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The archetypal BMI distribution is symmetrical

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Abstract

Background Currently used global standards and references for BMI are skewed to the right. We question that this feature reflects an archetypal human norm.

Sample and Methods We reanalysed 501 BMI distributions of 21 historic and contemporary populations from Westernized, Educated, Industrialized, Rich, Democratic (WEIRD) and Low- and Middle-Income Countries (LMIC) (Germany, Poland, Hungary, Kenia, South Africa, Indonesia, India, Guatemala) with altogether 111.197 boys and 101.688 girls aged 3 to 18 years. We tested age- and sex-specific skewness of these distributions.

Results Symmetrical BMI distributions were prevalent in European populations before the 1960s, and were found in children and adolescents from Kenya (1982), and contemporary Sikkim/India, rural Guatemala, and rural Indonesia. Right-skewed distributions are found in contemporary WEIRD countries and also prevail in contemporary urban children from LMICs. BMI distributions of girls are less skewed in the urban samples from Indonesia, Kolkata, rural Guatemala, and rural South Africa.

Conclusions Currently used growth charts suggest right-skewed distributions as a general feature of BMI at all ages. Yet, this feature is limited to contemporary WEIRD and urban LMIC societies and first occurred during the social and economic transition of the second half of the 20th century. Right-skewed BMI distributions capture a transient historic snapshot, with uncertain relevance for permanent global use. Right-skewness overestimates thinness and underestimates overweight and obesity in societies where symmetrical BMI distributions are still prevalent. We are concerned that the Global Burden of Diseases is much higher than currently rated and a serious future public health issue.

Take-home message for students Currently used global standards and references for BMI are skewed to the right. We question that this feature reflects an archetypal human norm. Skewed standards and references for BMI overestimate the prevalence of thinness and underestimate the prevalence of overweight and obesity in societies with symmetrical BMI distributions.

Introduction

This paper addresses the shape of the distribution of body weight and body mass index (BMI). Common agreement exists that humans can become extremely obese, but on the other side, there is a natural lower limit of thinness beyond which survival is not possible. The agreement aligns well with the observation that frequency distributions of weight and BMI obtained from contemporary populations tend to be right-skewed: the left tail of BMI distributions is constrained due to natural lower limits of thinness, whereas the right tail can extend far beyond.

Frequency distributions of weight and BMI have not always been skewed to the right. Historic European populations often show symmetrical distributions of body mass. The work of Dikanski (1914) may serve as a meticulously performed example of a representative study in healthy urban German school children. He presented data of height and weight of 6- and 7-year-old school girls. The girls (boys were not included in his study) were separated by social classes: daughters of wealthy pharmacists, doctors, bank officials, and railway administrators (Class I); daughters of chauffeurs, printers, electricians, field weavers, hairdressers, and gardeners (Class II); and daughters of assistants to various trades, hired hands, clerks, and factory workers (Class III). In all three classes the distributions of weight were symmetrical (Wilke et al. 2022).

Sporadic observations show that symmetrical distributions of weight and BMI are also found today in healthy rural Indonesia, healthy rural India, and rural Kenya (Scheffler et al. 2018; Scheffler et al. 2020; Jahn and Kirchengast 2024). These observations prompted us to deeper investigate the variation in the distribution of the BMI. When did the transition from symmetrical distribution of body mass to the right-skewed distributions take place in the European population, and which are the contemporary populations that still keep a symmetrical BMI distribution? We consider these questions as essential when constructing standards and references for defining thinness and overweight/obesity.

Statistical considerations

The BMI is often expressed in z-scores. Z-scores measure how many standard deviations a specific data point is above or below the mean in a normal distribution. Z-scores facilitate the comparability between age groups and sex. Global standards for BMI z-scores are provided by the WHO (WHO 2006a) and prescribe mean values, dispersion, and skewness for age and sex of the BMI distribution. Z-scores are conventionally calculated using the LMS method (Cole 1990). This method offers three parameters: M indicates the mean value, S the dispersion, and L a box-cox-transformation as an estimate of the skewness. The relationship between an observed BMI value (y) and its z-score (Z) is defined as follows:

$$\boldsymbol{y = M \cdot (L \cdot S \cdot Z + 1)^{1/L}}$$

In the case of symmetrical distributions, L=1, i.e., the box-cox-transformation corresponds to a linear scale. Figure 1 provides the example of a right-skewed distribution (the distribution corresponds to the BMI distribution of 18-year-old men, WHO reference (WHO 2007)) juxtaposed to a symmetrical Gauss distribution with the same mean, the same dispersion, and L=1 (i.e., no skewness). The figure illustrates the effect of the box-cox-transformation on the shape of a BMI frequency distribution.

