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What does stunting tell us?

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Abstract

Stunting is commonly linked with undernutrition. Yet, already after World War I, German pediatricians questioned this link and stated that no association exists between nutrition and height. Recent analyses within different populations of Low- and middle-income countries with high rates of stunted children failed to support the assumption that stunted children have a low BMI and skinfold sickness as signs of severe caloric deficiency. So, stunting is not a synonym of malnutrition. Parental education level has a positive influence on body height in stunted populations, e.g., in India and in Indonesia. Socially disadvantaged children tend to be shorter and lighter than children from affluent families.
Humans are social mammals; they regulate growth similar to other social mammals. Also in humans, body height is strongly associated with the position within the social hierarchy, reflecting the personal and group-specific social, economic, political, and emotional environment. These non-nutritional impact factors on growth are summarized by the concept of SEPE (Social-Economic-Political-Emotional) factors. SEPE reflects on prestige, dominance-subordination, social identity, and ego motivation of individuals and social groups.

Take-home message for students Stunting is not a synonym of under- or malnutrition. The regulation of body height is closely related to social, economic, political, and emotional factors. Being shorter than average may, thus, reflect shortcomings in any of these factors and/or poor parental education. Stunting in the modern sense has been the natural condition of human height for more than 10.000 years.

Stunting – the common knowledge

WHO-UNICEF reports that globally 144 million children (21.3%) under 5 years were stunted in 2019 (WHO 2021).

Stunting is defined as low height-for-age. "Stunting" means "short" – nothing else. It is considered the result of chronic or recurrent undernutrition, usually associated with poverty, poor maternal health and nutrition, frequent illness, and/or inappropriate feeding and care in early life (WHO 2022).

The term stunting is commonly linked with undernutrition. More than 23.700 publications are listed in pubmed under the keywords "stunting+malnutrition+undernutrition", documenting the common interpretation of stunting as being associated with nutrition. Meanwhile the terms "stunting", "malnutrition", and "undernutrition" are used as synonyms in the epidemiological, medical, and scientific literature. Prendergast and Humphrey (2014) have summarized: "Linear growth failure is the most common form of undernutrition globally".

Lartey states that "there is convergence among the nutrition community on the use of length-for-age as the indicator of choice in monitoring the long-term impact of chronic nutritional deficiency" (Lartey 2015).

But is this true?

The current definition of stunting is an inappropriate mixture of (1) a statistical statement and (2) an incomplete list of explanations. Many factors cause shortness of body height, but short body height is not proof of these factors. The current definition of stunting needs disentanglement, and as long as the list of explanations is considered part of this definition, it is essential to include the full spectrum of influencing factors. These are influences from social, economic, political, and emotional (SEPE) sources.

Nutrition is a prerequisite of growth. Lack of nutrition inhibits growth. There is ample evidence also in historic studies that this is the case. Keys et al. (Keys et al. 1950) explicitly state that "there can be no doubt from the evidence in the literature that the growth of children can be and is influenced by a restriction in the food intake". However, reversing the line of argument by connecting short stature with shortage of food lacks substantiation (Hermanussen and Wit 2017).

Macro- and micronutrient deficits lead to a growth retardation. This is usually a retardation in tempo (Hermanussen and Scheffler 2022). Growth retardations are usually followed by catch-up growth when the deficits have been compensated for. In cases of long-lasting deficits children my remain stunted. When stunding was caused by nutrition deficits nutritional intervention always have a remarkable impact on growth. This however is not the case in most stunted populations. Goudet et al. (2017) reviewed in a Cochrane study 15 intervention studies of macro- and micronutrients mainly located in Bangladesh, India, and Peru and found no evidence of an effect or unclear effect of nutrient supplementation in children. Other studies show marginal positive effects on height. Several authors found no effect of supplementary feeding on height, height-for-age or height-for-weight values in low- and middle-income countries (LMIC), e.g., Indonesia or Guatemala, in the various intervention programs (Goudet et al. 2017; Griffen 2016; Kristjansson et al. 2015; Sguassero et al. 2012; Uauy et al. 2011).

But why are so many children stunted, especially in the low- and middle-income countries?

What do we know from history?

Starvation and undernutrition have always been present in human prehistory and history and have frequently been reported (Rosenstock et al. 2019; Dikanski 1914; Wilke et al. 2021; Scheffler and Hermanussen 2022). Precise documents of growth and development of European children living under various condition are available since the 19th century, though most of these publications have little or no readership due to poor accessibility and language barriers (Hermanussen et al. 2018).

Severe maternal starvation is associated with smaller size already at birth. Multiple historic birth weight data support this association, including data from the siege of Leningrad (Antonov 1947) and the Dutch famine of 1944/45 (Dutch hunger winter near the end of World War II) (Rooij et al. 2010).

