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REVIEW

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One size does not fit all. How universal standards for normal height can hide deprivation and create false paradoxes

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Abstract

Public health practitioners and social scientists frequently compare height against one-size-fits-all standards of human growth to assess well-being, deprivation, and disease risk. However, underlying differences in height can make some naturally tall populations appear well-off by universal standards, even though they live in severe states of deprivation. In this article, I describe the worldwide extent of these population differences in height and illustrate how using a universal yardstick to compare population height can create puzzling disparities (eg, between South Asia and sub-Saharan Africa) while also underestimating childhood stunting in specific world regions (eg, West Africa and Haiti). I conclude by discussing potential challenges of developing and implementing population-sensitive standards for assessing healthy development.

1 | INTRODUCTION

Humans have a long history of judging others by the shape, size, and heft of their bodies, labeling those perceived as too short as dwarves (Dasen, 1993; Ghadessi, 2018), too tall as giants (Chemers, 2008), too heavy as corpulent (Bray, 2009), and too thin as anorexic or emaciated (Liles & Woods, 1999). In recent centuries, these tendencies to classify human bodies have become increasingly formalized. Beginning in the 1700s, militaries measured and classified human bodies, originally to weed out those who were too young, too short, too weak, or too sick to serve (Johnson, 1997; Komlos, Hau, & Bourguinat, 2003), and in more recent years to exclude those who have excessive body fat indicating a "poor state of health" or "lack of personal discipline" (Grumstrup-Scott & Marriott, 1992). By the 19th century, physical anthropologists began fastidiously measuring and reporting heights, weights, and cranial measurements around the world to characterize racial typologies of biological diversity (Hunt, 1959). In addition, around the same time, life insurance companies began collecting and analyzing weight and height tables to determine how being too thin or too heavy increased one's risk of dying early (Czerniawski, 2007). More recently, scholars and practitioners have used the size and shape of bodies as a proxy for many facets of well-being, including adequate nutrition, disease exposure and deprivation, economic standards of living, and health risks associated with excess fat (Beall, Baker, Baker, & Haas, 1977; Bogin, 2013; Cameron, 1984; Deaton, 2007; Eveleth & Tanner, 1976; Ferro-Luzzi, Norgan, & Durnin, 1978; Floud, Fogel, Harris, & Hong, 2011; Frongillo Jr, de Onis, & Hanson, 1997; Hruschka, 2017; Komlos & Baten, 2004; Martorell & Habicht, 1986; Schell, 1986; Steckel, 1983; Tanner, 1986; Troiano, Frongillo Jr, Sobal, & Levitsky, 1996; World Health Organization, 1995).

Today, quantitative measures for the size and shape of bodies have entered our daily lives in numerous ways. Health checks for both infants and adults routinely involve measurement of height and weight checked against growth curves and cutoffs (Hamill, Drizd, Johnson, Reed, & Roche, 1977). Many U.S. homes include a wall where families mark children's height every year on their birthday. In addition, mass-produced home scales have permitted people to monitor their weight on a daily basis (Bivins & Marland, 2016). Such pervasive measurement and monitoring of bodies has led many people to internalize these numbers as parts of their identity. Indeed, members of contemporary industrialized societies are likely unique in their ability to report a number for both their height and weight (Maupin & Hruschka, 2014). Moreover, people frequently use these and other numbers, such as waist and dress sizes, to set aspirations for their bodies (Calbom, 2011; Friedl, 2012).

In a similar vein, quantitative measures of bodies have become important tools for policymakers to evaluate population health, to prioritize populations at risk, and to set policy goals. International organizations, such as the World Health Organization and UNICEF, regularly report the percentage of children who are stunted (ie, too short) or wasted (ie, too thin) as indicators of a country's health status (Leroy & Frongillo, 2019; Mercedes & Branca, 2016; World Health Organization, 2020). Both national and international agencies routinely report the percentage of people who are too heavy for their height (ie, overweight and obese) as an indicator of risk for obesity-related diseases, such as diabetes and cardiovascular disease (Ogden, Carroll, Fryar, & Flegal, 2015). In addition to using these measures to monitor well-being, practitioners and policymakers also use them to set goals and assess the success of policies. Weight and height frequently serve as outcome measures for evaluation of interventions (Brown et al., 2019; Goudet, Bogin, Madise, & Griffiths, 2019). Doctors and parents regularly monitor the height and weight of children to ensure growth is on track (Hamill et al., 1977). In addition, policymakers use country-level measures of height and weight to judge the success of a government's public health efforts. For example, in 2016, the World Bank's then-president announced that he would single out and expose countries who did not show reductions in childhood stunting—which is simply a measure of a child's height (Boseley, 2016).

