WHAT IS ALREADY KNOWN ON THIS TOPIC

CD4 counting is the main laboratory investigation for monitoring people with HIV but is often deemed too expensive and too complex to perform in resource poor settings

CD4 counting with flow cytometry can be made more affordable by the use of simple technical modifications, but CD4 percentages required in children under 5 years and miniaturisation of blood and reagent volumes have received little attention.

WHAT THIS STUDY ADDS

Technical modifications of flow cytometry with miniaturisation can simplify and reduce the cost of absolute and percentage CD4 counts while maintaining diagnostic accuracy

This CD4 counting method could improve clinical decision making in patients with HIV disease in settings with limited resources

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Body mass index cut offs to define thinness in children and adolescents: international survey

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ABSTRACT

Objective To determine cut offs to define thinness in children and adolescents, based on body mass index at age 18 years.

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

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.

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

Results The World Health Organization defines grade 2 thinness in adults as BMI <17. This same cut off, applied to the six datasets at age 18 years, gave mean BMI close to a z score of −2 and 80% of the median. Thus it matches existing criteria for wasting in children based on weight for height. For each dataset, centile curves were drawn to pass through the cut off of BMI 17 at 18 years. The resulting curves were averaged to provide age and sex specific cut-off points from 2-18 years. Similar cut offs were derived based on BMI 16 and 18.5 at 18 years, together providing definitions of thinness grades 1, 2, and 3 in children and adolescents consistent with the WHO adult definitions.

Conclusions The proposed cut-off points should help to provide internationally comparable prevalence rates of thinness in children and adolescents.

INTRODUCTION

Much has been written about the epidemic of child obesity but malnutrition in infants, children, and adolescents poses a considerably larger public health problem internationally, and in the developed world anorexia nervosa is the third most common chronic condition of adolescence.[1] Obesity and malnutrition represent opposite extremes on the spectrum of adiposity, and both are routinely quantified in terms of weight and height relative to the child's age. Yet the classification of malnutrition in later childhood and adolescence is currently unsatisfactory because of the lack of suitable cut offs for international use.[2]

BMI has been used since the 1960s to assess obesity in adults and more recently in children. International BMI cut offs for child overweight and obesity, based on data from six countries, have been developed.[3] The

WHO 1995 expert committee[4] endorsed the use of BMI for assessing thinness in adolescence, based on the BMI reference data from Must et al.[5] The 2006 WHO growth standard also includes BMI for children aged 0-5 years.[6] However, this is insufficient for international use because the BMI cut offs from Must et al are based on US data from the early 1970s and the WHO standard is restricted in age. Thus there are no valid BMI cut offs for assessing underweight or wasting in adolescents or children over 5 years.

The international BMI cut offs for child overweight and obesity cover the age range 2-18 years and are based on the adult cut offs of 25 and 30 at 18 years.[3] It would be logical to produce BMI cut offs for underweight using the same principle. However, underweight in adults, also called thinness, indicates low BMI, whereas in children underweight is low weight for age and wasting is low weight for height.[4] We have extended the adult term of thinness to children, meaning low BMI for age.

METHODS

Subjects and data

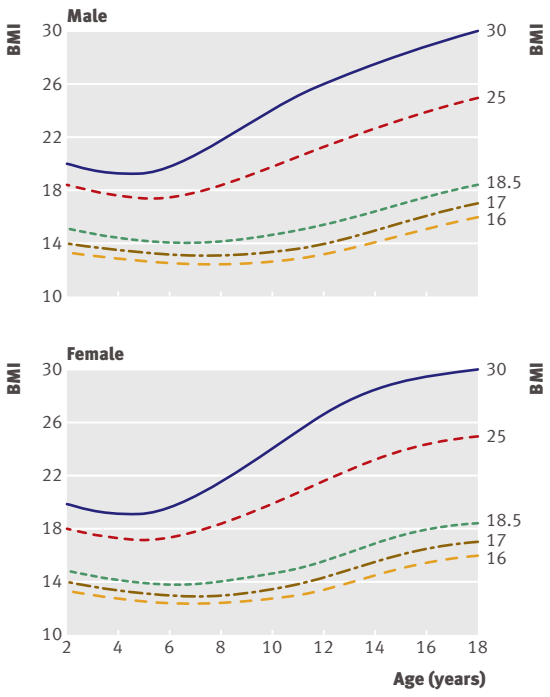
We used the same methods as those used for the international overweight and obesity cut offs.[3] We obtained BMI data from nationally representative surveys of children in six high and middle income countries: Brazil, Great Britain, Hong Kong, the Netherlands, Singapore, and the United States (see bmj.com). Each survey had over 20 000 subjects aged 6-18 years, and height and weight were measured with standard methods and quality control measures to minimise measurement error. A total of 192 727 subjects were involved, 97 876 males and 94 851 females from birth to 25 years.

