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

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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/m^2 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.[1] It is associated with several risk factors for later heart disease and other chronic diseases including hyperlipidaemia, hyperinsulinaemia, hypertension, and early atherosclerosis.[2–4] These risk factors may operate through the association between child and adult obesity, but they may also act independently.[5]

Because of their public health importance, the trends in child obesity should be closely monitored. Trends are, however, difficult to quantify or to compare internationally, as a wide variety of definitions of child obesity are in use, and no commonly accepted standard has yet emerged. The ideal definition, based on percentage body fat, is impracticable for epidemiological use. Although less sensitive than skinfold thicknesses,[6] the body mass index (weight/height^2) is widely used in adult populations, and a cut off point of 30 kg/m^2 is recognised internationally as a definition of adult obesity.[7]

Body mass index in childhood changes substantially with age.[8 9] At birth the median is as low as 13 kg/m^2, increases to 17 kg/m^2 at age 1, decreases to 15.5 kg/m^2 at age 6, then increases to 21 kg/m^2 at age 20. Clearly a cut off point related to age is needed to define child obesity, based on the same principle at different ages, for example, using reference centiles.[10] In the United States, the 85th and 95th centiles of body mass index for age and sex based on nationally representative survey data have been recommended as cut off points to identify overweight and obesity.[11]

For wider international use this definition raises two questions: why base it on data from the United States, and why use the 85th or 95th centile? Other countries are unlikely to base a cut off point solely on American data, and the 85th or 95th centile is intrinsically no more valid than the 90th, 91st, 97th, or 98th centile. Regardless of centile or reference population, the cut off point can still be criticised as arbitrary.

A reference population could be obtained by pooling data from several sources, if sufficiently homogeneous. A centile cut off point could in theory be identified as the point on the distribution of body mass index where the health risk of obesity starts to rise steeply. Unfortunately such a point cannot be identified with any precision: children have less disease related to obesity than adults, and the association between child obesity and adult health risk may be mediated through adult obesity, which is associated both with child obesity and adult disease.

The adult cut off points in widest use—a body mass index of 25 kg/m^2 for overweight and 30 kg/m^2 for obesity—are related to health risk[1] but are also convenient round numbers. A workshop organised by the International Obesity Task Force proposed that these adult cut off points be linked to body mass index centiles for children to provide child cut off points.[12 13] We describe the development of age and sex specific cut off points for body mass index for overweight and obesity in children, using dataset specific centiles linked to adult cut off points.

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

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Table 1 Six nationally representative datasets of body mass indices in childhood

			Males		Females		
Country	Year	Description	Age range	Sample size	Age range	Sample size	Reference
Brazil	1989	Second national anthropometric survey	2-25	15 947	2-25	15 859	14
Great Britain	1978-93	Data pooled from five national growth surveys	0-23	16 491	0-23	15 731	15
Hong Kong	1993	National growth survey	0-18	11 797	0-18	12 168	16
Netherlands	1980	Third nationwide growth survey	0-20	21 521	0-20	20 245	17
Singapore	1993	School health service survey	6-19	17 356	6-20	16 616	18
United States	1963-80	Data pooled from four national surveys	2-20	14 764	2-20	14 232	19

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.[19] In practice this decision made virtually no difference to the final cut off points.

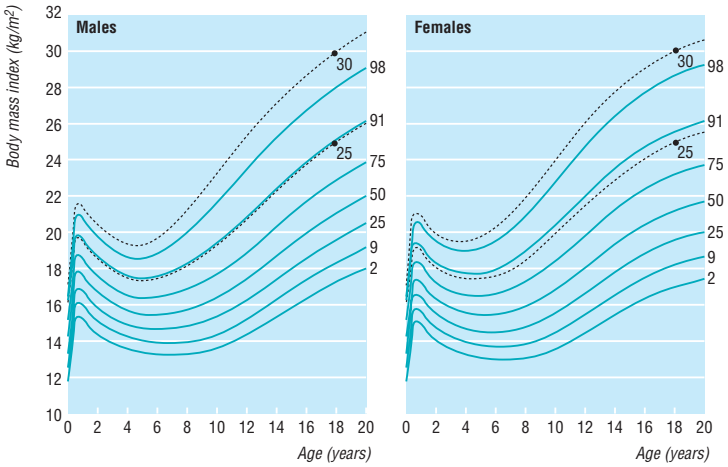


Fig 1 Centiles for body mass index for British males and females. Centile curves are spaced two thirds of z score apart. Also shown are body mass index values of 25 and 30 kg/m² at age 18, with extra centile curves drawn through them

