Establishing a standard definition for child overweight and obesity worldwide: international survey

Tim J Cole, Mary C Bellizzi, Katherine M Flegal, William H Dietz

Abstract

Objective To develop an internationally acceptable definition of child overweight and obesity, specifying the measurement, the reference population, and the age and sex specific cut off points.

Design International survey of six large nationally representative cross sectional growth studies.

Setting Brazil, Great Britain, Hong Kong, the Netherlands, Singapore, and the United States.

Subjects 97 876 males and 94 851 females from birth to 25 years of age.

Main outcome measure Body mass index (weight/height)².

Results For each of the surveys, centile curves were drawn that at age 18 years passed through the widely used cut off points of 25 and 30 kg/m² for adult overweight and obesity. The resulting curves were averaged to provide age and sex specific cut off points from 2-18 years.

Conclusions The proposed cut off points, which are less arbitrary and more internationally based than current alternatives, should help to provide internationally comparable prevalence rates of overweight and obesity in children.

Introduction

The prevalence of child obesity is increasing rapidly worldwide. It is associated with several risk factors for later heart disease and other chronic diseases including hyperlipidaemia, hyperinsulinaemia, hypertension, and early atherosclerosis. These risk factors may operate through the association between child and adult obesity, but they may also act independently. Because of their public health importance, the trends in child obesity should be closely monitored.

Subjects and methods

Subjects

We obtained data on body mass index for children from six large nationally representative cross sectional surveys on growth from Brazil, Great Britain, Hong Kong, the Netherlands, Singapore, and the United States (table 1). Each survey had over 10 000 subjects, with ages ranging from 6-18 years, and quality control...
measures to minimise measurement error. Four of the datasets were based on single samples whereas the British and American data consisted of pooled samples collected over a period of time. We omitted the most recent survey data from the United States (1988-94) because we preferred to use data predating the recent increase in prevalence of obesity. In practice this decision made virtually no difference to the final cut off points.

Centile curves

Centile curves for body mass index were constructed for each dataset by sex using the LMS method, which summarises the data in terms of three smooth age-specific curves called L (lambda), M (mu), and S (sigma). The M and S curves correspond to the median and coefficient of variation of body mass index at each age whereas the L curve allows for the substantial age-dependent skewness in the distribution of body mass index. The values for L, M, and S can be tabulated for a series of ages. The Brazilian and US surveys (table 1) used a weighted sampling design, and their data were analysed accordingly.

The assumption underlying the LMS method is that after Box-Cox power transformation the data at each age are normally distributed. The points on each centile curve are defined in terms of the formula:

\[ z = \frac{\text{BMI} - M(1+S\sigma)}{L} \]

where L, M, and S are values of the fitted curves at each age, and z indicates the z score for the required centile, for example, \( z = 1.33 \) for the 91st centile. Figure 1 shows centiles for body mass index by sex based on the British reference, with seven centiles spaced two thirds of a z score apart—that is, \( z = -2, -1.33, -0.67, 0, +0.67, +1.33, \) and +2.

Figure 1 also shows body mass index values of 25 and 30 kg/m\(^2\) at age 18; 25 kg/m\(^2\) is just below the 91st centile in both sexes, whereas 30 kg/m\(^2\) is above the 98th centile. The body mass index (BMI) values can be converted to exact z scores from the L, M, and S values at age 18, with the formula:

\[ z = \frac{\text{BMI} - M}{L} \]

The body mass index of 25 kg/m\(^2\) at age 18 is z score +1.19 in females, corresponding to the 88th centile, and +1.30 in males, on the 90th centile. Therefore the prevalence of overweight at age 18 is 10-12%. A body mass index of 30 kg/m\(^2\) at age 18 is on the 99th centile in both sexes, an obesity prevalence of about 1%.

Each z score substituted into equation 1 provides the formula for an extra centile curve passing through the specified point (dotted line in fig 1). Each centile curve defines cut off points through childhood that correspond in prevalence of overweight or obesity to that of the adult cut off point—the curve joins up points where the prevalence matches that seen at age 18.