LMS method

We analysed each dataset using the LMS method, which summarises the distribution of BMI by age and sex in terms of three curves called L (lambda), M (mu) and S (sigma). The M curve is median BMI by age, the S curve is the coefficient of variation of BMI, and the L curve expresses the skewness of the BMI distribution in terms of the Box-Cox power needed to transform the data to near normality (see bmj.com).

Conventionally a BMI centile chart is based on a prespecified set of centiles (for example, 3rd, 10th, 25th, 50th, 75th, 90th, 97th) or z scores (−2 to +2 in increments of two thirds of a z score). Here by contrast, quasi-centile curves are constructed to pass through a given BMI cut off at a given age (we chose 18 as it was the oldest age with data available in all six datasets).

We constructed centile curves of this form for each of the six datasets separately and then averaged the curves by age. The result is a single curve, based on all six datasets, that passes through the specified cut off at age 18. This exercise was repeated for each sex and for each of several distinct BMI cut offs at age 18.



Cut offs for thinness by age and sex defined to pass through BMI 16, 17, and 18.5 at 18 years, with the international cut offs for overweight and obesity based on BMI 25 and 30[3]

Choice of cut offs at age 18

In children, the diagnostic criteria for anorexia nervosa use BMI below the 5th or 10th centile, corresponding to −1.6 or −1.3 SD (z scores), to define underweight,[7 8] while the criteria for malnutrition, based on weight for height rather than BMI, use the graded WHO cut offs of −1, −2, and −3 SD, corresponding roughly to 90%, 80%, and 70% of expected weight for height.[4 9] Anomalously the WHO Expert Committee[4] defined thinness in adolescence as BMI below the 5th centile rather than below −2 SD, probably because the −2 SD cut offs were not available. At age 18 the 5th centiles in Must et al were 17.5 for males and 16.7 for females.[5] An important question is which cut off is the more appropriate, the 5th centile or −2 SD. WHO recommended the −2 SD criterion, while the 5th centile was a pragmatic alternative at a time when a −2 SD BMI cut off was not available. For this reason we feel that −2 SD is the more appropriate cut off to use.

On this basis, the simplest way to transfer the child cut offs from weight for height to BMI is to treat the two −2 SD cut offs as equivalent. Weight for height is weight adjusted for height while BMI for age is weight adjusted for height and age. So if weight for height were independent of age, as it is at certain ages, then the two cut offs would coincide. At other ages the variability in BMI is theoretically slightly less than for weight for height, as variability caused by age is adjusted for. Against that, the height adjustment for BMI is imperfect later in childhood, so on balance the variability is likely to be similar for the two indices.

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Thus the optimal cut off for our purposes would be a value of BMI at age 18 that coincided with a previously published adult cut off and which was also close to a child BMI cut off of −2 SD. But this introduces ambiguity as the z score corresponding to a given cut off will depend on the growth reference used. Here we use the six datasets as internal references to test the alternative cut offs. We also investigate the relation between z scores and BMI expressed as % of the median.

RESULTS

The table gives BMI z scores and centiles corresponding to various published BMI cut offs at age 18, averaged across the six datasets, where the centiles correspond to the sex averaged z scores. In general the results are similar for boys and girls, and the cut offs range from the 0.6th to the 16th centile. BMI 18.5 is on the 16th centile and approximates to a z score of −1, while BMI 17 is on the 3rd centile and close to z score −2, and hence is near optimal for our purposes.

The figure shows the composite curves for cut offs 16, 17, and 18.5, obtained by averaging the individual thinness curves at age 18 for the six datasets which can be seen on bmj.com, as well as a table giving the values of the composite curves.

When the relation between BMI as % of the median and BMI z score at different ages is averaged across the datasets by sex, up to 6 years a z score of −2 corresponds to 85% BMI while from 14 years the same z score matches 80 % BMI. This shift with age is caused largely by the sharp increase in variability in BMI that occurs between 6 and 12 years. See further figures and tables on bmj.com.

DISCUSSION

We propose that a BMI of 17 at age 18 is a suitable cut off to use as the basis for an international definition of thinness in children and adolescents. Three different criteria lead to this conclusion: BMI 17 is the WHO grade 2 cut off for thinness in adults[4]; BMI 17 at age 18 corresponds to a mean z score of −2 using our data; and, again with our data, BMI 17 at age 18 is 80% of the median. The latter two criteria mean that in childhood the new cut off will be similar in z score and % median terms to those used before, notably the WHO definition of wasting—that is, weight for height below −2 SD or 80% of the median.

Most mortality related to malnutrition occurs with mild or moderate malnutrition[10] so there is a need to distinguish between grades of malnutrition. In addition to our primary cut off of 17 we propose two secondary cut offs: 18.5, long used by WHO in adult studies[11] and for grade 1 thinness,[4] and 16, used for grade 3 thinness. Thus our three cut offs correspond to the WHO graded definition of thinness.

