PEDIATRIC OBESITY

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Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity

T. J. Cole[1] and T. Lobstein[2]

[1]MRC Centre of Epidemiology for Child Health, UCL Institute of Child Health, London, UK; [2]International Association for the Study of Obesity, London, UK

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What is already known about this subject

- The widely used international (IOTF) childhood BMI cut-offs for overweight, obesity and thinness (Cole *et al.*, 2000; 2007) are based on and linked to the corresponding adult BMI cut-offs.
- A disadvantage of the cut-offs is that they are not expressible as BMI centiles.
- The World Health Organization childhood BMI cut-offs (WHO, 2006; 2007) are based on SD scores and centiles.

What this study adds

- The international cut-offs are here reformulated in terms of underlying LMS curves, which allow BMI to be expressed as a centile or SD score.
- The reformulation leads to very minor changes in the existing cut-offs.
- It also has several benefits: existing cut-offs can be expressed as centiles or SD scores; new cut-offs are easy to derive, and the international and WHO cut-offs can be compared directly.

Summary

Background: The international (International Obesity Task Force; IOTF) body mass index (BMI) cut-offs are widely used to assess the prevalence of child overweight, obesity and thinness. Based on data from six countries fitted by the LMS method, they link BMI values at 18 years (16, 17, 18.5, 25 and 30 kg m^{-2}) to child centiles, which are averaged across the countries. Unlike other BMI references, e.g. the World Health Organization (WHO) standard, these cut-offs cannot be expressed as centiles (e.g. 85th).

Methods: To address this, we averaged the previously unpublished L, M and S curves for the six countries, and used them to derive new cut-offs defined in terms of the centiles at 18 years corresponding to each BMI value. These new cut-offs were compared with the originals, and with the WHO standard and reference, by measuring their prevalence rates based on US and Chinese data.

Results: The new cut-offs were virtually identical to the originals, giving prevalence rates differing by <0.2% on average. The discrepancies were smaller for overweight and obesity than for thinness. The international and WHO prevalences were systematically different before/after age 5.

Conclusions: Defining the international cut-offs in terms of the underlying LMS curves has several benefits. New cut-offs are easy to derive (e.g. BMI 35 for morbid obesity), and they can be expressed as BMI centiles (e.g. boys obesity = 98.9th centile), allowing them to be compared with other BMI references. For WHO, median BMI is relatively low in early life and high at older ages, probably due to its method of construction.

Keywords: BMI, international, reference values, LMS method.

Address for correspondence: Professor TJ Cole, MRC Centre of Epidemiology for Child Health, UCL Institute of Child Health, 30 Guilford Street, London WC1N 1EH, UK. E-mail: tim.cole@ucl.ac.uk

Introduction

The definition of childhood overweight and obesity based on body mass index (BMI) is complicated, as a recent review makes clear (1). It recommends the dual use of the international and World Health Organization (WHO) cut-offs. The international BMI cut-offs for overweight and obesity [the International Obesity Task Force (IOTF) cut-offs (2)] and cut-offs for thinness (3) have been widely used to assess prevalence rates for childhood overweight, obesity and thinness (note that the thinness cut-offs were not IOTF sponsored, so the term 'international cut-offs' is used here to cover both). They are based on BMI data from six countries, which were used to construct country-specific centile curves passing through BMI 25 (overweight), 30 (obesity) and 18.5, 17 and 16 (thinness grades 1, 2 and 3) at age 18. The curves were then averaged across countries by age to give sex-specific curves for each cut-off.

These international cut-offs are defined by values of BMI at age 18, whereas other published BMI references, such as the WHO growth standard (4) and WHO growth reference (5), rely on age-sex-specific BMI centiles (e.g. 85th or 95th centile) or standard deviation (SD) scores (e.g. +2 SDs) to define the cut-offs. In this paper, we explore the value of expressing the international cut-offs in a centile/SD score framework, based on the underlying datasets; we explain the benefits its use brings; show how it simplifies comparison with other published cut-offs; and in particular, we compare the international cut-offs with the corresponding WHO cut-offs.

Methods

The methods for constructing the international cut-offs have already been described (2,3). In brief, they involved combining nationally representative survey data from six countries: the UK, USA, the Netherlands, Brazil, Singapore and Hong Kong, covering the age range 2 to 18 years (6–18 for Singapore). The data were collected between 1963 and 1993. The age-sex-specific BMI distribution in each survey was summarized using the LMS method (6), expressing the median, coefficient of variation and skewness as quantities that change smoothly with age, and which can be plotted as smooth curves vs. age. They are termed the L (skewness λ), M (median μ) and S (coefficient of variation σ) curves, respectively. The curves are used to define centile curves using the formula

$$C_{100\alpha} = M(1+L\times S\times z_\alpha)^{1/L} \qquad (1)$$

where z_α is the normal equivalent deviate for tail area α. The value of z_α is equivalent to an SD score cut-off, e.g. +1 or +2 SDs. In addition, the LMS method allows a BMI measurement to be expressed as an SD score z using the formula

$$z = \frac{(BMI/M)^L - 1}{L\times S} \qquad (2)$$

where the values for L, M and S correspond to the child's age and sex.

The international cut-offs use formula (2) to obtain the SD score z_α corresponding to a given BMI value (e.g. 25) at age 18 in each country dataset. This is then substituted into formula (1) and values of the centile $C_{100\alpha}$ at different ages are obtained to give the country-specific centile curves. These curves are then averaged by age across countries to give a single cut-off corresponding to the chosen BMI value.

The advantage of this approach is that it allows the country-specific cut-offs to be compared with each other. Ideally, they should all be the same shape and superimposed on each other (as they are at age 18 by definition), though in practice, they are reasonably close but not superimposed (2,3). There is however an alternative approach to summarizing the country-specific information, which is to average the L, M and S curves across countries, and use these pooled curves to produce the cut-off values. However these 'pooled' cut-offs would inevitably differ slightly from the average of the separate country cut-offs, and if this difference were appreciable, it could lead to confusion if the two forms of cut-off were used in parallel. Only if very close together could they be used interchangeably.