The contemporary use of height and weight to assess health grew out of a century of accumulated evidence that these body measurements were *modifiable risk factors* for disease and mortality (Beaton, 1989). For example, by the late 19th century, actuaries were confident enough about the mortality risks of extreme weights (both low and high) that they included these measurements in calculations for life insurance premiums (Czerniawski, 2007). A century of research has further confirmed that high body mass index is a *risk factor* for a variety of diseases, including type 2 diabetes, heart disease, high blood pressure, and all-cause mortality (Zhu et al., 2019). However, BMI is more than simply a risk factor. It also depends on environmental inputs, including food intake, exercise, and infectious disease burden (World Health Organization, 1995). For this reason, it is potentially *modifiable* through interventions. Furthermore, BMI is strongly associated with body fat (correlations >.90), a well-established etiological factor in a number of outcomes, such as diabetes and heart disease (Camhi et al., 2011). As an easily measured risk factor that is modifiable and is associated with well-known etiological pathways to disease and mortality, BMI has been particularly attractive to health practitioners as a measure of disease risk.

For many of the same reasons, health practitioners use children's heights and weights as indicators of healthy growth. Studies have demonstrated in numerous contexts worldwide that shorter and thinner children are more likely to have infections, to die in the first years of life, and to experience slowed cognitive development (Black et al., 2008; Eveleth & Tanner, 1976; Hadley & Hruschka, 2017; Humphrey et al., 2019; Mercedes, Blössner, & Borghi, 2012; Prendergast & Humphrey, 2014; Tanner, 1992; Victora et al., 2008). Moreover, ample research in anthropology and global health has shown that both child height and weight are extremely sensitive to a range of environmental inputs, including nutrition and infectious diseases, thus making them potentially modifiable through public health interventions (Collaboration, 2016; Tanner, 1986; Waterlow, 1973). As modifiable risk factors, the height and weight of children are particularly attractive as targets of public health monitoring and intervention.

In many cases, global health organizations rely on quantitative cutoffs for these measures to decide if people are unhealthy or at risk (Table 1). For overweight and obesity among adults, practitioners commonly compare a person's body mass index against standard cutoffs (eg, > 30 kg/m^2 for obesity) to determine if a person is high risk. For child growth, practitioners often compare a child's height and age to the World Health Organization Growth Standards which were derived from 8,500 healthy children across six cities worldwide—Pelotas, Brazil; Accra, Ghana; Delhi, India; Oslo, Norway; Muscat, Oman and Davis, USA (De De Onis et al., 2006). When compared with this standard, a child whose height is 2 *SD* below the median is classified as "moderately stunted," and three *SD* below as "severely stunted." A similar system is used to assess if a child is too thin (or "wasted"), by comparing the child's weight, height and age against the WHO Growth Standards. Health

TABLE 1 Current public health cutoffs based on height, weight, and the reference populations they were originally derived from

Age	Label	Cutoff	Reference population	Citation
Adults	Obese	BMI > 30 kg/m^2	European descent populations from U.S. and Europe	WHO, 1995
	Overweight	BMI > 25 kg/m^2		
Children (0-5 years)	Moderately stunted	HAZ < −2	8500 healthy children from six cities worldwide—Pelotas, Brazil; Accra, Ghana; Delhi, India; Oslo, Norway; Muscat, Oman, and Davis, USA	De Onis, Garza, Onyango, & Martorell, 2006
	Severely stunted	HAZ < −3		
	Moderately wasted	WHZ < −2		
	Severely wasted	WHZ < −3		

Abbreviations: BMI, body mass index = weight/height^2; HAZ, height-for-age z-score; WHZ, weight-for-height z-score.

organizations also frequently report the proportion of individuals in a population who are obese, or stunted, or wasted as a measure of a population's overall health (Leroy & Frongillo, 2019).

Although these cutoffs are based on physical dimensions of the body, they often accrue new meanings beyond the simple physical dimensions that they actually reflect (Beaton, 1989; Beaton, 1992; Perumal, Bassani, & Roth, 2018). Someone with BMI greater than 30 is labeled "obese," which literally means having excess body fat. A child with weight-for-height well below the WHO Growth Standards would be classified as a case of "malnutrition," which implies nutritional deprivation. A child with height well below the WHO Growth Standards would be classified as stunted, which is defined as impaired linear growth due to under nutrition and deprivation (World Health Organization, 2020).