This process is repeated for all six datasets, by sex. Superimposing their curves leads to a cluster of centile curves that all pass through the adult cut off point yet
represent a wide range of overweight and obesity. The hypothesis is that the relation between cut off point and prevalence at different ages gives the same curve shape irrespective of country or obesity. If sufficiently similar the curves can be averaged to provide a single smooth curve passing through the adult cut off point. The curve is representative of all the datasets involved but is unrelated to their obesity—the cut off point is effectively independent of the spectrum of obesity in the reference data.

Results

Figure 2 shows the median curves for body mass index in the six datasets by sex from birth to 20 years. A wide range of values spans several units of body mass index in both sexes. These show the different extents of overweight across datasets, reflecting national differences in fatness. The median curves are all about the same shape, although the curve for Singaporean males is more curved, being lowest at ages 6 and 19 and highest at age 11.

Averaging the median curves would be a simple way to summarise the age trend in body mass index through childhood. But the resulting position of the curve at each age would depend on the overweight prevalence of the countries in the reference set, and so would be comparatively arbitrary. In any case the median is not an extreme centile and is ineffective as a cut off point. So averaging the median curves is not the answer.

Instead the centile curves are linked to adult cut off points of 25 and 30 kg/m², positioned at age 18 to maximise the available data. These values are expressed as centiles for each dataset, and the corresponding centile curves are drawn. Figure 1 shows the centile curves for overweight and obesity for the British reference.

Figure 3 presents the centile curves for overweight for the six datasets by sex, passing through the adult cut off point of 25 kg/m² at age 18. They are much closer together than the median curves (fig 2), particularly above age 10, because the national differences in overweight prevalence have been largely adjusted out. The divergence of the Singaporean curve is more pronounced than in figure 2.

Figure 4 gives the corresponding centile curves for obesity in each dataset, all passing through a body mass index of 30 kg/m² at age 18. There is less agreement than for the centiles for overweight, and again Singapore stands out.

Table 2 gives the centiles for overweight corresponding to body mass index of 25 kg/m² at age 18 years in six datasets, derived from fitted LMS curves.

Table 3 gives the centiles for obesity corresponding to body mass index of 30 kg/m² at age 18 years in six datasets, derived from fitted LMS curves.

### Table 2

<table>
<thead>
<tr>
<th>Country</th>
<th>Centile</th>
<th>z score</th>
<th>% above cut point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>95.3</td>
<td>1.68</td>
<td>4.7</td>
</tr>
<tr>
<td>Great Britain</td>
<td>90.4</td>
<td>1.30</td>
<td>9.6</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>88.3</td>
<td>1.19</td>
<td>11.7</td>
</tr>
<tr>
<td>Netherlands</td>
<td>94.5</td>
<td>1.60</td>
<td>5.5</td>
</tr>
<tr>
<td>Singapore</td>
<td>89.5</td>
<td>1.25</td>
<td>10.5</td>
</tr>
<tr>
<td>United States</td>
<td>81.9</td>
<td>0.91</td>
<td>18.1</td>
</tr>
</tbody>
</table>

### Table 3

<table>
<thead>
<tr>
<th>Country</th>
<th>Centile</th>
<th>z score</th>
<th>% above cut point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>99.9</td>
<td>3.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Great Britain</td>
<td>99.1</td>
<td>2.37</td>
<td>0.9</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>96.9</td>
<td>1.80</td>
<td>3.1</td>
</tr>
<tr>
<td>Netherlands</td>
<td>98.7</td>
<td>2.71</td>
<td>0.3</td>
</tr>
<tr>
<td>Singapore</td>
<td>98.3</td>
<td>2.12</td>
<td>1.7</td>
</tr>
<tr>
<td>United States</td>
<td>96.7</td>
<td>1.84</td>
<td>3.3</td>
</tr>
</tbody>
</table>
The amount of skewness, as measured by the sample L curves, is similar across countries. The Box-Cox powers are consistently between –1 and –2 indicating extreme skewness (not shown).