To explore this alternative approach, pooled L, M and S curves were obtained by averaging the country-specific curves, using the geometric means for M and S as they provided a better fit than the arithmetic means. The resulting curves were lightly smoothed to remove slight irregularities around 6 years due to the Singapore data starting at that age. The differences between the two forms of cut-off were analyzed by deriving the mean and SD of the differences across the range of ages, expressed both as BMI (i.e. new minus original) and as SD score (the nominal SD score at age 18 minus the original cut-off expressed as an SD score). The differences were also compared by applying the original and new cut-offs to two large datasets of child BMI measurements and comparing the resulting prevalence rates. The two datasets were the US NHANES 2005–2006 (7) and the China

Health and Nutrition Survey 2004, a long-standing Sino-American project described in detail at http://www.cpc.unc.edu/projects/china. For these analyses, two sets of cut-off reference tables were prepared using the original and new approach, with cut-offs calculated by sex for each month of age from 2 to 18 years, and for the equivalent of BMI 16, 17, 18.5, 25 and 30 kg m^{-2} at age 18.

Expressing the international cut-offs in terms of their LMS curves allowed direct comparison with the corresponding cut-offs based on the WHO growth standard and growth reference. The WHO BMI cut-offs are based on a combination of data from the WHO growth standard for age 0–5 years (4) and data from the US National Center for Health Statistics (NCHS) 1977 reference (8) re-analyzed to merge with the WHO standard (5). Thus, it is of interest to compare the international and WHO charts (9). The WHO LMS tables obtained from http://www.who.int/childgrowth/en/ and http://www.who.int/growthref/en/ were used here to calculate prevalence rates for thinness, overweight and obesity as defined by the WHO BMI SD scores (9):

- Thinness and severe thinness: –2 SDs and –3 SDs.
- Overweight: +2 SDs up to age 5, +1 SD thereafter.
- Obesity: +3 SDs up to age 5, +2 SDs thereafter.

Results

Original and pooled international BMI cut-offs

Figs 1 and 2 illustrate the two different ways of constructing the international overweight cut-off for males, corresponding to BMI 25 at age 18. Fig. 1 shows the separate *M* (top left), *S* (top right) and *L* (bottom left) curves for the six country surveys between 2 and 18 years. The *M* curves show the consistent fall then rise in median BMI at age 6, termed the adiposity rebound (10); the *S* curves show low variability (around 0.08 or 8%) until age 5 then a steep rise to 12–15% from age 12, and the *L* curves show skewness increasing with age (an *L* value of 1 corresponds to no skewness, and below 1 indicates progressively greater right skewness). The six cut-offs based on formula (1) passing through BMI 25 at age 18 are shown bottom right, along with the averaged cut-off (dashed heavy line). Similar graphs can be drawn for the other BMI cut-offs in the two sexes (2,3).

Fig. 2 shows the same *L*, *M* and *S* curves as in Fig. 1, but in addition, the average curves are shown (black dashed heavy lines). Supporting Information Table S1 gives these averaged *L*, *M* and *S* values by age and sex, in half years from 2 to 18 years (note that values for intermediate ages can be obtained using linear or cubic interpolation, e.g. with the Excel software LMSgrowth (11)). These average *L*, *M* and *S* values at age 18 can be plugged into formula (2) with BMI 25 to give the SD score $z = 1.310$ (90.5th centile), which substituted into formula (1) leads to a single country-averaged cut-off passing through BMI 25 at age 18 (Fig. 2, bottom right). This cut-off is here termed 'LMS-based' to distinguish it from the original 'country-averaged' cut-off.

Table 1 (columns 2–3) gives the SD scores and centiles corresponding to BMI 16, 17, 18.5, 25 and 30 kg m^{-2} at age 18 by sex, obtained with formula (2). For BMI 30, the centiles are nearer the 99th than the 98th centile (i.e. SD score > +2), while BMI 25 corresponds roughly to the 90th centile and BMI 17 to the 3rd. The table also summarizes discrepancies between the original country-averaged and new LMS-based cut-offs, which are discussed below.

As an example of what is possible with the new LMS values, Table 1 also includes the new cut-off BMI 35 kg m^{-2} for morbid obesity, which corresponds to the 99.8th centile at age 18. The Appendix derives this cut-off as a worked example.

Difference between old and new BMI cut-offs

Table S2 gives the LMS-based international cut-offs for thinness, overweight and obesity, including the new morbid obesity cut-off. They are also available by month of age from 2 to 18 years at http://www.iaso.org/publications/iotfreports/newchildcutoffs/.

A key question is, how close together are the pairs of cut-offs for each BMI value, country-averaged (as in Fig. 1) and LMS-based (as in Fig. 2)? Fig. 3 compares the country-averaged (solid line) and LMS-based (dashed line) cut-offs for the five BMI values by sex, and clearly, the pairs of curves are very similar. For overweight and obesity, they are virtually identical across the age range, and similarly for thinness grade 1, only thinness grades 2 and 3 show slight discrepancies below age 6.

Table 1 (columns 4–7) summarizes the differences between the two sets of cut-offs, in both BMI and SD score units, and in detail they are tiny, being slightly smaller for the overweight-obesity cut-offs than for the thinness grades, for males compared to females, and above age 6 compared to below (agreeing with Fig. 3).

