


Commentary: Is there a best index of weight for height?

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Nightingale et al. used skinfold thicknesses and body fat from bioelectrical impedance as measures of adiposity and compared body size and composition among groups of UK children from three different ethnic origins: South Asian, black African–Caribbean and white European origins. The adiposity measures, along with body mass index (BMI) and a height-standardized weight-for-height index were all compared across the three race-ethnic groups. Nightingale et al. found that the results of such comparisons differed depending on whether they used adiposity measures or BMI or a height-standardized index. This finding led them to question the use of BMI to compare adiposity across race-ethnic groups of children.

Interest in the problem of comparing anthropometric data between different race-ethnic groups of children has a long history. In a study published in 1951, Greulich compared the growth data collected in 1947 from a representative sample of Guamanian (Chamorro) children from Guam with data from a slightly earlier Brush Foundation study of a sample of affluent white children from Cleveland Ohio. The Guamanian children, who had been subjected to hardships and deprivation during the war and the Japanese occupation of Guam, were both shorter and lighter than the Cleveland children of the same age. To put the weights of the children on a comparable scale, given the height difference, Greulich chose what he termed the ‘height–weight index’ (the ratio of weight to height). Using this index, he concluded that the Guamanian children were underweight for height relative to the Cleveland children, which he attributed in part to genetic differences between the Micronesian children of Guam and the children of European ancestry in Cleveland, as well as to the deprivations suffered by the Guamanians during the war. He also concluded that, although both boys and girls of Guam had suffered growth retardation in comparison with the Cleveland children, the relative effects had been greater for boys, ‘consistent with the view that the human male is less successful than the female in withstanding the rigors of an unfavourable environment’.

When Gavan examined the same data using a linear regression of weight on height instead of a weight–height index, he came to conclusions almost completely opposite to those reached by Greulich. Gavan’s analyses found that the relation of weight to height in the regression model was the same for all four groups (the Guamanian boys and girls and the Cleveland boys and girls) and concluded that although the Guamanian children were clearly shorter than the Cleveland children at a given age, ‘the Guam children are no more underweight for their stature.
than the Cleveland children and the Guam boys are no more underweight for their stature than the Guam girls. Gavan also commented on the limitations of a weight–height index for this type of analysis, pointing out that when two measures show a constant relation via a regression equation they will show a changing relation via an index. He raised the question ‘Should comparisons be made via an index or a regression line?’

Gavan’s and Greulich’s concern in their studies of Guamanian children was how best to adjust weight for height. A decade later, Billewicz et al. discussed the idea that some form of weight-adjusted-for-height could serve as an approximate measure of adiposity and suggested that because adiposity in their sample of adults did not appear to vary with height, it was desirable that a weight–height index serving as an indicator of adiposity should be invariant with respect to height (though in fact these authors preferred weight relative to a weight standard over any of the candidate weight–height indices that they considered). Subsequently, Benn also addressed the issue of whether an index should be invariant with height. He showed that under the assumption that adiposity is independent of height, a power-type index of the form weight/height, where $p$ is the coefficient of the regression of log weight on log height, will ‘not only give us an index distributed nearly independently of height, but also, provided the correlation of height and adiposity is around zero, it will give almost the best correlation with relative adiposity that it is possible to achieve with any $p$.

Nightingale et al. use an ‘optimally height-adjusted index’, here calculated as weight/height, which was constructed to have almost no correlation with height in their sample. However, as pointed out by Billewicz et al. and by Benn, the criterion that a weight–height index used to assess adiposity should be uncorrelated with height depends on the validity of the assumption that adiposity does not vary with height. This assumption may not always hold even for adults and perhaps less so for children. Indeed, the data presented by Nightingale et al. show a correlation between adiposity and height among children that ranges from 0.28 (for adiposity measured as fat mass percent) to 0.33 (for adiposity measured as the sum of skinfolds), not far from the correlation of 0.38 between BMI and height. If taller children are also likely to have a higher body fat percentage, there is not necessarily an advantage in using a weight–height index that is uncorrelated with height as an indicator of adiposity; such an index may mask differences in adiposity.

An issue that complicates interpretation of racial differences in adiposity is that the constructs being used as measures of adiposity may themselves vary by race. It cannot always be assumed that these measures have precisely the same interpretation in different race-ethnic groups. Several of the measures of adiposity being used by Nightingale et al. are sums of various skinfold thicknesses. Skinfold thicknesses may be affected by racial differences in fat patterning, at least between blacks and whites. Nightingale et al. use another measure of adiposity calculated from bioelectrical impedance with an equation developed from a sample of white children. The equation includes height and weight, however, and it is possible that this equation performs differently for white children than for black or South Asian children, among whom height and weight may have a different relation to adiposity than they do in white children.

As Nightingale et al. show, comparisons of body size and composition between ethnic groups can be sensitive to the exact metric used. As Nightingale et al. found and as the articles by Greulich and Gavan also demonstrate, it is possible to arrive at rather different conclusions depending on how these highly correlated variables are transformed. Nightingale et al. use a transformation that makes the weight–height index minimally correlated with height in their entire sample but does not allow for possible differences in the weight–height relation among race-ethnic groups. Weight–height indices impose certain constraints on the weight–height relation. This prompts a return to consideration of Gavan’s question as to whether an index or a regression model should be used to make comparisons. The problems with the use of weight–height indices are a form of the general statistical problems with ratios, which have been noted in areas as diverse as periodontology and ungulate biology. Nightingale et al. approach the comparisons between groups by going beyond weight–height indices and standardizing all their adiposity measures into ratios in the form of indices that are calculated to have almost no correlation with height in their sample. The extensive use of height-standardized ratio measures for these analyses may not be necessary or even desirable. For analytic purposes, it might be preferable to use a more flexible approach to height adjustment.

Finding transformations to appropriately reflect changes with size is a difficult challenge. In the consideration of weight–height indices, it may be useful to keep in mind Voltaire’s liberally translated comment that ‘the perfect is the enemy of the good’. Weight–height indices, despite their limitations, are convenient for many purposes, particularly for surveillance and population statistics. They serve as an efficient summary of weight adjusted for height. Despite the many known imperfections of BMI, it is not clear what weight–height index would be better than BMI. The BMI may be considered as a serviceable although imperfect index.

Nightingale et al. argue that BMI may well not clearly reflect differences in body composition between children in different race-ethnic groups. This is likely to be the case, and their statement is supported by other data. For example, in the USA, data suggest...
that non-Hispanic black children have less body fat at a given BMI than do non-Hispanic white children,\textsuperscript{17} consistent with the results of Nightingale \textit{et al.} This issue goes beyond comparisons of race-ethnic groups, however, because BMI also does not necessarily reflect differences in body composition between children in different sex or age groups. For surveillance purposes, BMI is widely accepted, and BMI can be used to indicate population trends overall and also trends in adiposity within sex, age and race-ethnic groupings.\textsuperscript{16} Although other indices might perform better in some situations, for practical purposes BMI may be considered as good as any, despite its limitations. Neither BMI nor other functions of weight and height are likely to provide highly precise measures of adiposity on an individual level. As Nightingale \textit{et al.} show, group-level comparisons using BMI also do not always accurately reflect differences in adiposity between groups and should be interpreted cautiously.

\textbf{Conflict of interest:} The findings and conclusions in this commentary are those of the author and not necessarily those of the agency.

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