Table 4 shows international cut off points for body mass index for overweight and obesity from 2-18 years, obtained by averaging the centile curves in figures 3 and 4. From 2-6 years the cut off points do not include Singapore because its data start at age 6 years. Figure 6 shows the cut off points, with the values at 5.5 and 6 years adjusted slightly to ensure a smooth join between the two sets of curves.

Discussion

Our method addresses the two main problems of defining internationally acceptable cut off points for body mass index for overweight and obesity in children. The reference population was obtained by averaging across a heterogeneous mix of surveys from different countries, with widely differing prevalence rates for obesity, whereas the appropriate cut off point was defined in body mass index units in young adulthood and extrapolated to childhood, conserving the corresponding centile in each dataset. This principle, proposed at a meeting in 1997, was discussed in a recent editorial.

Although less arbitrary and potentially more internationally acceptable than other cut off points, this approach still provides a statistical definition, with all the advantages and disadvantages that that implies.

Our terminology corresponds to adult cut off points, but the health consequences for children above the cut off points may differ from those for adults. Children who are overweight but not obese should be evaluated for other factors as well. Nonetheless, the cut off points based on a heterogeneous worldwide population can be applied widely to determine whether the children and adolescents they identify are at increased risk of morbidity related to obesity.

Agreement of the centile curves

The major uncertainty with our approach, and the test of its validity, is the extent to which the centile curves for the datasets are of the same shape. Figures 3 and 4 show that although the agreement is reasonable it is not perfect. If it were perfect—that is, all the curves were superimposed—the reference cut off points applied to a given dataset would give the same prevalence for obesity at all ages, which could be predicted from the prevalence at age 18. So the different shapes in figures 3 and 4 show to what extent the age specific prevalence deviates from the age 18 prevalence within datasets.

We did consider six other datasets for our analysis (Canada, France, Japan, Russia, Sweden, and Venezuela) but we excluded them because they were either too small or nationally unrepresentative. Their centile curves for overweight in figure 7 are similar to those in figures 3 and 4. (Data for Japan and girls in Sweden and Venezuela are omitted as they do not extend to age 18). Singapore and Canada are clear outliers during puberty, whereas Russia stands out earlier in childhood. The median curves for Japan and Hong
Kong are similar in shape (not shown), suggesting that Singapore is atypical of Asia.

Nothing obvious explains Singapore's unusual pattern of overweight in puberty. Omitting it from the averaged country curves would lower the cut off points for both sexes by up to 0.4 body mass index units or 0.14 z score units at age 11-12. This compares to a range of three units between the lowest and highest curves at this age. Therefore, even though Singapore looks different from the other countries, its impact on the cut off points is only modest. Because there is no a priori reason to exclude Singapore, and because so little is known about growth patterns across countries, we have chosen to retain it in the reference population.

Extending the dataset
We recognise that the reference population made up of these countries is less than ideal. It probably reflects Western populations adequately but lacks representation from other parts of the world. The Hong Kong sample may, however, be fairly representative of the Chinese, and the Brazilian and US datasets include many subjects of African descent. Although additional datasets from Africa and Asia would be helpful, our stringent inclusion criteria of a large sample, national representativeness, minimum age range 6-18 years, and data quality control, mean that further datasets are unlikely to emerge from these continents in the foreseeable future. To our knowledge no other available surveys satisfy the criteria. It is not realistic to wait for them because there is an urgent need for international cut off points now. Also, our methodology aims to adjust for differences in overweight between countries, so it could be argued that adding other countries to the reference set would make little difference to the cut off points. None the less, further research is needed to explore patterns of body mass index in children in Africa and Asia.

Puberty
The body mass index curves in figure 6 show a fairly linear pattern for males but a higher and more concave shape for females. This sex difference can also be seen in the individual curves of figures 2 to 4 reflecting earlier puberty in females. The sensitivity of the curve's shape to the timing of puberty may affect the performance of the cut off points in countries where puberty is appreciably delayed, although delays of less than two years are unlikely to make much difference.