Table 2 uses existing survey data to see how these differences impact on prevalence. It compares the

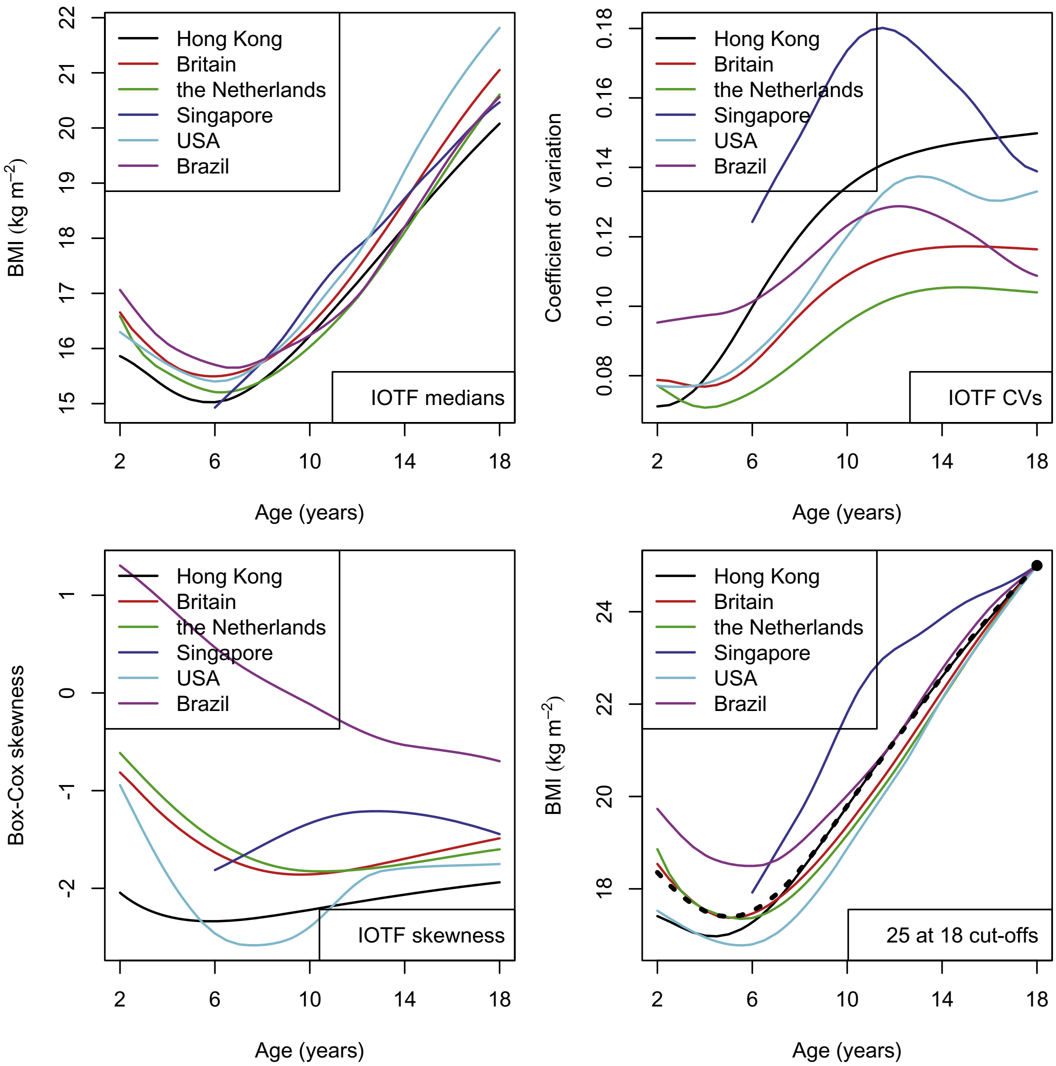

Figure 1 Derivation of the IOTF cut-offs for BMI 25 at age 18 in boys. The *L*, *M* and *S* curves are shown by country, as median (*M*), coefficient of variation (*S*) and skewness (*L*), with the corresponding country-specific cut-offs and their mean (heavy dashed line). See text for details.

prevalence rates of thinness, overweight and obesity based on the original and LMS-based cut-offs as applied to the US NHANES and Chinese data, split by sex and age 2–5 and 5–18 years. The differences in prevalence between old and new are generally tiny. Across the 40 age/sex/study/cut-off cells in Table 2, 20 agree exactly while only five, all for age 2–5, have discrepancies exceeding 1%. For comparison, the standard errors of the corresponding prevalence rates are upwards of 1%. Thus, in practice, the prevalence rates based on the new cut-offs are extremely close to those based on the old, and the cut-offs by the two methods can be used interchangeably.

Prevalence rates by international and WHO BMI cut-offs

Table 2 also compares the prevalence rates in the two surveys based on the international and WHO cut-offs. The surveys are very different – in China, overweight and obesity prevalence is higher in early life than later, whereas in the USA, the reverse is true. This may reflect higher rates of stunting in young Chinese children, which will increase the rate of overweight. Note particularly their high rates of morbid obesity, exceeding 15% in both sexes. Thinness rates are also higher in China than the USA, but the age pattern varies with thinness grade.

