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The dilemma of misclassifying weight in short and in historic population

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Abstract

Background Clinicians often refer anthropometric measures of a child to so-called "growth standards" and "growth references. Over 140 countries have meanwhile adopted WHO growth standards.

Objectives The present study was conducted to thoroughly examine the idea of growth standards as a common yardstick for all populations. Weight depends on height. We became interested in whether also weight-for-height depends on height. First, we studied the age-group effect on weight-for-height. Thereafter, we tested the applicability of weight-for-height references in short and in historic populations.

Sample and Methods We analyzed body height and body weight and weight-for-height of 3795 healthy boys and 3726 healthy girls aged 2 to 5 years measured in East-Germany between 1986 and 1990.
We chose contemporary height and weight charts from Germany, the UK, and the WHO growth chart and compared these with three geographically commensurable growth charts from the end of the 19th century.

Results We analyzed body height and body weight and weight-for-height of 3795 healthy boys and 3726 healthy girls aged 2 to 5 years measured in East-Germany between 1986 and 1990.
We chose contemporary height and weight charts from Germany, the UK, and the WHO growth chart and compared these with three geographically commensurable growth charts of the end of the 19th century.

Conclusion Weight-for-height depends on age and sex and apart from the nutritional state, reflects body proportion and body built particularly during infancy and early childhood. Populations with a relatively short average height are prone to high values of weight-for-height for arithmetic reasons independent of the nutritional state.

Take home message for students Weight-for-height reflects the variation in body proportion and body built, particularly early in life. At a young age, short children have lower weight-for-height z-scores than tall children of the same age. Weight-for-height does not solely characterize the nutritional state. Particularly short populations are prone to high weight-for-height for arithmetic reasons.

Introduction

Clinicians often refer anthropometric measures of a child to so-called “growth standards” and “growth references”. Growth standards and references are based on samples of children that are considered healthy, normally developed, and representative for the variables of interest. In recent years, World Health Organization (WHO) standards and references for height and weight, and also for body mass index (BMI) and weight-for-height (WHO 2006) have been widely used in public health and medicine and by governmental and health organizations for monitoring the well-being of children. The latter is of particular interest because already in 1973 it was stated that “the expected weight of a child of given height is independent of age and largely independent of race” (Waterlow 1973). Over 140 countries have meanwhile adopted WHO growth standards. United Nations agencies use WHO growth standards and references as the “common yardstick to assess and monitor child growth” (Zorlu 2011).

The present study was conducted to thoroughly examine the idea of growth standards as a common yardstick for all populations. It is unquestionable that weight depends on height. Taller people tend to be the heavier people. However, we became interested in the question of whether also weight-for-height depends on height. First, we studied the age-group effect on weight-for-height. Thereafter, we tested the applicability of weight-for-height references in short and in historic populations.

The age group effect

In groups of children of different ages (“mixed-age” groups), the youngest children are usually the shortest and lightest ones. The same applies to groups of children of the same age (“same-age” groups). Also in these groups, the shorter children tend to be the lighter children. Referring weight to height can be done in two ways: either within groups of children of different ages (“mixed-age” groups) or in groups of children of the same age (“same-age” groups). The commonly used modern weight-for-height reference tables published by the Centers for Disease Control and Prevention CDC (CDC 2001; Kuczmarski et al. 2002) and WHO (WHO 2006) are “mixed-age” tables for boys and girls aged 2 to 5 years.

Children differ in proportion. Young children have greater sitting height, and appear more “robust” than older children (Mumm et al. 2018; Schüler 2009). In “mixed-age” groups of children of the same height, the younger children tend to be the heaviest-for-height for reasons of proportion and robusticity. On the other hand, for the same reason in “same-age” groups, the shorter children should tend to have the least weight-for-height. We hypothesize that the shortest children of “same-age” groups will have the lowest weight-for-height z-scores.

Historic weight-for-height

Since the end of the 19th century, height and weight of European children of all ages has increased significantly. Similar trends in size have meanwhile been observed in many countries throughout the world. Yet, as height and weight tend to change with each other, we hypothesize that despite the obvious trend in size, the ratio weight-for-height has remained unchanged in recent history.