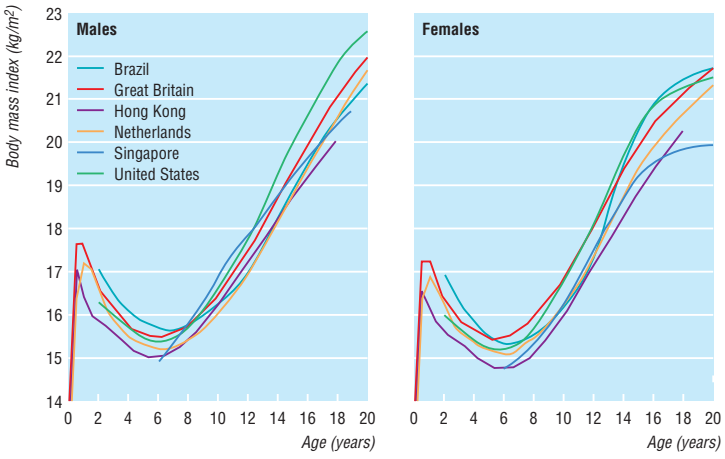


Fig 2 Median body mass index by age and sex in six nationally representative datasets

Centile curves

Centile curves for body mass index were constructed for each dataset by sex using the LMS method,[15] 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[15]:

$$M(1+LSz)^{1/L}$$

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,[9] 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/m² at age 18; 25 kg/m² is just below the 91st centile in both sexes, whereas 30 kg/m² 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[2]:

$$Z = \frac{\left[\frac{BMI}{M}\right]^{L} - 1}{LS}$$

The body mass index of 25 kg/m² 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/m² 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

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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/m^2, 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/m^2 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/m^2 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 a body mass index of 25 kg/m^2 at age 18 for each dataset by sex. For example, they approximate the 95th centile for Dutch males and the 90th centile for British males—that is, prevalences of overweight of 5-10%. The centiles for obesity corresponding to a body mass index of 30 kg/m^2 in table 3 are mainly above the 97th centile, less than 3% prevalence, and they show more variability.

The curves in figures 3 and 4 are reasonably consistent across countries between ages 8 and 18, although those for Singapore are higher between ages 10 and 15. This is due partly to the increased median (fig 2) and partly to greater variability. The LMS method estimates the coefficient of variation (or S

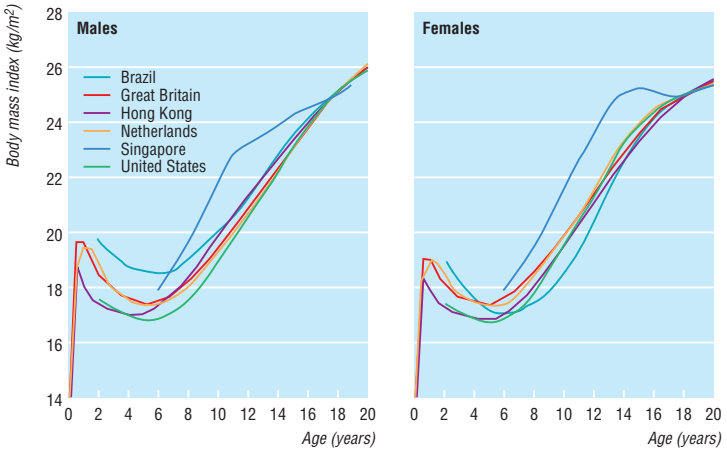


Fig 3 Centiles for overweight by sex for each dataset, passing through body mass index of 25 kg/m^2 at age 18

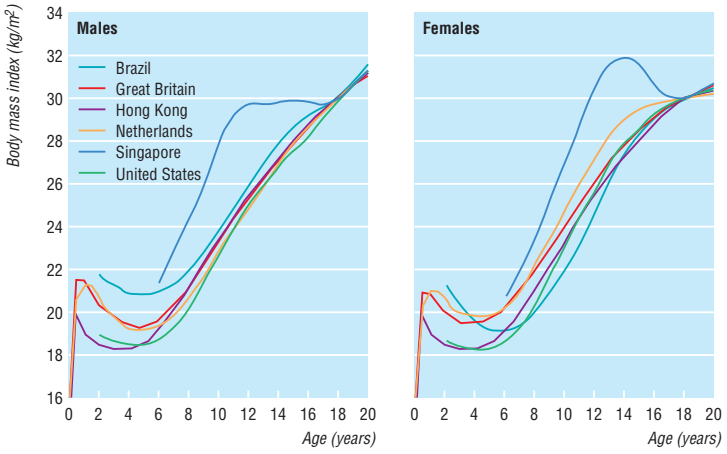


Fig 4 Centiles for obesity by sex for each dataset, passing through body mass index of 30 kg/m^2 at age 18