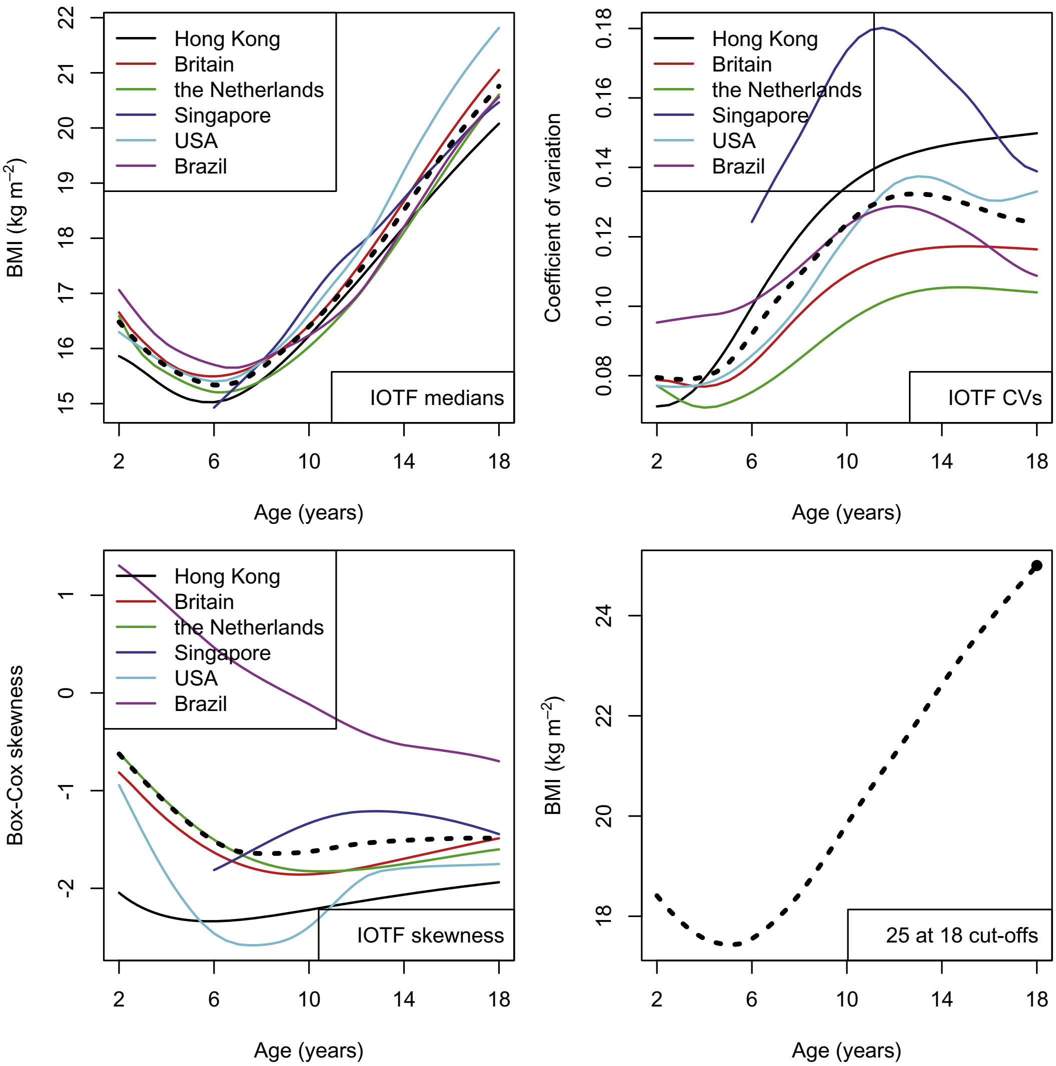

Figure 2 Alternative derivation of the IOTF cut-offs for BMI 25 at age 18 in boys. The *L*, *M* and *S* curves are shown as in Figure 1, but their means are also shown (heavy dashed lines). The averaged cut-off is shown based on the averaged *L*, *M* and *S* curves. See text for details.

Comparing the prevalence rates based on the international and WHO cut-offs, it is striking that for age 2–5, the WHO rates are all lower, while for age 5–18, they are higher, except for the thinnest girls. We explore the reason for this by comparing the underlying centile curves.

International and WHO BMI centile charts

The new LMS table permits the construction of an international BMI centile chart, shown in Fig. 4 in the UK nine-centile format (12). The chart can be used to monitor overweight and thinness in the clinical context, displaying small changes in the individual's BMI centile over time. The centiles display the familiar adiposity rebound, the second rise in BMI at around 5 years and then a steep rise during puberty, which falls away in girls but continues until age 18 in boys.

The corresponding WHO centile curves are shown in Fig. 4 as grey lines. The two sets of centiles are broadly similar in shape, but they show a crossover around age 6 with WHO consistently lower before and higher after. This pattern arises because the two medians are different shapes. To explore this further, Fig. 5 compares the WHO median with the six country medians underlying the international cut-offs (i.e. the median curves of Figs 1 and 2 with WHO superimposed), and it is apparent that the WHO is

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Table 1 SD score cut-offs corresponding to the international BMI cut-offs

BMI cut-off at age 18 (kg m^{-2})	SD score equivalent	Centile equivalent	Comparison with original cut-offs			
			BMI difference (kg m^{-2})		SD score difference	
			Mean	SD	Mean	SD
Boys						
16	–2.565	0.52	0.05	0.08	0.06	0.09
17	–1.877	3.0	0.03	0.06	0.03	0.06
18.5	–1.014	15.5	0.01	0.04	0.01	0.04
25	1.310	90.5	–0.03	0.01	–0.01	0.01
30	2.288	98.9	–0.02	0.04	–0.01	0.02
35*	2.930	99.83	–	–	–	–
Girls						
16	–2.436	0.74	0.02	0.06	0.03	0.06
17	–1.789	3.7	0.02	0.06	0.02	0.06
18.5	–0.975	16.5	0.01	0.06	0.02	0.05
25	1.244	89.3	–0.02	0.06	0.00	0.03
30	2.192	98.6	–0.08	0.08	–0.01	0.02
35*	2.822	99.76	–	–	–	–

*New cut-off for morbid obesity.