The recent publication of the WHO child growth standard[6] is likely in time to have a major impact on the growth assessment of young children. The centiles on the WHO BMI chart overlap with our proposed cut offs between 2 and 5 years. The BMI 17 cut off lies between the WHO −1 and −2 SD curves and corresponds to the 5-7th WHO centile, somewhat higher than the 3rd centile seen in the table. Thus far there is no advice from WHO about how to use the BMI chart for assessment of malnutrition.

Limitations and strengths

The key assumption of our analysis is that the cut offs have the same meaning irrespective of age, sex, and country. The choice of 18 as the crossover age between child and adult is not ideal as BMI increases after this age faster in males than females. Age 20 would have been better, but some of our datasets lacked data at that age. The cut offs should also apply equally to males and females, but in detail the male cut offs are slightly more extreme. Also Hong Kong and Singapore have appreciably higher prevalences of thinness than the other countries, which arise from their greater variability in BMI.

The lack of an adjustment for puberty is another limitation. BMI is known to be higher in more mature individuals of the same age,[2 12] and delayed puberty is associated with thinness,[13] which an adjustment for pubertal stage might avoid.

Finally, BMI is based on weight and does not differentiate between fat mass and lean mass, therefore it is an imperfect measure of either adiposity or leanness. In children it correlates with fat mass more strongly at the upper end of the adiposity spectrum than at the lower end.[14]

We believe that none of these differences invalidates the underlying principle of the cut offs. As with any screening tool the sensitivity and specificity need testing in the field. The main strength of the cut offs is their ability to compare rates of prevalence of thinness across countries, regions, and time. The cut offs avoid the conventional concept of a reference population in that they include data from several disparate populations. This increases their perceived generalisability, even though they clearly cannot be universally representative. Instead a fixed BMI in adulthood acts as the reference point. A side effect is that because there is no reference, there are also no underlying z scores—individuals can be classified only relative to the cut offs.

z scores corresponding to different BMI cut offs at age 18, averaged by sex across six datasets

	16		17		17.5		18.5	
	Male	Female	Male	Female	Male	Female	Male	Female
Mean z score	−2.6	−2.4	−1.9	−1.8	−1.6	−1.5	−1.0	−1.0
Centile	0.6		3		6		16	

WHAT IS ALREADY KNOWN ON THIS TOPIC

Malnutrition in children and adolescents is a serious public health concern

It is better assessed as thinness (low body mass index for age) than as wasting (low weight for height)

There are no suitable thinness cut offs for this age group

WHAT THIS STUDY ADDS

A new graded definition of thinness in childhood and adolescence is proposed, based on pooled international data for BMI and linked to the WHO recommended adult cut off points of 16, 17, and 18.5 at age 18

The thinness cut off linked to 17 is close to the wasting cut off based on −2 z scores

The new definitions should encourage direct comparison of trends in child and adolescent thinness worldwide

Also, the cut offs are resilient to the possible addition of other datasets to the reference because of the way they are constructed.

Implications for practice and policy

We have developed a Microsoft Excel module called lmsGrowth,[15] which converts BMI to an ordered grade by interpolating to the child's exact age. The module codes normal weight as 0 and overweight (between 25 and <30 cut offs) and obesity (≥30) as +1 and +2, respectively, while thinness grades 1, 2, and 3 are coded as −1 (17 to <18.5), −2 (16 to <17), and −3 (<16).

We emphasise that these cut offs need to be tested against new data. We hope they will prove helpful in providing a unified definition of thinness in children and adolescents based on thinness in adults. They can also be used in conjunction with the corresponding international definition of overweight and obesity.

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Depression screening via Paris

My patient was in her early 40s and had had several bouts of severe depression in the past. She had a good job, though a very busy one, and her family was very supportive, especially her husband. On this occasion, she came to see me with inability to cope with anything, boiling down to sheer exhaustion. Work had been putting the last straw of load on the unfortunate camel's back.

When I asked if this experience was something she recognised from previous episodes of depression she strongly denied it: "It's nothing like it. In the past if I were unwell and my husband suggested a weekend in Paris, I would sigh and could think only of the packing needed. Now I would jump at the chance if he offered."

Should this approach be tested among a large number of patients—randomised, controlled, and double blinded, of course—and then implemented with the next change of policy regarding diagnosing depression?

Interesting research opportunities, possibly funded by Eurostar, spring to mind. I personally could offer to be a guinea pig until we know more. I love Paris, but wouldn't mind Venice either, if it's a problem.

Later, I heard that my patient's workload had been spread among four people; she recovered, and no antidepressants were required.

I think she went to Paris, because I heard no more from her.

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