More importantly, cutoffs for obesity, wasting, and stunting have traditionally been one-size-fits-all, based on a universal model of human biology. Such models assume that healthy human bodies are sufficiently similar that a single cutoff carries roughly the same meaning of deprivation and disease risk across all people worldwide (Habicht, Yarbrough, Martorell, Malina, & Klein, 1974; Waterlow, 2011). Based on this assumption, a BMI greater than 30 should indicate the same level of body fat or the same increased risk of mortality for someone whether they are from the Netherlands, Japan, or Bangladesh. However, over the last decade, researchers and practitioners have increasingly realized that BMI is associated with body fat and disease risk in very different ways in different parts of the world. For example, populations can differ dramatically in the slenderness of their underlying frames even before fat is added (Deurenberg, Deurenberg-Yap, & Guricci, 2002; Hruschka, Hadley, & Brewis, 2014; Hruschka, Rush, & Brewis, 2013; Wells, 2010). In one study comparing populations of South Asian descent (who on average have more slender frames) with Pacific Islanders (who on average have stockier frames), the Pacific Island males had 4 kg/m^2 greater average BMI than South Asian males *with the same body fat* (Hruschka et al., 2013). For 5′9″ males, this 4 kg/m^2 difference is equivalent to 27 pounds or 12 kg! This is because at the same level of body fat, an individual with a more slender frame will have a lower BMI than one with a stockier frame. This illustrates how very different cutoffs for BMI would be required to indicate the same quantity of body fat in these different populations.

Parallel to these differences in the relationship between BMI and body fat, populations also differ remarkably in the relationship of BMI with disease risk (Yajnik & Ganpule-Rao, 2010). For example, one recent study of more than 5 million U.S. residents showed that Asian-American populations experienced increased diabetes risk at 5 kg/m^2 lower BMIs than non-Hispanic Whites (Zhu et al., 2019). "One-size-fits-all" cutoffs for BMI that fail to adjust for this difference would miss many Asian-Americans at risk for diabetes. This problem amplifies globally. One recent study of low- and middle-income countries worldwide calculated that single BMI cutoffs might underestimate the worldwide burden of overweight by more than half a billion people, with neglected populations in South Asia, East Asia, and parts of East Africa (Hruschka & Hadley, 2016). This emerging realization has led policymakers to recommend region- and country-specific cutoffs (eg, Asia-Pacific region, Japan, and China) that more accurately reflect local relationships between BMI, body fat, and health outcomes (Kanazawa et al., 2002; Wu, 2006).

While these region- and country-specific cutoffs are crucial adjustments to a one-size-fits-all approach, they are still limited for a number of reasons. First, macro-regional adjustments (eg, Asia-Pacific) mix populations (eg, South Asians and Pacific Islanders) that have very different relationships between BMI and body fat, and possibly disease risk (Hruschka et al., 2013; Kanazawa et al., 2002; WHO Western Pacific Region, 2000). Moreover, countries with adequate public health infrastructure have developed new cutoffs (eg, obesity defined as BMI ≥25 rather than ≥30 in Japan), but we know very little about how to adjust cutoffs in less studied parts of the world, such as sub-Saharan Africa or Latin America. Despite these ongoing challenges, the global health community has made substantial progress over the past 10 years in developing BMI cutoffs for adult obesity that are locally meaningful.

Even as international organizations recognize the limits of a one-size-fits-all cutoff for adult BMI, current recommendations for children's height and weight do not acknowledge that universal cutoffs may suffer from problems of a similar nature and magnitude (Goldstein & Tanner, 1980; Waterlow, 2011; World Health Organization, 2009). In this article, I discuss how ongoing use of one-size-fits-all cutoffs can lead to dramatic underestimates of child stunting in specific world regions and create apparent paradoxes in the relationship between child growth and economic development. I start by discussing the original rationale for one-size-fits-all approaches. I then outline evidence indicating there is no universal model of healthy human growth. I review plausible reasons for population differences in healthy growth trajectories. Finally, I outline ways of adjusting for local differences that can account for a number of confusions and paradoxes that arise when uncritically applying a one-size-fits-all approach to assessing child growth.