Nutrition has only a distinct impact on growth during pregnancy and early childhood under severe starvation. This is different under mild caloric restriction. Humans have evolved to react with phenotypic plasticity – not only but also in growth – to a broad frame of environmental conditions, including variation in nutrition. Nutrition has always been a limiting factor, and growth patterns of children are adapted to react. If a mother is suffering from mild starvation during pregnancy, the fetus and later a breastfed child will still get enough food to grow. Compensation mechanisms exist. In the case of mild malnutrition, intrauterine countermeasures are taken and the affected fetus even grows better – this was stated by Antonov (1947), and a similar statement had already been made by Gassner (1862). Mildly undernourished mothers tend to increase their investment of energy in the actual offspring as a biological answer of the life history tradeoff between actual and future offspring. If the mother had stored her energetic reserves for future offspring, the current offspring would have been left with a lower chance of survival.

This is different in children older than 2 years and in adolescents. Already at the end of the 19th century and in view of the catastrophic nutritional situation of the German civilian population suffering from mass starvation particularly in the winter 1916/17 near the end of World War I and shortly thereafter, German pediatricians had observed that even severely undernourished children and adolescents completely caught up in height growth, and explicitly stated that "the longitudinal growth of the child is largely independent of the extent and type of nutrition..." (Schlesinger 1919). The same was observed in persons exposed to the "Dutch famine" during the winter of 1944/45. Adult women exposed to famine as children before the age of one year reached 4.45 cm less adult height, and 4.08 cm less adult height when exposed before the age of 2 years. Adult males exposed to famine before age one are 3.16 cm shorter, and when exposed before age 2 are 4.09 cm shorter than when exposed at an older age (Portrait et al. 2017).

It appears that the first 1000 days of life are critical for optimal growth and development. This period is sensitive due to the rapid development, increased energy needs, and the changing nutrient requirement (Beluska-Turkan et al. 2019). Starvation in early childhood restricts growth and leads to shorter body height. Yet, even when considering the 4 cm loss in adult height of the Dutch exposed to the famine in 1944/45, these people are not stunted.

At present, the average final height is 184.0 cm for young men and 170.6 cm for young women (Fredriks et al. 2000). At this point, it may be useful to mention that the minute effects of undernutrition on height clearly contrast the well-known detrimental effects of prenatal and early infant undernutrition on the future regulation of body weight and metabolism.

Based on very similar observations in German schoolchildren, Koch (1935) explicitly wrote that "food would have been quite a handsome explanation for the increase in linear growth. But linear growth has been demonstrated to be almost independent of this factor … Size recklessly increases even during marked undernutrition … until the body has wasted its last depot. One might talk about parasitic growth in length".

Several pediatricians explicitly questioned any prominent role of nutrition and instead highlighted the association between economic affluence, social strata, (Adriany and Tesar 2022) and growth. The German pediatrician Meinhard von Pfaundler (1916) stated that „this question [short stature of the socially disadvantaged children] is important when considering the reason for the undersize of the poor. Malnutrition has often been mentioned, but, it does not seem appropriate to me to address malnutrition as the decisive factor in the undersize of the poor." Pfaundler particularly emphasized that these people's body weight is not reduced to the extent that the reduction in body length would suggest but, in fact, less. The differences are not great but quite constant. Other authors of the early 20th century published similar observations (Hermanussen et al. 2018) and later also pointed to the importance of emotional deprivation and its effect on infant and child growth (Scheffler et al. 2021a).

Severe undernutrition impairs growth and goes along with characteristic clinical signs like edema, Bitot's spots, goiter, and typical changes in hair, skin, and general appearance (Behrman et al. 1999). Undernourished children are not only short for age but also delayed in developmental tempo (Hermanussen and Scheffler 2022). A seminal Mexican study published by Gomez et al. (1955) reported on 584 severely malnourished children submitted to the Hospital Infantil, Mexico City, in the early 1950s. 90% of them were aged between 6 months and 5 years. Weight was "from 40 to 60 per cent of the average normal theoretic weight in 509 children, and under 40 per cent in 75 children". In these children, the authors found that "the difference in height from the normal theoretic height increases with the age of the child; at 5 years, the difference was 15.8 per cent". This study marked the starting point of the modern debate on stunting.

Drawing on these observations, Waterlow (1972) introduced a medical classification of malnutrition based on height-for-age that served as the basis for the modern understanding of the causes of short stature. He presented it by the example of "two hypothetical children", rather than empirical data. The term "stunting" has become a synonym for malnutrition in scientific literature since an international Nestlé workshop in 1988 (Waterlow 1988).

The political consequences of this interpretation are severe: populations with significant numbers of stunted children are pressured into implementing nutritional interventions even though the effect of such interventions has been shown to be only marginally relevant for body height and, on the contrary, boost the prevalence of child obesity (Goudet et al. 2017).

Stunting is not a synonym of malnutrition

Starvation is a severe deficiency in caloric energy intake, below the level needed to maintain an organism's life (UIA 2022). Starvation leads to decrease in body mass, respectively BMI, skinfold thickness, and mid upper-arm circumference (MUAC). Therefore, these parameters have been used as indicators for caloric undernutrition in recent populations. Based on the prevalent perception that stunting is linked with starvation, we might hypothesize that in stunted populations strong positive associations exist between body height and caloric intake, respectively with related parameters like BMI, skinfold thickness, or MUAC.