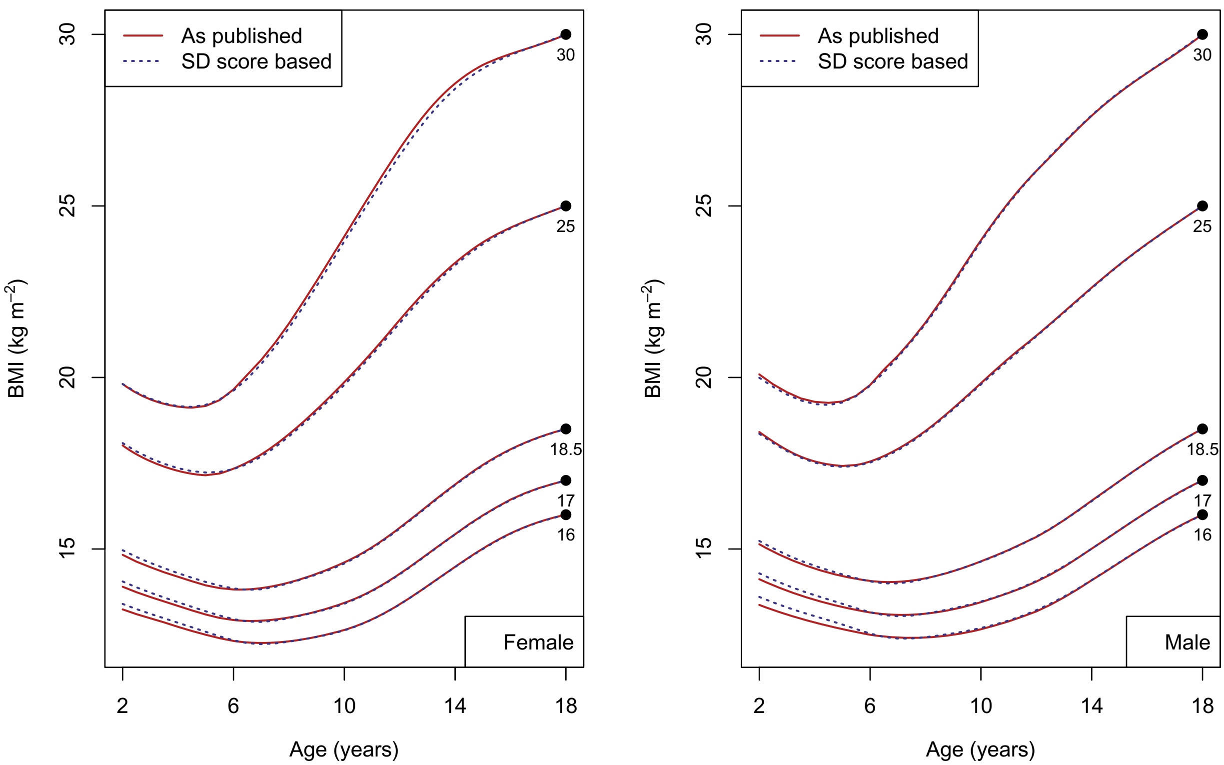

Figure 3 Comparison of the international cut-offs as originally published (i.e. Figure 1; red solid lines) and as derived from the new *L*, *M* and *S* curves (i.e. Figure 2; blue dotted lines).

the second lowest curve before age 5 and the second highest after age 12, in both sexes. At older ages, the WHO curve is similar to the IOTF USA curve, which is unsurprising as the WHO reference is based on data from three US national examination surveys (NHES2, NHES3 and NHANES1) while the US dataset in the international definition includes these three datasets plus the 1984 NHANES2.

Table 2 Prevalence (%) of thinness, overweight and obesity in Chinese and US children using the international* and WHO cut-offs†, and comparison between the original and new pooled international cut-offs

Age group (years)	n	Thinness								Overweight			Obesity			Morbid Obesity	
		< BMI 16*		WHO < -3SD	< BMI 17*		WHO < -2SD	< BMI 18.5*		≥ BMI 25*		WHO†	≥ BMI 30*		WHO†	≥ BMI 35*	WHO†
		Old	New – old		Old	New – old		Old	New – old	Old	New – old		Old	New – old		New	
China 2004 – Boys																	
2.0–5.0	147	5.5	+0.6	2.0	8.2	+2.7	6.1	19.0	+0.7	25.2	0.0	22.4	18.4	0.0	17.0	15.6	–
5.1–17.9	720	1.7	0.0	1.8	4.4	+0.3	7.2	18.5	0.0	16.4	0.0	21.4	6.4	0.0	9.8	3.5	4.9
2.0–17.9	867	2.3	+0.1	1.8	5.1	+0.7	7.0	18.6	+0.1	18.0	0.0	21.7	8.4	0.0	11.1	5.5	–
China 2004 – Girls																	
2.0–5.0	119	5.0	+0.9	0.8	7.6	0.0	5.9	14.3	+0.8	27.7	–1.6	21.0	20.2	0.0	16.8	15.1	–
5.1–17.9	630	1.9	+0.2	0.6	8.7	–0.3	8.1	26.0	–0.1	10.8	0.0	14.0	4.9	+0.2	5.7	2.5	2.5
2.0–17.9	749	2.4	+0.3	0.7	8.5	–0.2	7.7	24.2	+0.1	13.5	–0.3	15.1	7.3	+0.2	7.5	4.5	–
US NHANES 2005/06 – Boys																	
2.0–5.0	374	0.2	0.0	0.0	0.8	+0.6	0.2	8.8	+1.3	13.0	+0.8	9.1	3.8	0.0	2.7	1.8	–
5.1–17.9	1458	0.1	0.0	0.3	0.5	0.0	1.1	6.7	0.0	30.0	+0.1	38.4	11.5	0.0	18.0	4.5	4.9
2.0–17.9	1832	0.1	0.0	0.3	0.6	+0.1	0.9	7.1	+0.2	27.0	+0.2	33.0	10.2	0.0	15.3	4.0	–
US NHANES 2005/06 – Girls																	
2.0–5.0	384	0.2	0.0	0.0	0.4	0.0	0.2	6.3	+1.7	17.5	–2.7	8.9	5.8	0.0	1.8	1.9	–
5.1–17.9	1469	0.7	0.0	0.0	2.1	0.0	2.0	6.7	+0.1	29.8	+0.4	35.2	13.5	+0.2	16.4	4.5	3.4
2.0–17.9	1853	0.6	0.0	0.0	1.8	0.0	1.7	6.7	+0.3	27.6	–0.1	30.4	12.1	+0.2	13.7	4.0	–

*Indicates BMI centile corresponding to BMI at age 18; Cole *et al*. (3) for thinness, Cole *et al*. (2) for overweight/obesity.
†WHO growth standard tables (http://www.who.int/childgrowth/standards/en/) for ages 2.0–5.0 years, using > +2SD and > +3SD for overweight and obese; and WHO growth reference tables (http://www.who.int/growthref/en/) for ages 5.1–17.9 years using > +1SD, > +2SD and > +3SD for overweight, obese and very obese.
Note that the categories are inclusive, i.e. overweight includes obesity and morbid obesity, obesity includes morbid obesity, and similarly for the thinness grades.