2 | ORIGINS OF ONE-SIZE-FITS-ALL APPROACHES

The cutoffs and growth curves we use today have a relatively recent history. In the U.S., the National Center for Health Statistics began disseminating growth charts to pediatricians, nurses and parents in the late 1970s to track adequate child growth. Soon after, the World Health Organization adopted these charts for international use (Wang, Moreno, Caballero, & Cole, 2006). For adults, the well-known BMI cutoffs of 25 for "overweight" and 30 for "obese" were first proposed by a WHO committee in 1995 (World Health Organization, 1995).

These original cutoffs were based on available evidence at the time, which largely represented European ancestry populations. For BMI, this involved a meta-analysis of 23 studies of European-ancestry men and women from North America and Europe which examined the association of BMI with mortality risk (Troiano et al., 1996). For children, the first U.S. growth curves were based on measurements from a sample of predominantly white children in southwestern Ohio (Hamill et al., 1977). The dissemination of these cutoffs, references and standards to much broader populations worldwide relied on an assumption that healthy humans grow in roughly similar ways. According to this view, a benchmark developed from one set of people should work equally well for any other set (Habicht et al., 1974). Over time, child growth curves have been redrawn to reflect nationally representative data from the U.S. and later to reflect samples of children from six cities worldwide (Wang et al., 2006). While incorporating a broader sample at each stage, the end result of these improvements has still been a single set of cutoffs that policymakers assumed would work equally well for any set of people worldwide.

There are a number of reasons why one-size-fit-all approaches might be attractive for practitioners and policymakers. First, from an implementation perspective, a single set of benchmarks is easier to communicate to a range of stakeholders, including health practitioners, parents, researchers, and policymakers. Second, a single standard can also help mobilize global efforts. For example, the WHO growth standards played a key role in convincing international stakeholders to monitor and combat child undernutrition. Within 5 years of their introduction, the growth standards had been adopted by 125 countries worldwide (De Onis et al., 2012). Moreover, they spurred the accumulation of new knowledge on growth and health in a much broader range of contexts.

Third, from a fairness perspective, one might argue that using the same cutoffs ensures all people are treated equally and that resources are distributed fairly. However, this argument confuses equality—the application of a single standard—with equity—application of flexible standards to meet diverse needs. For example, if there are underlying differences in how healthy bodies grow, then applying a "one-size-fits-all" cutoff might inadvertently lead to unfair allocation of resources. Consider two children—child A and child B—who reached the same height through different paths. Child A enjoyed adequate nutrition and low disease burden and reached her maximum potential height. By contrast, Child B had a genetic potential to grow much taller than child A in an optimal environment, but was chronically undernourished and subjected to substantial disease burden (Hackman &

Hruschka, 2020). A one-size-fits-all cutoff for height would make these two children look equally healthy, despite drastic differences in their environments and mortality risks. In this case, child B is tall, but unhealthy, and would be missed by universal cutoffs. Now consider a country that has a disproportionate number of children in Child B's situation. This country would look like its children are overall healthy compared to other countries, but in fact are facing severe deprivation.

Of course, this is a hypothetical situation, and without more information about how environmental inputs shape human growth and well-being worldwide, it is not possible to determine if this is a serious concern. Fortunately, we can turn to a growing body of data worldwide to illustrates the extent of this problem. Prior work has already shown how populations differ in what counts as a healthy BMI, and how one-size-fits all approaches can dramatically underestimate fat-linked risk for disease and mortality in particular world regions (Hruschka et al., 2014; Yajnik & Ganpule-Rao, 2010; Zhu et al., 2019). In the next section, I outline emerging evidence for height that illustrates similar issues.

3 | THERE IS NO UNIVERSAL TRAJECTORY OF HEALTHY GROWTH IN HEIGHT

Japan and the Netherlands rank among the wealthiest nations in the world, with low infant mortality, low disease burden, and excellent healthcare (The World Bank, 2020). Both countries have seen substantial improvements in adult height in the last century, with the average stature of men and women increasing by ~6 to 7 cm in both countries since the 1930s (Figure 1). This upward trajectory in average height clearly demonstrates how improving living standards and healthcare can profoundly shape early growth.

However, Figure 1 also reveals that improving living standards and healthcare cannot explain all variation in height. Specifically, for men and women born since the 1970s there are no further improvements in height in either country, and the average maximum reached by Japanese men and women is ~13 cm (~5 in.) shorter than the average maximum reached by Dutch men and women.

More importantly, there is no evidence that this decreased height has negatively affected the well-being of Japanese men. Indeed, Japan's life expectancy in 2018 was 2 years greater than the Netherlands' (84 vs 82 years) (The World Bank, 2020). This case illustrates quite dramatically how two populations living in optimal environments both of which should have healthy growth trajectories can achieve very different average adult heights.