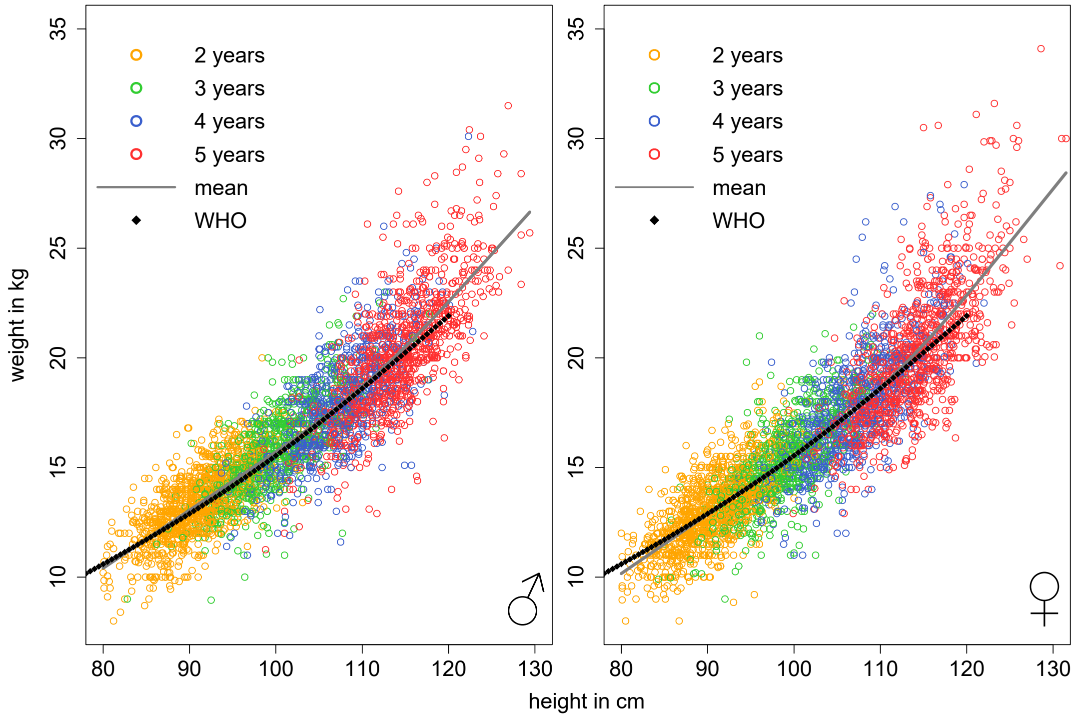

Figure 1 Weight-for-height in healthy East German boys and girls aged 2 to 5 years. Colors indicate the different age classes. The grey line indicates mean values of weight-for-height of the German sample. Black diamonds show mean values of weight-for-age referred to mean values of height-for-age of the WHO growth standards (WHO 2006).

Sample and Method

We analyzed body height and body weight of 3795 healthy boys and 3726 healthy girls aged 2 to 5 years measured in East-Germany between 1986 and 1990. Details of this investigation were published elsewhere (Greil 1988). We calculated weight-for-height, and weight-for-height z-scores based on WHO growth standards (WHO 2006).

In addition, we chose contemporary height and weight charts of 2-to-10-year-old boys from Germany (Neuhauser et al. 2013), the UK (Freeman et al. 1995), and the WHO growth chart (WHO 2006), and compared these with three commensurable growth charts from the 19th century (Germany (Camerer 1893), England (1890 after (Weissenberg 1911), p.170) and 5-to-10-year-old boys from Boston, USA (Bowditch 1877)). All analyses were done with the statistical software R (R Core Team 2021).

Results

Weight depends on height. Figure 1 illustrates the relation between height and weight in healthy East German boys and girls aged 2 to 5 years. In each age group, the shortest children are the lightest children. Mean values of weight for height are indicated. Black diamonds show mean values of weight-for-age referred to the corresponding mean height-for-the same age obtained from the WHO growth standards