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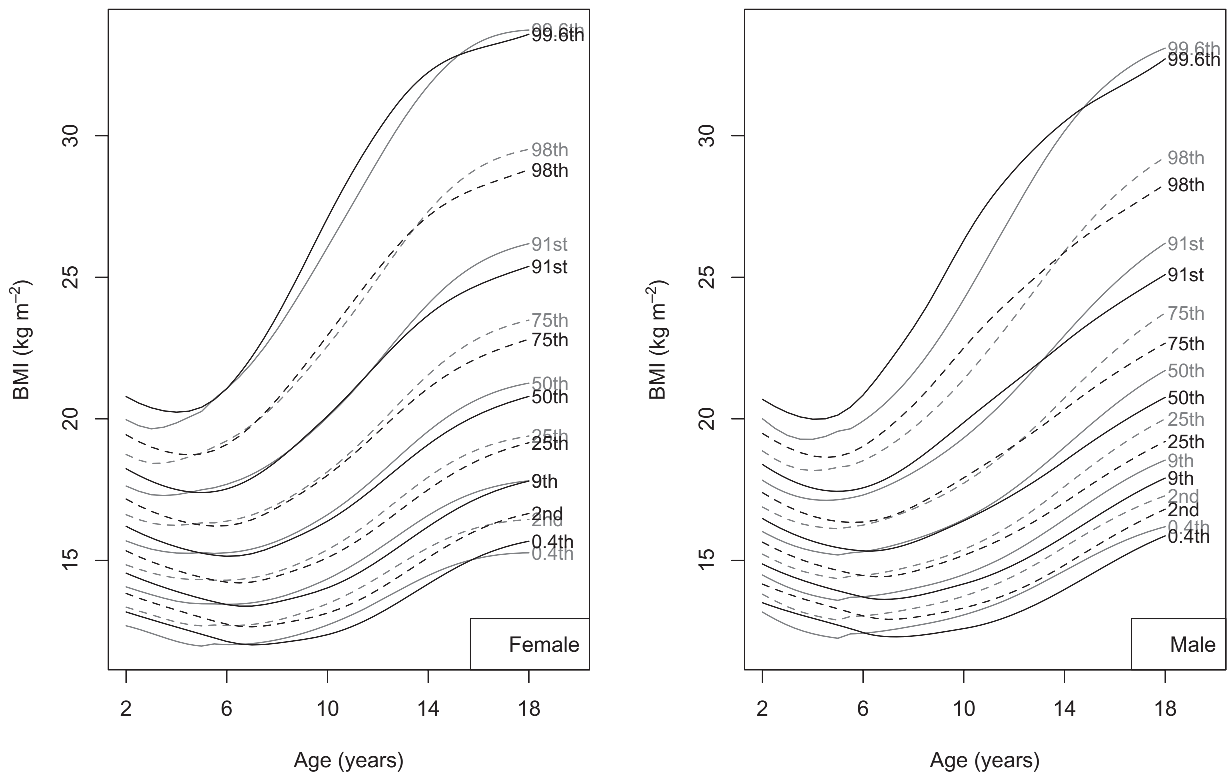

Figure 4 International (black) and WHO (grey) BMI centiles by sex, based on the British nine-centile format (12).

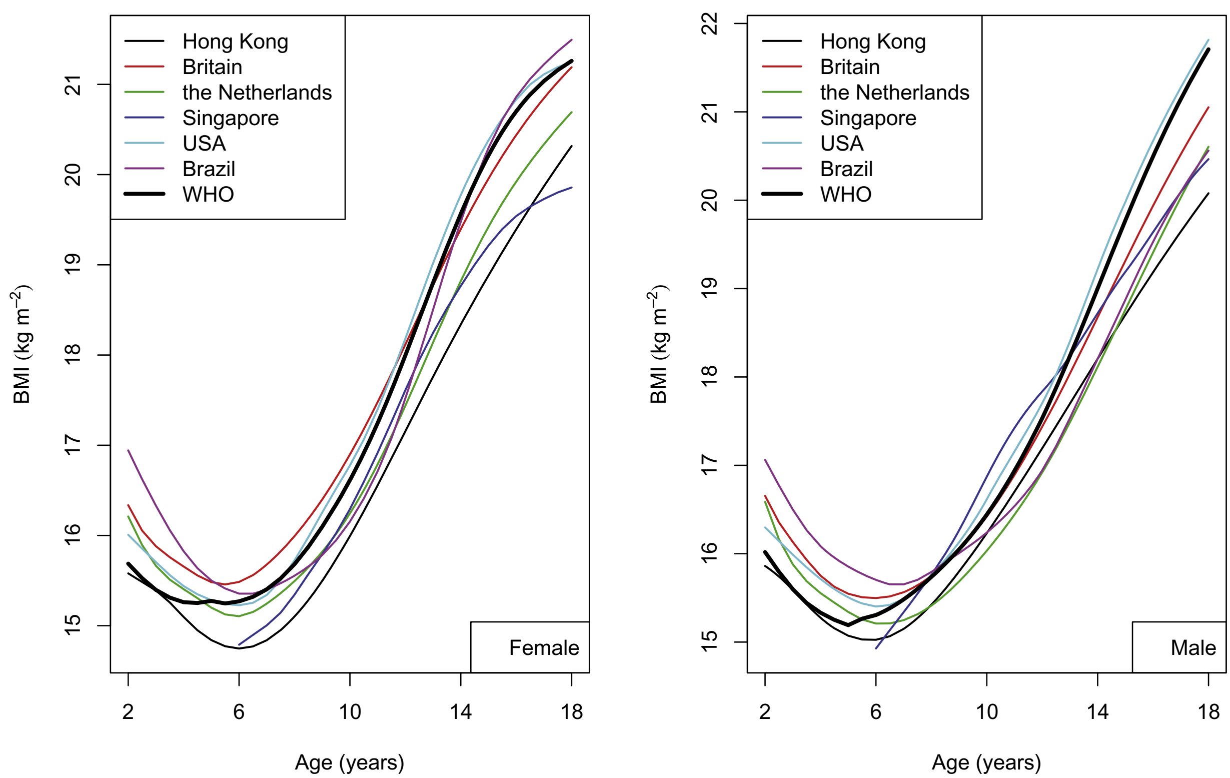

Figure 5 The median (*M*) curves for the six international datasets and WHO by sex.