Looking to early stages of the life course, we also see substantial variation in how healthy growth trajectories compare against universal standards. In 2010, seven out of 100 Japanese children were deemed unhealthily short (ie, moderately stunted) by WHO standards (World Health Organization, 2020). By contrast, around the same time period, only one in 100 Dutch children were classified as stunted by the same standard (de Wilde, Peters-Koning, & Middelkoop, 2020). Yet, there is no reason to believe that so many more Japanese children are unhealthy because they are shorter than the WHO standards.

Japan and the Netherlands are among the most well-off countries in the world, and thus provide a useful comparison between two populations living in optimal conditions. However, we can also find similar examples in low- and middle-income countries. Consider India and Haiti.

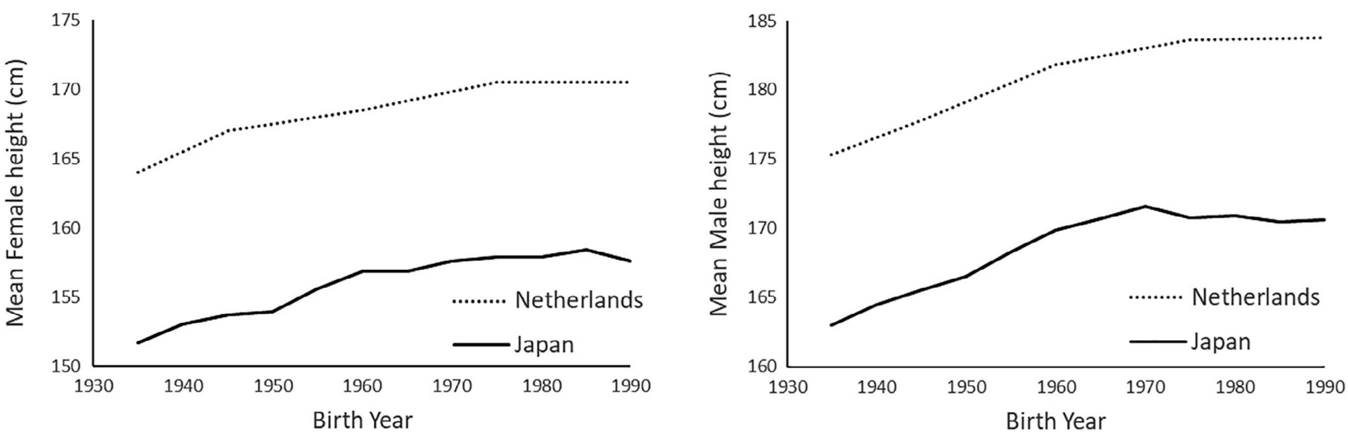

FIGURE 1 Increasing mean heights by birth year among women and men in Japan and the Netherlands (Mori, 2017; Schönbeck et al., 2013)

By most objective measures, Haitian children on average live in more deprived conditions. Haiti's infant mortality rate is 50% greater and its GDP per capita is less than a third of India's. Yet, by the WHO growth standards, Haitian children seem to be doing much better than Indian children, with only 6% of Haiti's children classified as severely stunted compared to 14% in India (Hackman & Hruschka, 2020).

This specific instance is related to a general phenomenon variously labeled the "South Asian enigma," "Asian enigma" or "South Asian height disadvantage." Specifically, children and adults from South Asian countries are on average shorter than their peers from sub-Saharan Africa (or with African ancestry). This is puzzling because South Asian countries outperform most African countries on a range of health and development indicators (Deaton, 2007; Gwatkin et al., 2007; Panagariya, 2013; Ramalingaswami, Jonsson, & Rohde, 1996). Researchers have proposed a number of environmental explanations for this puzzling disparity, including differences in sanitation (Spears, 2018), investment in first born children (Jayachandran & Pande, 2017), infant mortality (Harttgen, Lang, & Seiler, 2017), maternal health during development (Deaton & Drèze, 2009), reproductive lifespan (Coffey, 2015). Some factors such as open defecation can account for a small portion of the difference, while other flawed analyses claim to account for up to 50% of the gap (Hruschka & Hackman, 2020). However, none of these explanations has yet to fully account for the enigma (Hackman & Hruschka, 2020).

Notably, recent international analyses suggest that the Japan-Netherlands puzzle and South Asian Enigma are just two examples of pervasive worldwide height differences that appear to be independent of environmental inputs and health outcomes (Christesen, Pedersen, Pournara, Petit, & Júlíusson, 2016; Hackman & Hruschka, 2020; Hruschka, Hackman, and Stulp, 2019; Natale & Rajagopalan, 2014). This raises interesting questions about the sources of these apparently neutral differences.