Use of cut off points
The cut off points in table 4 are tabulated at exact half year ages and for clinical use need to be linearly interpolated to the subject's age. For epidemiological use, with age groups of one year width, the cut off point at the mid year value (for example, at age 7.5 for the 7.0-8.0 age group) will give an essentially unbiased estimate of the prevalence.

The centiles for obesity involve more extrapolation than the centiles for overweight, which may explain the greater variability across datasets in figure 4 compared with figure 3. For this reason the obesity cut off points in figure 6 are fairly imprecise and are likely to be less useful than the cut off points for overweight.

The approximate prevalence values for overweight and obesity in tables 2 and 3 are calculated as the tail areas of the body mass index distribution in each sample at age 18, as estimated by the LMS method. This assumes that the distribution is normal after adjusting for skewness, which is inevitably only an approximation. In the British data there was slight kurtosis (heavy tails) in the distribution of body mass index, with 2.8% of the sample rather than the 2.5% expected exceeding a z score of 2. Therefore the true prevalences for the other datasets here may differ slightly from the values quoted.

The principle used to obtain cut off points for overweight and obesity in children could also provide a cut off point for underweight in children, based on the World Health Organisation's cut off point of a body mass index of 18.5 kg/m² for adult underweight. A body mass index of 18.5 kg/m² in a young adult is, however, equivalent to the British 12th centile, an unacceptably high prevalence of child underweight. A possible alternative would be a cut off point of a body mass index of 17 kg/m², on the British second centile at age 18. Although substantial data link cut off points of 25 and 30 kg/m² to morbidity in adults and the corresponding centile cut off points are associated with
Papers

What is already known on this topic

Child obesity is a serious public health problem that is surprisingly difficult to define.

The 95th centile of the US body mass index reference has recently been proposed as a cut off point for child obesity, but like previous definitions it is far from universally accepted.

What this study adds

A new definition of overweight and obesity in childhood, based on pooled international data for body mass index and linked to the widely used adult obesity cut off point of 30 kg/m², has been proposed.

The definition is less arbitrary and more international than others, and should encourage direct comparison of trends in child obesity worldwide.

Conclusions

Our analysis provides cut off points for body mass index in childhood that are based on international data and linked to the widely accepted adult cut off points of a body mass index of 25 and 30 kg/m². Our approach avoids some of the usual arbitrariness of choosing the reference data and cut off point. Applying the cut off points to the national datasets on which they are based gives a wide range of prevalence estimates at age 18 of 5-18% for overweight and 0.1-4% for obesity. A similar range of estimates is likely to be seen from age 2-18. The cut off points are recommended for use in international comparisons of prevalence of overweight and obesity.

We thank Carlos Monteiro (Brazil), Sophie Leung (Hong Kong), Machteild Roede (the Netherlands), Uma Rajan (Singapore), Claude Bouchard (Canada), Marie Françoise Rolland Cacheira (France), Yuji Matsuawa (Japan), Barry Popkin (USA, for the Russian data), Gunilla Tander-Lindgren (Sweden), and Mercedes Lopez de Blanco (Venezuela) for allowing us access to their data.

Contributors: TJ C had the original idea, did most of the statistical analyses, and wrote the first draft of the paper. TJ C, MCB, KMF, and WHD provided the data. KMF did further analyses of the US data. All authors attended the original childhood obesity workshop, participated in the design and planning of the study, discussed the interpretation of the results, and contributed to the final paper. TJ C will act as guarantor for the paper.

Funding: This work was supported by the Childhood Obesity Working Group of the International Obesity Task Force. TJ C is supported by a Medical Research Council programme grant. Competing interests: None declared.

6 Malina RM, Katzmarzyk P. Validity of the body mass index as an indicator of the risk and presence of overweight in adolescents. Am J Clin Nutr 1999;70:131-6S.

(Accepted 21 January 2000)