made to ensure that only those with excess body fat are classified as overweight or obese. The cut-off points for Māori and East Asian girls were closer to the IOTF criteria than the Pacific Island and South Asian curves; however we suggest that each
non-European curve showed sufficient divergence to warrant inclusion in an ethnic-specific BMI classification system for overweight and obesity in New Zealand girls.

To our knowledge, only one other study has modified the IOTF classification system to suit a specific population. Kim et al\(^9\) proposed a series of BMI percentiles for Korean girls aged 8 to 18 years that corresponded to the IOTF thresholds for overweight and obesity in Asian adults at age 18 years (23 and 25 kg.m\(^{-2}\), respectively). Similar to our observations in East and South Asian girls, the adjusted BMI-for-age curves for Korean girls were substantially lower than the IOTF cut-off points. However, it remains uncertain if these ethnic-specific BMI values correspond to excess adiposity in Korean individuals.

An advantage of the present study was the use of %BF to standardise the classification of weight status across diverse ethnicities. The %BF of European girls at the IOTF BMI cut-off points was selected as the appropriate criteria given that the IOTF standards are applied most frequently to children and adolescents of European descent. Nevertheless, these criteria are not necessarily the most suitable markers of increased health risk. While several studies have posited single %BF thresholds ranging from 20 to 30% that are associated with an elevated risk of negative health outcomes,\(^{13-16}\) the age-related increase in %BF observed in female children and adolescents raises concerns about the appropriateness of a single %BF point.

In the present study, %BF values corresponding to the IOTF criteria in European girls were age-dependent, ranging from 25% to 36% for overweight and from 28% to 41% for obesity. The %BF-for-age curves reported in another investigation of the IOTF BMI cut-off points in New Zealand (predominantly European) children aged 3-18 years showed a similar overall pattern in female subjects: 20-34% for overweight and 26-46% for obesity.\(^17\) The findings from both studies suggest that a single %BF threshold may underestimate health risk in younger girls and overestimate health risk in older girls.

Clearly, there is a need to elucidate the associations between adiposity, age, and negative health outcomes in young people. While the delayed onset of many obesity-related complications makes this a challenging task, an understanding of the unhealthy body fat levels in a variety of ethnic groups would facilitate the development of ethnic-specific BMI thresholds for overweight and obesity that are closely linked with disease risk. Indeed, data that enable the comparison of established risk factors in youth, such as blood pressure, blood lipids, or other blood markers, with total and regional body fatness in different age and ethnic groups is urgently required. More information about the role of fat distribution in the risk of disease would also be valuable given the evidence that peripheral and central adiposity have significantly different effects on health outcomes.\(^18\)

A limitation of this study is that only female children and adolescents were assessed. It is possible that ethnic differences in the association between %BF and BMI follow different patterns in boys. However, Rush et al\(^19\) showed that the significant differences in body composition among European, Māori, and Pacific Island girls are not evident among boys from the same ethnic groups. This suggests that ethnic adjustments to the IOTF BMI cut-off points may not be necessary for Māori and Pacific Island boys. In contrast, there is evidence that differences in the %BF-BMI ratio exist between European and both East and South Asian boys.\(^3,7\) Further research
is required to establish the appropriate BMI thresholds for overweight and obesity in boys from these ethnicities.

It should be remembered that the ethnic-specific BMI cut-off points proposed in this study were generated from girls living in New Zealand. The existence of population-specific differences in physical characteristics within girls from the same ethnic background would reduce the international applicability of our results. Thus, cross-validation of the regression equation in other samples of Māori, Pacific Island, East Asian, and South Asian girls is recommended, especially in those living in countries other than New Zealand. It would also be worthwhile to establish the ethnic adjustments necessary to standardize overweight and obesity in girls aged 2-4 and 17-18 years, thereby covering the entire age range of the IOTF BMI standards. Nevertheless, we suggest that the ethnic-specific BMI cut-off points provided in this study represent the most appropriate definition of overweight and obesity for New Zealand girls aged 5-16 years.

In summary, this study provides the first ethnic-specific BMI cut-off points for defining overweight and obesity in a multiethnic population of female children and adolescents. Our results showed that the current IOTF standards for overweight should be raised by an average of 1.5 and 0.6 kg.m\(^{-2}\) for Pacific Island and Māori girls (respectively), and lowered by an average of 3.3 and 1.1 kg.m\(^{-2}\) for South and East Asian girls. Similarly, the ethnic-specific BMI cut-off points for obesity were (on average) 1.8 and 0.7 kg.m\(^{-2}\) greater than the IOTF thresholds for Pacific Island and Māori girls, and 3.9 and 1.3 kg.m\(^{-2}\) lower for South and East Asian girls. Application of the proposed adjustments will reduce the misclassification of excess adiposity common in ethnic groups that differ from the typical European phenotype.

**Competing interests:** None known.

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**References:**