4 | POTENTIAL ORIGINS OF THESE POPULATION DIFFERENCES

Both the Japan-Netherlands puzzle and the South Asian enigma suggest that populations can differ in both child and adult height in ways that are unrelated to: (a) environmental inputs or (b) health outcomes of interest, such as infant mortality and life expectancy. In this way, these differences are unrelated to the "small, but healthy hypothesis" which proposes that children adapt to environmental constraints by growing less (Beaton, 1989). Rather, these differences appear to be unrelated to environmental influences or health outcomes of interest altogether.

If environmental factors cannot account for these puzzling population differences in height, then where do they come from? Some researchers have proposed that the puzzle may be explained by genetic differences between populations (Panagariya, 2013). Indeed, height is influenced by hundreds of genes which appear to exert substantial influence on height across most of the lifespan (Wood et al., 2014). Large meta-analyses of international twin studies indicates that additive genetic variance can account for the majority (50% to 90%) of variance in height (Dubois et al., 2012; Jelenkovic et al., 2016). Moreover, in one recent analysis, researchers were able to predict a person's height within a few centimeters simply by knowing that person's genome (specifically 20 000 specific single nucleotide polymorphisms) (Lello et al., 2018). In addition to accounting for individual differences in height, researchers are beginning to identify specific genetic variants responsible for height differences between populations. For example, recent studies have identified specific genetic variants that contribute to the extremely short stature of Baka hunter-gatherers living in Cameroon (Zoccolillo et al., 2020). These diverse sources of evidence suggest that genetic differences account for substantial variation in height between individuals and populations.

Many of these findings about specific genetic influences on height have emerged in only the last few years, and most are limited to European populations. In the coming decades with more genetic studies in diverse settings worldwide, a firmer picture should emerge of how the population differences outlined above arise from specific suites of genetic variants or as yet unmeasured environmental inputs. However, if the puzzling differences in average height between Japan and the Netherlands and between people of South Asian and sub-Saharan African descent are due to genetic differences, this could help explain why these differences are insensitive to environmental influences and uncorrelated with health outcomes. It would also indicate that we need to adjust for these differences when we want to use height as a measure of deprivation or disease risk when comparing different populations.

5 | TOWARD MORE MEANINGFUL METRICS

Regardless of the reasons for these puzzling differences in height between the Japan and the Netherlands or between South Asia and sub-Saharan Africa, these persistent differences pose a problem for efforts to use height as a measure of health across populations. Unadjusted height may be perfectly fine for examining improvements in health within a population over time, such as the height increases in Japan over the last century (Figure 1). However, comparing across different countries (eg, Japan and the Netherlands) is difficult because of differences in height that have nothing to do with environmental influences or health outcomes.

When measures have weaknesses, one knee-jerk reaction is to simply discard them for other measures. For example, in the context of obesity, one might turn to alternative anthropometric measures, such as waist circumference. For child undernutrition, one might turn to medial upper arm circumference or hemoglobin. However, discarding well-established measures throws out the baby with the bathwater, along with a century of accumulated knowledge of how existing measures vary (and do not vary) with environmental influences and health. Moreover, the problems identified here are not unique to height or weight. Indeed, they will likely arise with any attempt to measure human bodies and use standard cutoffs to decide what is healthy or unhealthy. Furthermore, some more recently proposed measures may have not had sufficient time for deficiencies to be detected. For example, one recent study showed that quick measures of hemoglobin introduced recently into population-based studies may not produce reliable population estimates of anemia (Hruschka et al., 2020). Thus, simply replacing existing measures, such as height-for-age, weight-for-height, or BMI, with alternatives is likely not a viable solution.

One approach to improving comparability of measures across populations is to assess how quickly individuals grow over time, rather than focusing on their height at a specific point in time (Prentice, Moore, & Fulford, 2013; Prentice, Nabwera, Unger, & Moore, 2016; Wells et al., 2019). By considering an individual's starting point, this approach can help control for prior individual and population differences. Emerging evidence also suggests that differences in growth velocity can tell us more about mortality risk than static measures, such as height-for-age z-scores (Schwinger, Fadnes, & Van Broeck, 2016). A key challenge of using this approach for global monitoring of health is the added complexity and cost of data collection (Prentice et al., 2016). Most studies used for global monitoring of stunting are designed to capture an accurate snapshot of a country or region at one point in time. These involve complex, cluster-based designs with thousands of respondents randomly sampled across a country. Adding a follow-up component that assesses the same children several months later would require substantial additional complexity and cost. Innovations in survey design that lowers these costs may ultimately increase the feasibility of such approaches. However, until then, global monitoring of health with anthropometrics will likely rely on static measures, such as height-for-age z-scores.