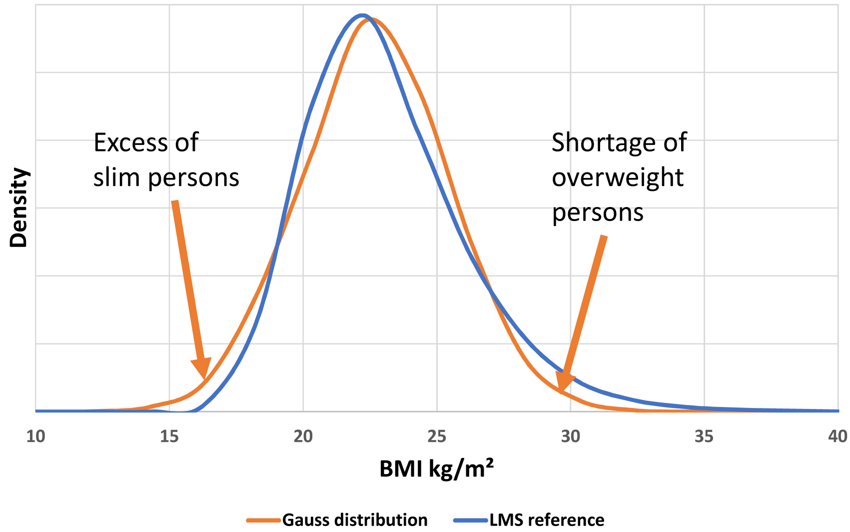

Figure 1 (1) A skewed distribution of BMI with L=-1.026, M=21.708, S=0.128 (the distribution corresponds to the WHO reference, male BMI, age 18 years, blue). (2) A symmetrical Gaussian distribution with the same mean (M) and the same dispersion (S), but with skewness L=1 (Cole 1990) (orange). The distributions differ particularly in the tails. When considering the skewed distribution (blue) as the reference for BMI, a population with a symmetrical BMI distribution (orange) will appear to have an excess of slim and a shortage of overweight individuals.

Distributions that differ in skewness do not overlap. Particularly the tails increasingly differ as they move away from the mean. Using a right-skewed distribution as the reference for a symmetrical distribution results in misclassification, particularly in the tails, and suggests an excess of thin people and a shortage of overweight and obese people (Figure 2).

The misclassification can be quantified by converting the two distributions into each other by:

$$\mathbf{z_2} = \frac{(\mathbf{z_1\,L_1\,S+1})^{\mathbf{L_2/L_1}} - \mathbf{1}}{\mathbf{L_2\,S}}$$

Solving the formula for z1:

$$\mathbf{z_1} = \frac{(\mathbf{z_2\,L_2\,S+1})^{\mathbf{L_1/L_2}} - \mathbf{1}}{\mathbf{L_1\,S}}$$

Hypothesis

Currently used growth charts prescribe right-skewed distributions as a general feature of the BMI at all ages. We question this assumption as this feature was absent in healthy historic European populations and has first occurred in the second half of the 20th century. It is still absent in contemporary rural populations of Low- and Middle-Income Countries (LMIC). We hypothesize that (1) the currently used global standards and references for BMI do not reflect an archetypal human norm, but that mean values and the shape of BMI distributions rather capture a transient snapshot reflecting the social and economic transition at the end of the 20th century; and that (2) long-term observations in selected national populations in the Westernized, Educated, Industrialized, Rich, Democratic (WEIRD) (Henrich et al. 2010) countries over historic