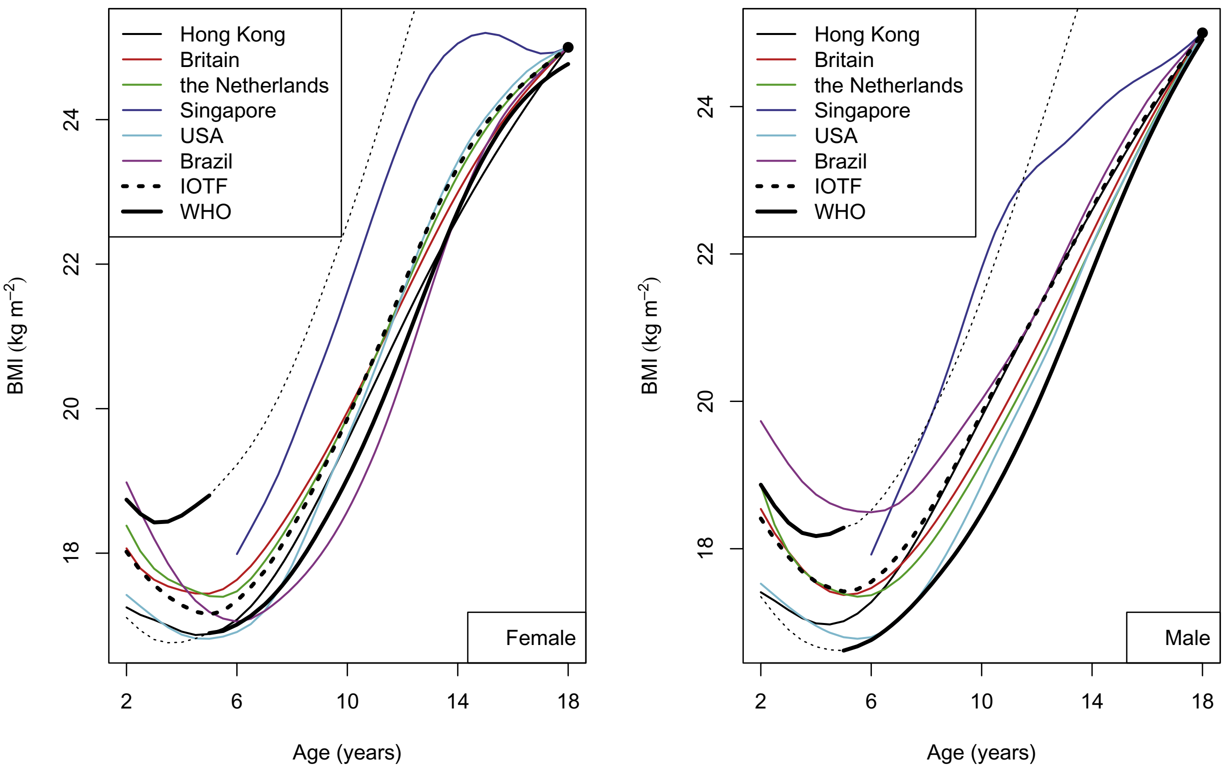

Figure 6 Cut-offs for overweight by sex: the six IOTF cut-offs (BMI 25 at age 18) and their average (heavy dashed line), plus the WHO cut-offs of +2 SDs up to age 5 and +1 SD thereafter (heavy solid lines). The dotted lines are the continuations of WHO +1 SD before age 5 and WHO +2 SDs after age 5.

Definitions of overweight and obesity

The international cut-off for overweight is based on the country-averaged centile corresponding to BMI 25 at age 18 (Fig. 1). In contrast, the WHO cut-off for overweight uses a definition that depends on age: +2 SDs before age 5 and +1 SD after. These alternative cut-offs are shown in Fig. 6 for the separate countries by sex. Before age 5, the WHO cut-offs are appreciably higher than for the other countries, leading to relatively low rates of overweight, while after age 5, the WHO cut-offs are very low and the prevalence rates correspondingly high. This matches the pattern seen in Table 2, where the WHO prevalence rates are lower for age 2–5 and higher for age 5–18.

Discussion

The BMJ 2000 paper (2) describing the international (IOTF) cut-offs has been cited around 4000 times to date, and has been the basis for many hundreds of prevalence studies around the world. The follow-up paper in 2007 (3) added cut-offs for three grades of thinness, and it has been cited over 250 times thus far. Here, we show how these cut-offs can be summarized as an LMS table (Supporting Information Table S1), which provides a more rational way to generate the cut-offs (Supporting Information Table S2).

In detail, the new cut-offs are slightly different from the originals, but the differences are tiny and do not impact materially on estimates of overweight or obesity prevalence, and only marginally affect estimates of thinness in the youngest age groups (Table 2).

The ability to base the international cut-offs on the newly derived LMS curves leads to four advantages. The first is the ability to express them in terms of equivalent SD scores and centiles, as shown in Table 1. Secondly, international cut-offs can be constructed based on new BMI values at age 18, e.g. BMI 35 for morbid obesity as in Tables 1 and 2. Thirdly, it is possible to construct an international BMI centile curve (Fig. 4), and finally individual BMIs can be converted to SD scores using formula (2) for longitudinal analysis purposes.