An alternative approach aims to refine current standards to accurately reflect population differences in healthy growth. This usually means developing population-specific adjustments for standards or cutoffs that permit more meaningful comparison across countries and ethnic groups (Christesen et al., 2016; de Wilde et al., 2020; de Wilde, van Dommelen, van Buuren, & Middelkoop, 2015; Goldstein & Tanner, 1980; Hackman & Hruschka, 2020; Khadilkar et al., 2007). There is already precedent for such adjustments to cutoffs for adult BMI in a few regions and countries worldwide (eg, Japan, Asia-Pacific). However, few, if any, official adjustments have been made for stunting among children. One way to identify population-specific cutoffs is to derive these standards among children living in optimal environments (de Wilde et al., 2020). A few organizations, such as the Indian Academy of Pediatrics, have adopted country-specific standards for assessing child growth based on local, affluent samples (Khadilkar et al., 2007). However, many low- and middle-income countries and ethnic groups worldwide do not have sufficiently large populations living in optimal environments to use that approach (Karra, Subramanian, & Fink, 2016). Moreover, influential organizations, such as the World Health Organization and UNICEF, continue to use one-size-fits-all standards for comparing populations, countries, and regions worldwide (World Health Organization, 2020).

An alternative approach that does not require studying populations in optimal environments is to partial out variation in height that is due to a range of environmental inputs (eg, sanitation, diet, disease burden, wealth), and then see what differences still remain between populations (Hackman & Hruschka, 2020; Hruschka et al., 2014). These remaining population differences represent differences that persist even when populations experience the same standards of living. As such, they are equivalent to the height gap between the Netherlands and Japan shown in Figure 1. Of course, there is always a possibility that one has left out specific environmental influences in such analyses. However, when members of our lab recently attempted this for child height across a range of low- and middle-income countries, we found that the substantial remaining differences between countries had an important property. They no longer bore any relationship with infant mortality. Thus, we were able to estimate population differences in height that were: (a) unrelated to available environmental variables, and

(b) unrelated to a key health outcome (ie, infant mortality) (Hackman & Hruschka, 2020). In short, these persistent differences appear to capture the component of height that is *not modifiable* or a *risk factor*.

When we used these remaining population differences to develop country-specific growth cutoffs, our estimates of stunting made a lot more sense. Recall the puzzling disparity between Haiti and India outlined above. With the country-specific cutoffs, Haiti now had 21% prevalence of severe stunting compared to India's 15% prevalence, a finding more consistent with India's better infant mortality rates and economic standing. More generally, the results showed that WHO growth standards for stunting appear to miss large numbers of children in specific world regions. Specifically, they appear to underestimate the burden of severe stunting most dramatically in Haiti (6% vs 21%) and West Africa (8% vs 27%), but also in other parts of sub-Saharan Africa, including southern Africa (9% vs 17%), central Africa (19% vs 30%) and eastern Africa (16% vs 26%). More generally, stunting estimates based on these country-specific cutoffs had stronger correlations with infant mortality across over 70 countries than did stunting estimates based on one-size-fits-all cutoffs (Hackman & Hruschka, 2020). Thus, these country-specific cutoffs provide estimates of stunting that resolve a number of puzzles and paradoxes created by one-size-fit-all standards. They also point to countries and regions where one-size-fit-all cutoffs are potentially missing large numbers of children and giving the false impression that some countries are doing better than they are.

While these results show promise, more studies will be needed to: (a) test key assumptions of models used to calculate population-specific cutoffs, and (b) explore how well population-specific cutoffs predict a broader range of health outcomes of interest (Hackman & Hruschka, 2020). Furthermore, any effort to develop population-specific standards or cutoffs will also need to address a number of issues outlined below.