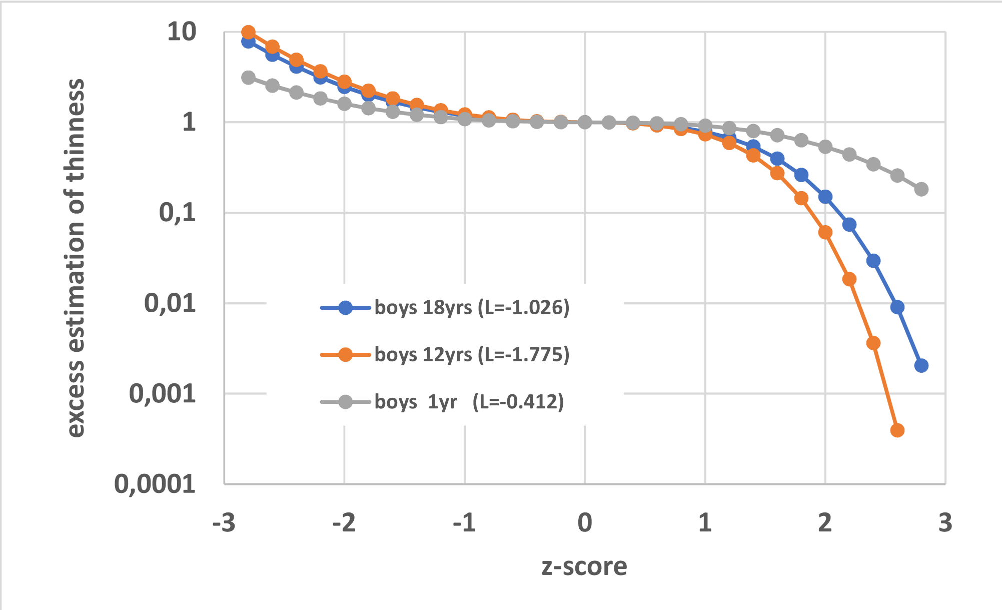

Figure 2 Excess estimation of thinness and underrating of overweight in three populations of boys (age 18, 12, and 1 year) with symmetrical BMI distributions (same mean, same dispersion, and no skewness, L=1) when referred to the WHO reference (L=-1.026 (age 18 years), L=-1.775 (12 years), L=-0.412 (1 year)). The slimmer the children in each age group, the more prone to being misclassified as "very thin", the heavier the children, the less prone to be classified as "very heavy". In the population of 18-year-old boys with symmetrically distributed BMI, the prevalence of "thinness" (BMI<17 kg/m^2) is more than 3-fold overestimated and the prevalence of "obesity" (BMI>30 kg/m^2) is almost 10-fold underestimated.

periods of up to 100 years, are suitable to depict the moment at which symmetrical BMI distributions have turned into right-skewed distributions. We consider right-skewed BMI distributions as a recent anthropometric feature that has meanwhile also evolved in many urban societies of LMIC.

Sample

We present an analysis of 501 annual BMI distributions of 111.197 boys and 101.688 girls aged between 3 and 18 years from 21 historic and contemporary growth studies from Germany, Poland, and Hungary, and from LMIC (Table 1). This broad dataset provides an opportunity to explore long-term and cross-cultural variation in BMI distributions. The historic German data on child and adolescent BMI were part of the legacy of Hans Grimm that were bequeathed to the Human Biology Group of the University of Potsdam. Hans Grimm (1910–1995) was a German social physician and biological anthropologist and Professor of Anthropology at the newly founded Institute of Anthropology at Humboldt University of Berlin since 1959 (Greil and Wustmann 1996 ; Bogin et al. 2018). The body measurements of height and weight were conducted in the late 1920s, 1930s and early 1950s. The data sets originated from school health screening investigations and comprised school children of all social strata. The data can be considered representative for the child and adolescent population of that time. Yet, these data have not been found in any of the publications of Hans Grimm and apparently, have never been analysed and published before. According to additional material found in the archives, data collection was meticulously controlled and conducted according to Rudolf Martin (Martin 1914).