There have been calls for cut-offs based on other BMI levels at age 18, in particular 35 for morbid obesity as well as 23 for overweight in Asia (13,14). The effort involved to construct and publish new cut-offs has in the past been a substantial barrier to their introduction (pace the 7-year gap between the

IOTF and thinness cut-offs), but with the publication of this international LMS table, individual researchers can now construct their own cut-offs for any required BMI at age 18.

This is clearly a benefit, but it is also a risk. The original motivation for the IOTF cut-offs was to provide a single definition of childhood overweight and obesity to replace the plethora of definitions that had emerged throughout the 1990's, when many researchers used their own data, their own national reference and their own choices of cut-off as the basis for definitions of overweight and obesity. Yet all these definitions, and hence the prevalence rates based on them, were incompatible with each other, so it was not possible to form a global perspective of childhood overweight and obesity. The IOTF cut-offs changed that, as was clearly illustrated by the 2004 review article that assembled prevalence studies from many countries based on the IOTF cut-offs (15).

The danger with the introduction of a flexible version of the IOTF cut-offs is that there will again be a rash of other, incompatible definitions proposed. We strongly encourage researchers tempted down this path to first ask themselves two questions: (i) is there a compelling case for the new cut-off, as compared to using a pre-existing cut-off, and (ii) are many other studies likely to use the new cut-off in the future? If the answer to either question is no, then our advice is *do not do it*.

The ability to express the international cut-offs as SDs and centiles shows that the overweight cut-off is close to the 90th centile, while the obesity cut-off is well above the 98th centile (Table 1). In both cases, the male cut-offs are about 0.1 SDs higher than the female, perhaps corresponding to the sex bias in the cut-offs identified by Chinn and Rona (16). The obesity cut-offs are confirmed as being appreciably higher than other centile-based cut-offs, e.g. the 95th centile (+1.64 SDs) or +2 SDs (97.7th centile). This explains why the IOTF obesity prevalence rates are consistently lower than others, and why the sensitivity of IOTF obesity to detect high body fat is also relatively low and the specificity is high. Conversely, the 30 cut-off being so high means that IOTF obesity is a more serious condition than obesity according to other definitions.

The comparison of the international cut-offs with the WHO BMI standard and reference is instructive. The skewness of the two sets of centiles in Fig. 4 is very similar. The IOTF overweight cut-off is higher than for WHO because its equivalent SD score is 1.2–1.3 as against the WHO's 1.0. Comparing medians (Fig. 5), the WHO curve is lower at age 2–5 than all the country curves except Hong Kong, indicating that optimally growing children, on which the growth standard is based, are generally less fat. After age 5, the WHO curve is similar to the IOTF USA curve, reflecting the fact that the WHO reference (age 5–19) is based on the US NCHS 1977 data. US children have always been among the fattest in the world. Thus, WHO's combining the datasets of the WHO 2006 growth standard and the NCHS 1977 growth reference has combined less fat preschool data with more fat childhood data.

WHO proposes different SD definitions for overweight above and below age 5, i.e. +1 and +2 SDs, respectively (9). Fig. 6 illustrates the dual WHO cut-offs, highlighting the disjunction at age 5 that it causes, which is clearly a limitation. It is likely to lead to confusion, where a child categorized as at risk of overweight at 4 years 11 months becomes overweight on reaching their fifth birthday.

There are also limitations to the IOTF cut-offs. They are restricted to the age range 2–18 rather than all childhood. Chinn and Rona (16) have pointed out that normalizing the cut-offs to age 19 or 20 rather than 18 would have reduced the sex difference in the cut-offs, as BMI in boys is still rising at age 18, whereas in girls, it is tailing off (see the centiles by sex in Fig. 4). Unfortunately, the Hong Kong data stopped at age 18, leaving little leeway in the choice of age. The absence of data from Singapore before age 6 is also a limitation, though it is less critical than for age 18 to which the data are standardized.

In conclusion, we present LMS coefficients relating to the international child BMI cut-offs for thinness, overweight and obesity. They make it easier to compare them with other approaches, such as the WHO cut-offs, and they increase the utility of the cut-offs in several ways, allowing a range of BMI levels to be explored such as a cut-off for morbid obesity. We recommend the use of the new, rather than the old, cut-offs to take advantage of its SD score/centile framework and to ensure consistency in the future. But we emphasize that prevalence rates based on the new cut-offs are consistent with, and can be compared directly with, rates based on the original cut-offs.

The new cut-offs are available by month of age from 2 to 18 years at http://www.iaso.org/publications/iotfreports/newchildcutoffs/.

Conflict of Interest Statement

The authors have no competing interests.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. BMI LMS coefficients corresponding to the international (IOTF) cut-offs.

Table S2. Revised international IOTF BMI cut-offs (kg m^{-2}) using the pooled LMS curves.

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Appendix

As an example, the morbid obesity cut-off based on BMI 35 at age 18 is derived here for boys. First, the corresponding SD score is obtained by substituting 35 for BMI in formula (2). The *L, M* and *S* values for boys at age 18 are –1.487, 20.759 and 0.12395 from Supporting Information Table S1, and the resulting SD score is

$$z = \frac{(BMI/M)^L - 1}{L \times S} = \frac{(35/20.759)^{-1.487} - 1}{-1.487 \times 0.12395} = 2.930$$

as in Table 1. This is substituted as z_α into formula (1) using the *LMS* values for each age from 2 to 18 years. For example, at age 2 the *LMS* values are –0.624, 16.482 and 0.07950 (Supporting Information Table S1), which give the cut-off

$$\begin{aligned} C_{100\alpha} &= M(1 + L \times S \times z_\alpha)^{1/L} \\ &= 16.482(1 + -0.624 \times 0.07950 \times 2.930)^{1/-0.624} \\ &= 21.20 \end{aligned}$$