6 | FURTHER CONSIDERATIONS FOR POPULATION-SPECIFIC STANDARDS OR CUTOFFS

The best approach to deriving population-specific adjustments for stunting is still unclear. However, a number of considerations are likely important when creating such adjustments. First, region- and even country-level adjustments may not be sufficiently fine-grained to capture important population differences. For example, India is a diverse country with thousands of distinct communities representing the convergence of populations from at least five disparate linguistic groups (Indo-Aryan, Dravidian, Austroasiatic, Sino-Tibetan, and Kra Dai). Thus, to establish a single standard for the entire country of India may mask important genetic differences in height that exist between communities. For the same reason, regional cutoffs for "sub-Saharan Africa" or "Asia and Pacific" would likely hide substantial variation as well.

Second, creating population-specific cutoffs inevitably requires categorizing people into distinct populations, a practice which can inadvertently lead to antiquated racial typologies (Gould, 1996; Wells, 2020). Ultimately, we must remember that categories are abstractions, and some do a better or worse job of approximating reality for specific purposes. As we outlined earlier, "Asia Pacific" is not a very useful category for developing cutoffs for BMI because of massive differences in average body form between Pacific Islanders and many South Asian populations (Hruschka et al., 2013). Similarly, "sub-Saharan Africa" conflates many populations with diverse backgrounds, and does not provide a useful category for adjusting height (Hackman & Hruschka, 2020). In many cases, countries may provide a more fine-grained, good-enough categorization scheme. However, many countries (e.g., India) also exhibit striking population diversity within their boundaries. Another possibility is to focus on categories based on ethnic and linguistic affiliation. However, ethnic categories often arise from the merging of diverse populations, and thus may also mask important population variation (Wells, 2020). These examples illustrate that there is no natural categorization that represents truly distinct populations. Rather, some categorizations can be more useful than others to capture variation for adjusting standards and cutoffs. Ultimately, how fine-grained to go in any specific situation and what categories to use would depend on a better understanding of biological diversity among humans as well as the relationships between height, environmental inputs, and disease and mortality risk in diverse settings.

Third, it is important to note that adjusting cutoffs still rely on a common procedure in medicine and public health—mapping complex health states to a simple categorical distinction, such as healthy-unhealthy, stunted-not stunted, or obese-not obese. Categorization provides a simple rule for counting and decision-making, but can also mask important variation in health status (Mirowsky & Ross, 2002). Using quantitative measures, such as BMI and height-for-age z-scores, instead of categorical indicators, potentially provides more information on the health status of individuals and populations. However, these also suffer from similar challenges when there are substantial population differences in healthy body proportions. That said, the procedures outlined above for developing population-specific standards could also assist in adjusting these quantitative measures for more meaningful comparisons of health status across populations.

Fourth, population-specific adjustments need to be useful. Specifically, adjusted cutoffs should improve our prediction of risk for mortality and morbidity over unadjusted cutoffs. If they do not perform better, then it is not clear what adjusting the cutoffs accomplishes (Braun, 2015). Recent analyses with country-specific cutoffs for child height suggest that adjusting by country can indeed improve predictions of one outcome—infant mortality (Hackman & Hruschka, 2020). However, future studies should further assess how well this approach also improves predictions of other health outcomes of interest.

Finally, and most importantly, anthropology and medicine have a long history of incorrectly and unethically interpreting observed population differences in terms of superiority, inferiority, and deficiency (Braun, 2015; Gould, 1996). For this reason, the population differences used for adjustments should not be interpreted in terms of ranked hierarchy or deficiency, but rather as reflections of natural variation between human populations (Gould, 1996).

7 | CONCLUSION

Global health practitioners have long relied on height and weight as easy-to-use measures of modifiable risk factors, because they are sensitive to environmental inputs and also reflect risks for disease and mortality. Traditionally, practitioners have used one-size-fits-all cutoffs based on the assumption that all humans in similar circumstances should grow roughly the same. Emerging evidence suggests that this basic assumption is incorrect, and that one-size-fits-all cutoffs often miss at-risk populations when these cutoffs are uncritically applied. In the case of child height as a proxy for stunting, children who grow tall even in deprived situations may look healthy through a one-size-fits-all lens. In turn, populations with many tall, but unhealthy, children may look like they are at lower risk for disease and mortality, even when they are not. Given the importance of such numbers for establishing global health priorities and for evaluating the success of country's efforts, one-size-fits-all approaches have the potential too neglect or disadvantage these populations. Here, we point out populations in West Africa and Haiti as especially prone to underestimates of stunting based on height. However, more study is needed to determine which other populations are also susceptible to such underestimation. More generally, we outline potential ways to refine cutoffs that permit meaningful comparison across different populations. Only further research in diverse settings that examines the relationship between height, environmental inputs, and health will tell us when and under what circumstances such refinements are needed.

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