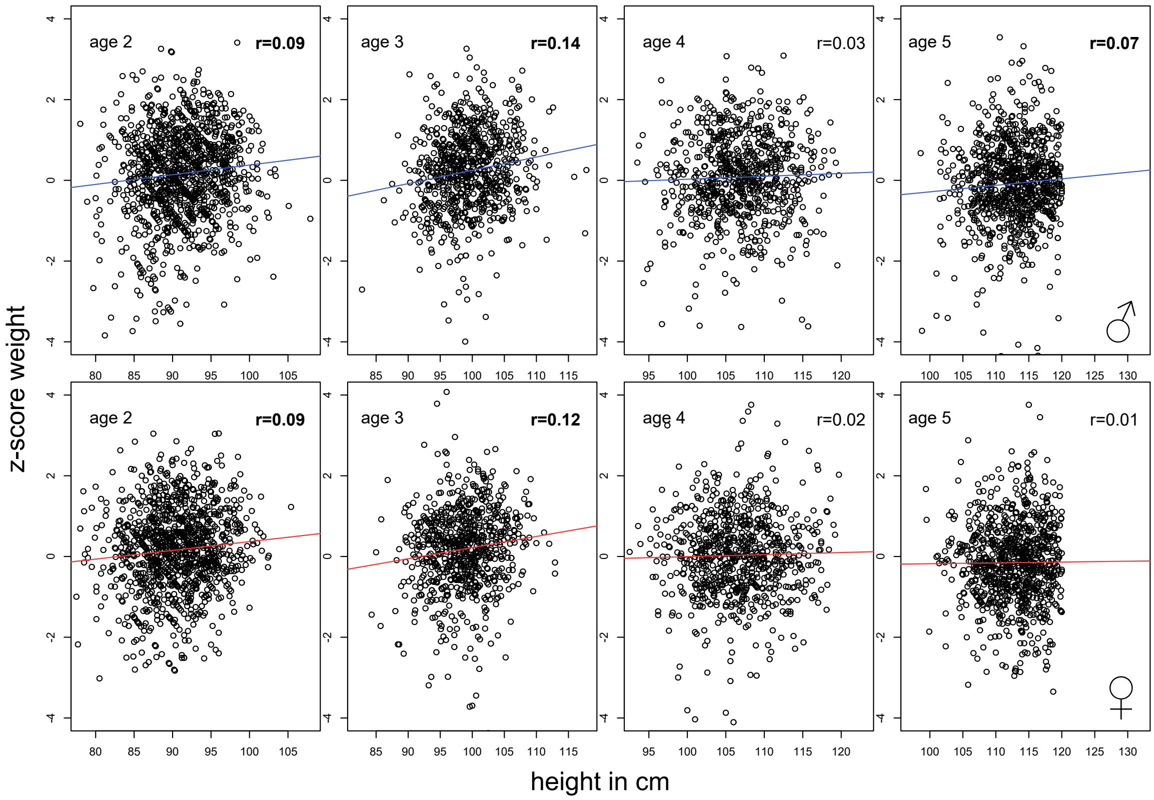

Figure 2 Weight-for-height z-scores (WHO growth standards (WHO 2006) referred to height at age 2 to 5 years. Short-for-age children tend to have lower weight z-scores than tall-for-age children of the same age. Significant Pearson-correlations in bold.

(WHO 2006). The figure highlights the similarity between the German curve, and the pattern obtained from the WHO standard.

Figure 2 refers z-scores of weight-for-height based on WHO growth standards (WHO 2006) to height. The figure illustrates that in "same-age" groups, the shorter children tend to be lighter-for-height than the taller children. This feature is significant as it reflects age-related differences in body proportion and body built. Yet, the effect is small with correlation coefficients (Pearson correlation) between r=0.02 and r=0.14, and may be ignored for practical reasons. This is however different in historic settings.

We visualized mean weight-for-height in contemporary and historic data by plotting mean values of weight-for-age against the corresponding mean values of height-for-the-same-age. Figure 3 illustrates mean weight-for-height of three contemporary and three historic growth charts of similar ethnic background. Historic weight-for-height ranges significantly above contemporary weight-for-height. Beyond body heights of some 80 cm, historic-children were up to 3 kg heavier than contemporary-children of the same height.

Discussion

Weight-for-age depends on height-for-age with a coefficient of correlation close to r=0.7 (Mumm and Hermanussen 2021).

Weight-for-height depends on age and sex, and apart from the nutritional state, reflects body proportion and body built