Table 2 Centiles and z scores for overweight corresponding to body mass index of 25 kg/m^2 at age 18 years in six datasets, derived from fitted LMS curves

	Males			Females		
Country	Centile	z score	% above cut off point	Centile	z score	% above cut off point
Brazil	95.3	1.68	4.7	84.8	1.03	15.2
Great Britain	90.4	1.30	9.6	88.3	1.19	11.7
Hong Kong	88.3	1.19	11.7	90.2	1.29	9.8
Netherlands	94.5	1.60	5.5	93.5	1.52	6.5
Singapore	89.5	1.25	10.5	93.0	1.48	7.0
United States	81.9	0.91	18.1	83.5	0.97	16.5

Table 3 Centiles and z scores for obesity corresponding to body mass index of 30 kg/m^2 at age 18 years in six datasets, derived from fitted LMS curves

	Males			Females		
Country	Centile	z score	% above cut off point	Centile	z score	% above cut off point
Brazil	99.9	3.1	0.1	98.0	2.1	2.0
Great Britain	99.1	2.37	0.9	98.8	2.25	1.2
Hong Kong	96.9	1.86	3.1	98.2	2.10	1.8
Netherlands	99.7	2.71	0.3	99.7	2.73	0.3
Singapore	98.3	2.12	1.7	99.0	2.33	1.0
United States	96.7	1.84	3.3	96.0	1.76	4.0

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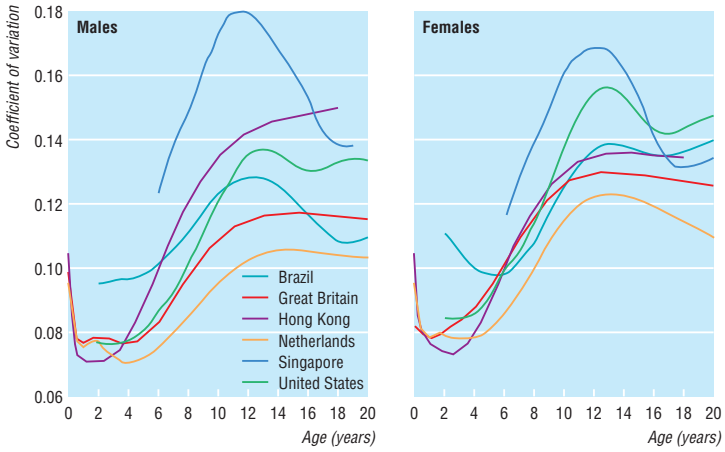


Fig 5 Plots of coefficient of variation of body mass index by age and sex for each dataset

curve) of body mass index during the centile fitting process, and figure 5 compares the S curves for the six datasets. Between ages 6 and 15 the coefficient of variation in Singapore is greater than for the other countries. The range of values for the coefficient of variation in puberty is greater for males than females, and for Brazil, Singapore, and the United States the curves for both sexes show a peak in puberty.

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.

Table 4 International cut off points for body mass index for overweight and obesity by sex between 2 and 18 years, defined to pass through body mass index of 25 and 30 kg/m^2 at age 18, obtained by averaging data from Brazil, Great Britain, Hong Kong, Netherlands, Singapore, and United States

	Body mass index 25 kg/m^2		Body mass index 30 kg/m^2	
Age (years)	Males	Females	Males	Females
2	18.41	18.02	20.09	19.81
2.5	18.13	17.76	19.80	19.55
3	17.89	17.56	19.57	19.36
3.5	17.69	17.40	19.39	19.23
4	17.55	17.28	19.29	19.15
4.5	17.47	17.19	19.26	19.12
5	17.42	17.15	19.30	19.17
5.5	17.45	17.20	19.47	19.34
6	17.55	17.34	19.78	19.65
6.5	17.71	17.53	20.23	20.08
7	17.92	17.75	20.63	20.51
7.5	18.16	18.03	21.09	21.01
8	18.44	18.35	21.60	21.57
8.5	18.76	18.69	22.17	22.18
9	19.10	19.07	22.77	22.81
9.5	19.46	19.45	23.39	23.46
10	19.84	19.86	24.00	24.11
10.5	20.20	20.29	24.57	24.77
11	20.55	20.74	25.10	25.42
11.5	20.89	21.20	25.58	26.05
12	21.22	21.68	26.02	26.67
12.5	21.56	22.14	26.43	27.24
13	21.91	22.58	26.84	27.76
13.5	22.27	22.98	27.25	28.20
14	22.62	23.34	27.63	28.57
14.5	22.96	23.66	27.98	28.87
15	23.29	23.94	28.30	29.11
15.5	23.60	24.17	28.60	29.29
16	23.90	24.37	28.88	29.43
16.5	24.19	24.54	29.14	29.56
17	24.46	24.70	29.41	29.69
17.5	24.73	24.85	29.70	29.84
18	25	25	30	30

