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A short note on the BMI and its secular changes

Rebekka Mumm[1] • Michael Hermanussen[2]

[1] University of Potsdam, Institute of Biochemistry and Biology, Human Biology, Potsdam, Germany.
[2] Aschauhof, 24340 Eckernförde-Altenhof, Germany

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Correspondence to:

Rebekka Mumm
email: rebekka.mumm@gmail.com

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Abstract

Human size changes over time with worldwide secular trends in height, weight, and body mass index (BMI). There is general agreement to relate the state of nutrition to height and weight, and to ratios of weight-to-height. The BMI is a ratio, and considered to be "a simple index to classify underweight, overweight and obesity in adults". Yet, the BMI is inappropriate to provide any immediate information on body composition.

It is stated that "policies, programmes and investments need to be "nutrition-sensitive", which means they must have positive impacts on nutrition". It is also stated that there is "a need for policies that address all forms of malnutrition by making healthy foods accessible and affordable, while restricting unhealthy foods through fiscal and regulatory restrictions". But these statements are neither warranted by arithmetic considerations, nor by historic evidence.

Measuring the BMI is an appropriate screening tool for detecting an unusual weight-to-height ratio, but the BMI is an inappropriate tool for estimating body composition, or suggesting medical and health policy decisions.

Take home message for students The BMI is a ratio. Measuring the BMI is an appropriate screening tool for detecting unusual weight to height ratios, but the BMI is an inappropriate tool to estimate body composition, or to suggest medical and health policy decisions.

Human size changes over time. Worldwide secular trends in height during the last century with highest trends in South Korean women and lowest increases in Sub-Saharan Africa have recently been summarized (NCD Risk Factor Collaboration [NCD-RisC], 2016). Height is related to weight. The association between height and weight during childhood is close to r=0.7 (Figure 1), and appears to be similar in adults (Greil, 1988).

Worldwide secular trends have also been reported for weight (Bodzsaŕ and Susanne, 1998), and for body mass index (NCD Risk Factor Collaboration [NCD-RisC], 2021).

There is general agreement to relate the state of nutrition to height and weight. The worldwide increases in BMI have meanwhile fueled global debates on healthy food and obesity. It is accepted that "BMI is a simple index of weight-to-height that is commonly used to classify underweight, overweight and obesity in adults" ("OECD Glossary of Statistical Terms – BMI Definition," n.d.), and that "malnutrition refers to deficiencies, excesses, or imbalances in a person's intake of energy and/or nutrients. The term malnutrition addresses 3 broad groups of conditions: undernutrition, which includes wasting (low weight-for-height), stunting (low height-for-age) and underweight (low weight-for-age)" ("Fact sheets – Malnutrition," n.d.).

Yet, BMI is a ratio (weight divided by height taken to the square). It is presumptuous to assume that this ratio may be appropriate to provide any immediate information on body composition. Only in a stationary population that lacks trends in height, variation in BMI can be ascribed to variation in body composition and fat mass. This is different in a population that increases in height. The BMI depends on height for arithmetic reasons.

A geometric body that increases in one dimension (body height), but remains the same in its proportions, will increase in surface by a square function, and increase in volume (body weight) by a cubic function. The ratio: volume divided by the surface, or by one of its dimensions taken to the square, will increase for arithmetic reasons. A cube with an edge length of d=1 has the surface A=6*d^2 and the volume V=d^3. For d = 1cm, the ratio V/A = 1/6 cm; for d = 2cm, A = 24cm^2, and V= 8cm^3, the ratio V/A = 1/3 cm; for d = 3cm, the ratio V/A = 1/2 cm. The ratios increase with increasing edge length. This trivial arithmetic consideration is also true for the BMI. Be-

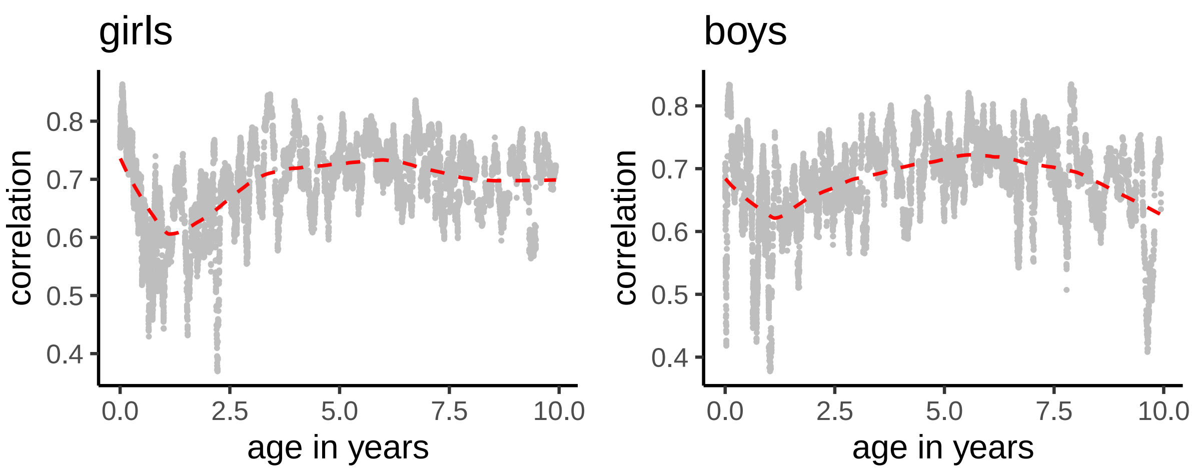

Figure 1 The association between height and weight from birth to age 10 years of healthy German children. Data were obtained from (Greil, 1988).

tween the age of 72.5 months (6 years) and 18 years, school boys on average increase in height from 115.66 cm to 176.85cm (CDC growth charts [de Onis et al., 2007]). This increase does not imply any relevant change in body proportion. Relative sitting height and leg length remain quite unchanged after age 6 years. Weight however increases from 20.78kg to 70.60kg. In consequence, the ratio: weight divided by height taken to the square (BMI), also increases from 15.38kg/m^2 to 23.02kg/m^2. I.e. the 52% increase in height is accompanied by a 50% increase in BMI. The rise in BMI of growing school boys neither reflects any equivalent rise in relative fat (López-Sánchez et al., 2019) nor relative muscle mass (Cossio Bolaños et al., 2019). The BMI of school boys rises for arithmetic reasons.

As a weight-to-height ratio, the BMI also depends on body proportion. Secular changes in height usually coincide with secular change in sitting height and leg length as described in Japanese children (Tanner et al., 1982). Taller people tend to have relatively longer legs, but they are not to the same extent, heavier.

Stating that the BMI is a simple index to classify underweight, overweight and obesity in adults and that "policies, programmes and investments need to be "nutrition-sensitive", which means they must have positive impacts on nutrition" and that "a need for policies that address all forms of malnutrition by making healthy foods accessible and affordable, while restricting unhealthy foods through fiscal and regulatory restrictions" (Global Panel on Agriculture and Food Systems for Nutrition, 2020) is neither warranted by arithmetic considerations, nor by historic evidence, and should be considered with utmost caution.

Measuring the BMI is an appropriate screening tool for detecting an unusual weight-to-height ratio, but the BMI is an inappropriate tool for estimating body composition, or suggesting medical and health policy decisions.

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