Representative data were obtained from East Germany of the 1960s (Dribbisch 1969), the 1980's (Flügel et al. 1986; Greil 1988), and the 1990s (Schilitz 2001; Trippo 2005), from all Germany from KiGGs study after 2003 (Neuhauser et al. 2013), from Poland 1966 (Rösler et al. 2023) and from Hungary from 1980s (Eiben et al. 1991) and 2000 (Bodzsar et al. 2016; Zsakai and Bodzsar 2012). Details of data collection can be found in the respective publications. LMIC data were obtained from rural Kenya, measured in 1982 (Jahn and Kirchengast 2024), from rural (Maya) and urban (mostly Ladino) Guatemalans measured in the 1980s (Bogin 2018), from rural and urban South Africa measured in the 1980s (Henneberg and Louw 1998), from rural Sikkim, India, measured in 2015 (Dorje 2020), from urban Kolkata in 1982 and 2011 (Scheffler et al. 2018) and from rural (Soe, West Timor) and urban Indonesia (Medan, Sumatra; Kupang, West Timor; Ubud, Bali) measured in 2018 (Scheffler et al. 2020). The original data were kindly provided by the colleagues and authors of the respective papers. WHO-reference were added for comparison (WHO 2006b) (Table1). All measurements had been performed by standard protocols and by professional personnel and can be considered representative for the time of these studies. Except for the Guatemalan children and adolescents who experienced substantial food insecurity and emotional (SEPE) (Bogin 2021) insecurity during civil war, the studies were carried out under unimpaired nutritional conditions.

All studies had been performed according to the respective relevant historic concepts of ethics, contemporary studies were performed according to the Helsinki declaration (World Medical Association 2013)

Skewness (γ) was calculated for all BMI distributions and tested for significance using Shapiro-Wilk test ($p < 0.001$). As this test is standard, but tends to detect even trivial deviations from normality as statistically significant in very large samples, we used $p < 0.001$ as critical threshold for rejecting symmetry. Raising the significance level helps to ensure that minor deviations from a symmetrical Gaussian distribution are not overestimated.

The precision of the standard error of skewness $SE_{skewn} = \sqrt{(6/n)}$ depends on sample size. As most of the annual samples of children are comparably small (Table 1) and rarely surpass n=100 for each age group, the 95%-confidence intervals of skewness are usually wide and rarely narrow below +/-0.5. In order to avoid misleading over-accuracy, we refrained from explicitly presenting the exact skewness of each of the 501 distributions and instead created 5 categories (intervals within which the respective skewness values can be found) ($\gamma > 0$, $\gamma > 0.5$, $\gamma > 1$, $\gamma > 1.5$, $\gamma > 2$) (Figure 3).

All calculations were performed using the statistical program R "Version R 4.3.1" (Groth 2024; Groth 2025).

Results

Symmetrical distributions of child and adolescent BMI were predominantly found in the Polish population in 1966, in the German populations before the 1960s, and in the populations of rural Kenya (1982), in contemporary rural Sikkim/India, in the rural Maya population of Guatemala, and in contemporary rural Indonesia. Predominantly symmetrical BMI distributions

(Shapiro-Wilk test $p > 0.001$) were also found in contemporary Indian girls of Kolkata. Right-skewed BMI distributions prevailed (Figure 3) in all contemporary European samples and in the urban populations of the LMIC, with a trend towards increasing skewness in the more recent cohorts. BMI distributions of girls appear on average less skewed in the urban samples from Indonesia, Kolkata and in rural Guatemala and South Africa suggesting sex bias in child nutrition and care. The skewness (γ) in the BMI distributions of the WHO standards and references is significant in all age groups, with maxima in 7–11-year-old girls and 8–12-year-old boys.

Long-term data from Germany between 1930 and 2015 illustrate the shift from predominantly symmetrical to right-skewed BMI distributions after the 1960s. Symmetrical BMI distributions are found in the Polish data from the 1960s, right-skewed BMI distributions appear in the more recent Hungarian data. Symmetrical BMI distributions are preferentially found in the contemporary rural samples from LMIC.