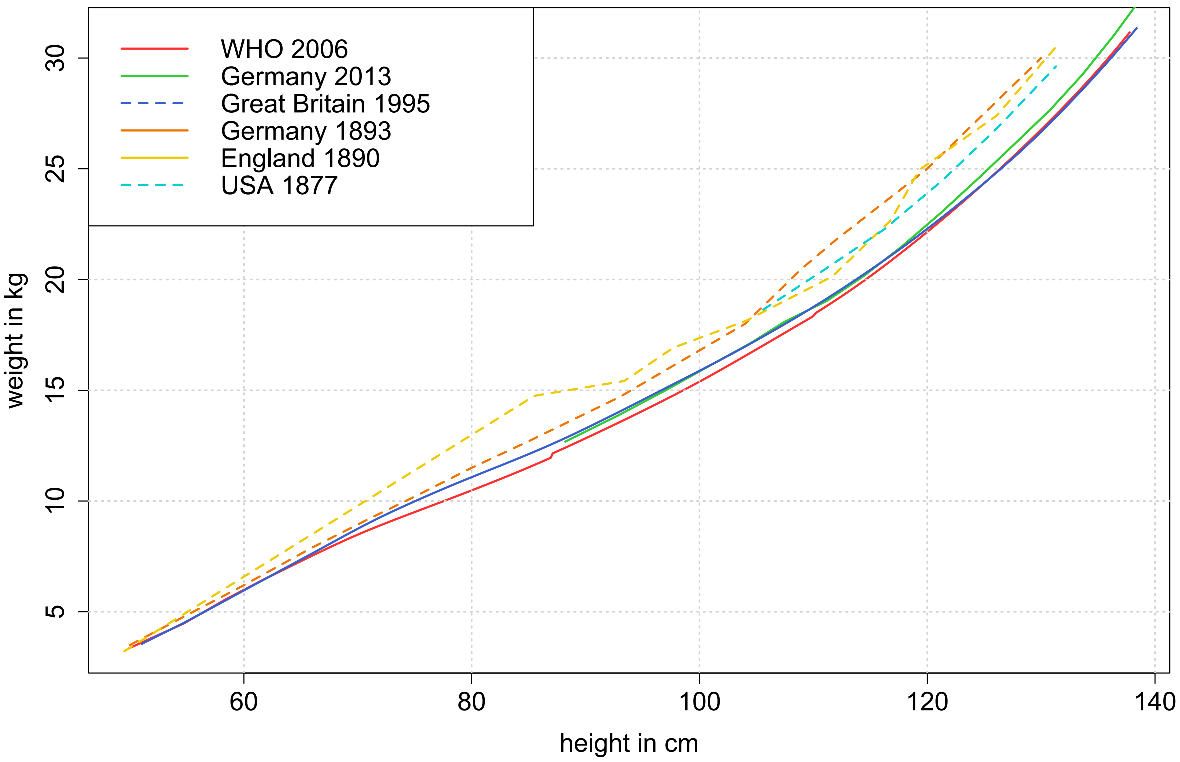

Figure 3 Mean weight-for-height of boys of three contemporary (Germany (Neuhauser et al. 2013), Great Britain (Freeman et al. 1995), WHO (WHO 2006)) and three historic growth charts (England from 1890 after (Weissenberg 1911)), Germany (Camerer 1893), USA (Bowditch 1877).

particularly during infancy and early childhood. Our first hypothesis that short children of "same-age" groups have lower weight-for-height z-scores than tall children of the same age appears true. This is contrary to the statement of Waterlow that "the expected weight of a child of given height is independent of age and largely independent of race" (Waterlow 1973). However, the effect is small and of questionable practical relevance. Thus, for practical reasons, weight-for-height references may ignore the age factor.

Contemporary references of weight-for-height resemble each other. Even weight-for-height of East German children measured some 40 years ago is strikingly similar to the contemporary weight-for-height reference tables published by the Centers for Disease Control and Prevention (Kuczmarski et al. 2002; CDC 2001) and WHO (WHO 2006). This was different at the end of 19th century. Previous European populations were shorter (Scheffler and Hermanussen 2021; Hermanussen et al. 2018). As child obesity was not an issue in those days, the children were certainly not "too heavy for their body height", rather "too short for their weight". Weight-for-height has significantly changed throughout recent history with up to 3 kg less weight in contemporary children of the same height. We thus reject the second hypothesis. Weight-for-height is sensitive to secular changes. Short populations are prone to high values of weight-for-height for arithmetic reasons independent of the nutritional state. The data highlight the effect of stature on the weight-for-height ratio and emphasize that by no means weight-for-height solely characterizes the nutritional state.

Additional studies are in progress which focus on similar arithmetic problems when using BMI for classifying the nutritional status of populations that differ in height from the references they are referred to. Preliminary data suggest that currently used critical cut-off values of BMI for defining "thinness", "overweight" and "obesity" (Cole and Lobstein 2012) (Nutrition Landscape Information System 2022) may lead to serious clinical misinterpretations (Hermanussen et al. 2022).

Conclusion

Weight-for-height depends on age and sex, and apart from the nutritional state, reflects body proportion and body built particularly during infancy and early childhood. Populations with a relatively short average height are prone to high values of weight-for-height for arithmetic reasons independent of the nutritional state.

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