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,[13] was discussed in a recent editorial.[12]

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.[20] 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.[11] 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

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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,[21] 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,[15] with 2.8% of the sample rather than the 2.3% 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/m^2 for adult underweight. A body mass index of 18.5 kg/m^2 in a young adult is, however, equivalent to the British 12th centile,[9] an unacceptably high prevalence of child underweight. A possible alternative would be a cut off point of a body mass index of 17 kg/m^2, on the British second centile at age 18.[9] Although substantial data link cut off points of 25 and 30 kg/m^2 to morbidity in adults[22] and the corresponding centile cut off points are associated with

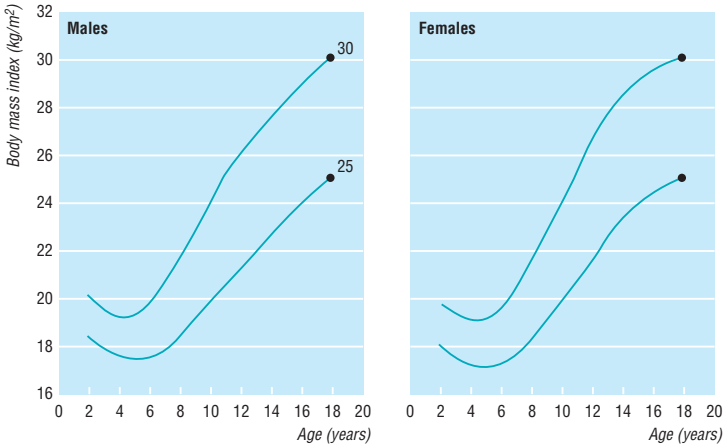


Fig 6 International cut off points for body mass index by sex for overweight and obesity, passing through body mass index 25 and 30 kg/m^2 at age 18 (data from Brazil, Britain, Hong Kong, Netherlands, Singapore, and United States)

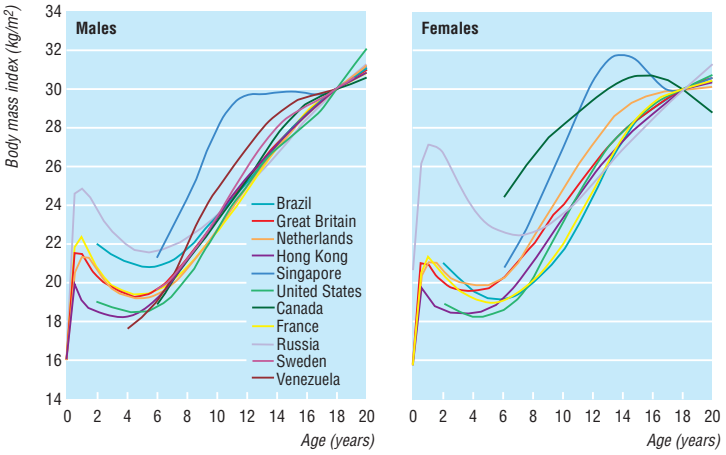


Fig 7 Centiles for overweight by sex for 11 datasets

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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/m^2, has been proposed

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

morbidity in children,[23] the health effects of cut off points corresponding to a body mass index below 17 or 18.5 kg/m^2 have not been studied. These cut off points for underweight need validating as markers of disease risk.

Based on cross sectional data the curves give no information about centile crossing over time—a weakness of most "growth" charts. Longitudinal data are needed to derive correlations of body mass index from one age to another, which then define the likely variability of centile crossing.[24 25]

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/m^2. 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.

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Contributors: TJC had the original idea, did most of the statistical analyses, and wrote the first draft of the paper. TJC, 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. TJC will act as guarantor for the paper.

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Competing interests: None declared.

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