The study highlights the inherent difficulty of deriving unambiguous, prescriptive standards from data drawn from highly heterogeneous human environments — especially when such standards are based on evidence from a single historical time point. WHO BMI distributions fail to represent

Table 1 Description of the data set used for the analyses of skewness of BMI (author-references are mentioned in the text)

Country		Years	Sample size		Age range	Author
	region/population		male	female		
Germany		1920-29	114		16-18	Grimm
		1930-39	452		14-17	Grimm
		1953	648	1439	11-15	Grimm
		1960-69	521	516	10-18	Dribbisch
		1980-89	20.281	20.067	3-18	Flügel, Greil
		1990-99	12.147	11.542	3-18	Schilitz, Trippo
		2003	8.442	8.122	2-17	KiGGS
Kenia		1982	135	81	4-9	Jahn&Kirchengast
India	Sikkim	2015	258	276	3-16	Dorje
	Kolkata	1982	808		7-16	Scheffler
	Kolkata	2011	1.599	1.738	7-18	Scheffler
Poland		1966	966	2.343	3-18	Rösler
Indonesia	rural West Timur	2018	197	110	6-12	Scheffler
	urban West Timur	2018	197	194	6-12	Scheffler
	Sumatra	2018	268	215	6-12	Scheffler
	Ubud/Bali	2018	316	274	6-12	Scheffler
Guatemala	rural (Mayas)	1980	3.202	2.276	6-18	Bogin
	Urban (Ladinos)	1980	26.939	20.679	6-18	Bogin
South Africa	Urban	1986-88	898	810	6-18*	Henneberg&Louw
	Rural	1986-88	1.060	894	6-18*	Henneberg&Louw
Hungary		1983-86	20.153	18.697	3-18	Eiben
		2003-06	11.707	11.415	3-18	Zsákai &Bodzár

*age calculated after MARTIN (+/- 6 month)

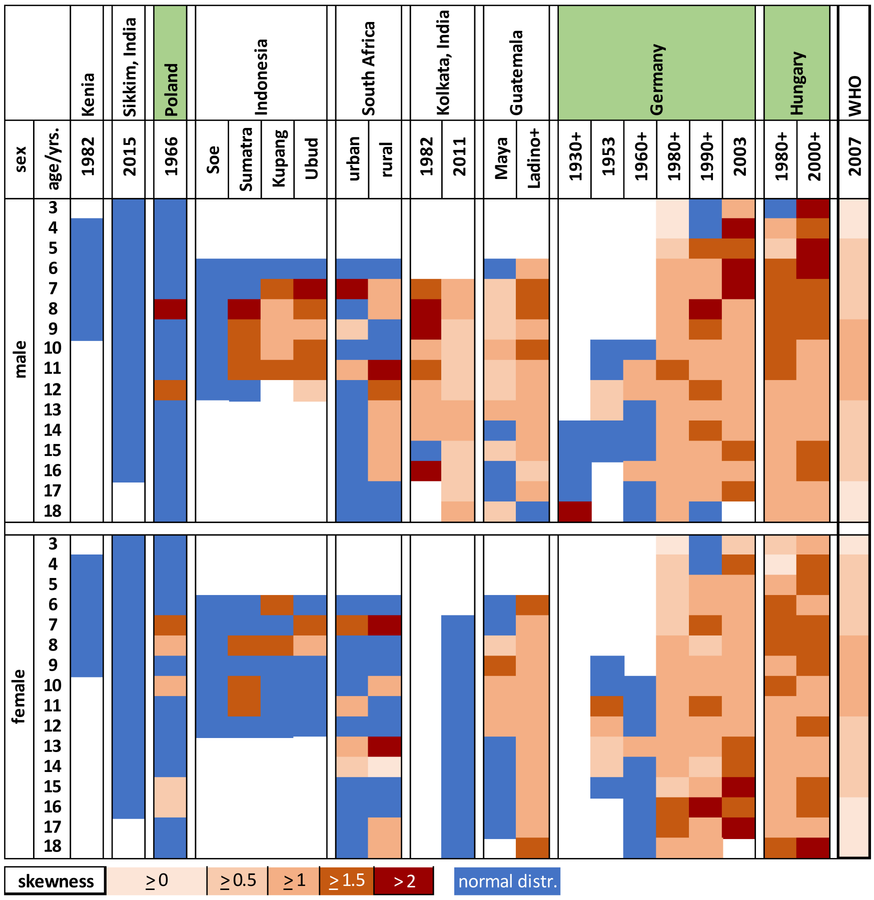

Figure 3 Allocation of symmetrically (blue) and right-skewed (brown) BMI distributions in 501 samples of children and adolescents, aged 3–18 years. The figure comprises data from 3 European societies (green), and 5 Low-Middle-Income Countries. WHO distributions are added for comparison. Skewness is given in 5 categories ($\gamma = 0$ (blue); $\gamma \geq 0$; $\gamma \geq 0.5$; $\gamma \geq 1$; $\gamma \geq 1.5$; $\gamma \geq 2$ (shades of brown)) and depicted by colors to improve clarity.

the shape of contemporary BMI distributions in LMICs.

Discussion

Frequency distributions of weight and BMI have not always been skewed to the right. In contrast to current perception, historic European populations as exemplified in the work of Dikanski (1914) (Wilke et al. 2022) and numerous healthy contemporary rural populations of LMIC show symmetrical distributions of body mass such as populations of Indonesia, India and Kenya (Scheffler et al. 2018; Scheffler et al. 2020; Jahn and Kirchengast 2024). The similarity between the historic European and the contemporary LMIC samples prompted us to further study the transition from symmetrical to right-skewed distributions of body mass that are now regarded as universal references for defining thinness and overweight/obesity.

The present compilation of BMI distributions of historic European and contemporary rural populations of LMIC, in particular, the long-term assessments of the German population between 1930 and 2003, suggest that there is an archetypal shape of the distribution of body mass in populations that were, or still are, unaffected by contemporary Western diet and lifestyle. On the other side, the data also emphasize the dynamics of the shape of BMI distributions throughout history and challenge the modern assumption that a single standard shape exists that can serve as a universal reference for defining thinness and overweight/obesity. We can accept our first hypothesise that the currently used global standards and references for BMI do not reflect an archetypal human norm, but that they capture a transient snapshot of the BMI that was shaped by the environmental and dietary habits at the end of the 20th century. The German examples suggest that we can also accept our second hypothesis: repeated growth studies over historic periods of many decades are suitable to depict the moment at which symmetrical BMI distributions have turned into right-skewed distributions. In the German case, the studies suggest that the shift from a symmetrical to a right-skewed distribution of the BMI occurred in the second half of the 20th century somewhere in or after the 1960s. It remains to be elucidated whether similar phenomena occurred in other European countries during this period. The Polish BMI data from 1966 follow a normal distribution, the more recent data for Hungary (1980s, 2000s) show a marked skewness in BMI. The two examples support the view that BMI distributions also of other European countries have changed after the 1960s.

We consider the currently observed skewness of modern BMI distributions as a mirror of diet, lifestyle and environmental changes that the contemporary societies of WEIRD countries and many urban societies of LMIC experienced during the second half of the 20th century. Lopsided BMI distributions are even found in the stressed urban Guatemalan societies that suffered from food and emotional (SEPE) (Bogin 2021) insecurity during times of civil war. This suggests that the modern BMI skewness to the right is a complex phenomenon and seems to depend on more than mere food availability.

The study underscores the inherent difficulty of deriving unambiguous and prescriptive standards from data drawn from highly diverse human environments. The study shows that the dynamics of the BMI is not limited to variation in mean values – there are “heavy” and “light” populations (NCD-RisC 2017). The dynamics include variation in the shape of the BMI distribution throughout history, at least since the 1960s in WEIRD societies and later in urban LMIC societies. Trends towards increasing skewness have been reported from urban Australian adults (Peeters et al. 2015) and in Canada (Lebel et al. 2018). A recent NCD Risk Factor Collaboration (NCD-RisC 2021) also addressed the shape of BMI distributions based on a compilation of 2.896 population-based studies conducted from 1985 to 2019 with measurements of 187 million participants. Apart from discussing the global rise in mean BMI, these authors confirmed the trend towards rising skewness to the right, even though they falsely considered this trend to be small and outweighed by the rise in mean BMI.

The impression that the trend towards rising skewness may be small, is deceptive. The NCD Risk Factor Collaboration (NCD-RisC 2021) was derived from a cross-sectional global set of studies. The impression changes when considering long-term data as exemplified in the German studies between 1930 and 2003. Whereas symmetrical BMI distributions prevailed in most age cohorts up to the 1960s, right-skewed distributions became rampant in the later decades with $\gamma \geq 1$ in all age cohorts.

Despite the historic dynamics of the BMI, over 140 countries have meanwhile adopted the WHO standards and references (Zorlu 2011) as their single reference chart for clinical purposes. This means that these countries use standards and references that were exclusively constructed from populations that lived in WEIRD conditions within a short historic window between the 1970s and the early 2000s. We are concerned that applying these standards and references to populations that did not participate in the lifestyle transition that contemporary WEIRD countries had experienced in recent decades, will cause falsely elevated prevalence of children that appear underweight and a fallacious shortage of children that appear overweight, simply for statistical reasons.

The skewness of BMI standards and references even though developed from complex international datasets and sophisticated methodological considerations does not reflect a permanent feature. The skewness of BMI is a recent phenomenon of the contemporary urban WEIRD societies that has evolved during the socio-economic transition of the second half of the 20th century and has meanwhile also affected the urban centres of LMIC. It captures a transient snapshot of BMI and simply represents a recent distribution of body mass in the contemporary societies, with uncertain relevance for global and permanent use.

The present data suggest that the currently used global BMI charts do not represent an "archetypal human norm". The data rather support the vision that the genuine distribution of weight and BMI in healthy populations is symmetrical.

This assumption has substantial implications on clinical assessments of the prevalence of overweight and obesity. The current global estimates of 390 million overweight children and adolescents including 160 million affected by obesity (WHO 2006b; WHO 2024) are statistical estimates based upon right-skewed standards and references. Far more robust epidemiological evidence is needed to determine whether only those who are currently classified as overweight or obese, are clinically at relevant risk, or whether the existing prevalence still underestimates the true burden with a substantial proportion of overweight and obesity remaining "hidden" under the right-skewed upper tail of the modern reference charts.

The higher prevalence of skewed BMI in the boys in contemporary Kolkata, in Indonesian, in rural Maya settlements, and in rural South African societies, might suggest that the girls are less vulnerable to obesogenic environments, but we rather consider gender inequality in care and nutrition as described in several LMIC (Abiri et al. 2024; Shah et al. 2020) to be responsible for this phenomenon.

As the data summarized in this study are limited to information on sex, age, and degree of urbanisation, further analyses with respect to the influence of socioeconomic status, dietary patterns, physical activity, or disease environment on the skewness of BMI distributions, were not possible. Thus, the data lack information about the association of these factors with the trend towards rising right-skewness in the distribution of body mass. The present data are limited to one long-term series of six German studies carried out between 1930 and 2015, 3 European studies of the second half of the 20th century, and data from 5 contemporary LMIC countries, and thus, need confirmation from a larger historic and geographic spectrum of countries. We deliberately refrained from data obtained by harmonized global datasets (Integrated Public Use Microdata Series) as these series conflate high quality with self-reported data sets as common in census samples (e.g., some IPUMS-USA, IPUMS-International datasets), and thus, appear inappropriate for studying details of frequency distributions.

However, the present analysis suggests serious reconsideration regarding the shape of the currently used global BMI references, and to critically question the modern cut-off limits both for thinness and overweight/obesity. The use of right-skewed standards and references for symmetrically distributed data leads to systematic misjudgements on both sides of frequency distributions. We are concerned that this statistical effect substantially impairs clinical assessments of thinness and overweight/obesity. We are concerned that the Global Burden of Diseases (GBD 2019 Risk Factors Collaboration 2020) is much higher than estimated by the currently used, and a serious future public health issue (UN News 2025).

Conclusion

Currently used growth charts suggest right-skewed distributions as a general feature of BMI at all ages. Yet, this feature has evolved in the contemporary WEIRD and urban LMIC societies and first occurred during the social and economic transition of the second half of the 20th century. The feature captures a transient historic snapshot of BMI, with uncertain relevance for permanent global use. The use of right-skewed BMI standards and references for populations where BMI is symmetrically distributed, systematically misjudges both tails of frequency distributions. It overestimates thinness and underestimates overweight and obesity in societies where symmetrical BMI distributions are still prevalent. We are concerned that the Global Burden of Diseases is much higher than currently rated, and a serious future public health issue.

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