However, this is not the case. Mumm and Scheffler (2019) re-analyzed data of the Young Life Study originally performed to investigate associations between poverty and stunting in Ethiopia, Vietnam, Peru, and India. Scheffler et al. (2018) also analyzed data from India as well as from Indonesian schoolchildren (Scheffler et al. 2020; Scheffler et al. 2021a) and in all cases failed to show any relevant association between body height and anthropometric parameters related to caloric intake.

Whereas anthropometric data are often freely available, information about the individual nutritional intake are rare. Even in careful studies such as the longitudinal study "Young Lives – Measuring Child Poverty and Health" (Boyden 2022; Jones 2018; Woldehanna et al. 2018; Mumm and Scheffler 2019), the information on food consumption, e.g., pasta/rice, meat, fish, milk, vegetables/fruit, cheese, sweets, etc., is limited to information per household. Re-analyzing household food consumption failed to show any clear pattern of food groups related to height, neither within the same country nor between countries (Mumm and Scheffler 2019). There was no relevant association between the amounts of nutritional intake of protein, fats, carbohydrates, vegetables and fruit, sweets, or processed food, and body height and weight in stunted populations. Figure 1 illustrates the lack of association between body height and various nutritional components.

We also re-analyzed anthropometric measurements of the Kolkata Growth Study, India. This study took place in 1982–1983, with data on 825 Bengali boys aged 7 to 16 years (KG1). A second Kolkata Growth Study (KG2) was performed between 1999 and 2011, with data of 1999 boys aged 7 to 21 years from Bengali Hindu families, and between 2005 and 2011, with data of 2195 girls (Scheffler et al. 2018).

The number of stunted children slightly decreased between KG1 and KG2. Mean values standard deviation scores of body height (hSDS) of boys increased from -0.71 hSDS in 1982 to -0.49 hSDS in 2011, and as the BMI also increased from -1.4 SDS to -0.29 SDS, these data were originally interpreted as evidence of improved nutritional conditions. Yet, this impression, though in line with accepted knowledge, is false.

Figure 2 illustrates the association between body height and skinfold thickness in a subpopulation of boys of the 2011 Kolkata Growth study (KG2). Evidently, height is not associated with skinfold thickness. The same was true for measurements obtained in KG1.

Similar results were obtained in a 2018 study in Indonesia performed on three Islands (Bali, West-Timor, Sumatra) in rural and urban areas (Scheffler et al. 2020). Indonesian children lack relevant associations between skinfold thickness ($\bar{x}$SF-mean of subscapular and triceps skinfold) and body height (hSDS). Rural boys of Soe (West-Timor) were shortest (hSDS = -2.08), and thinnest (BMI_SDS = -1.41), closely followed by the girls (hSDS = -

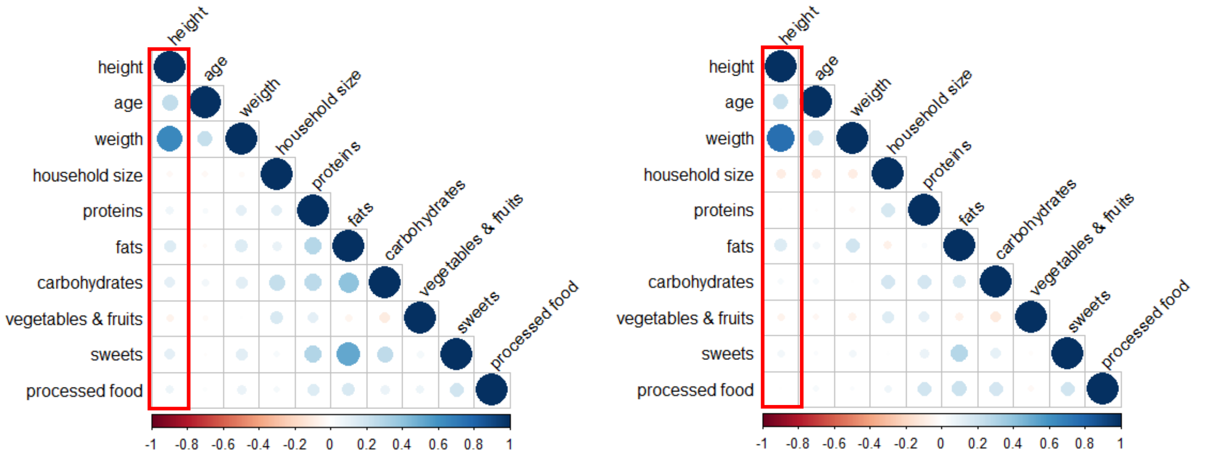

Figure 1 Association of height and different nutritional components of 5-year-old (left) and 12-year-old (right) Ethiopian children (n = 2000) measured longitudinal between 2006–2012. Strength of colors indicates the strength of the association (blue: positive, red: negative).

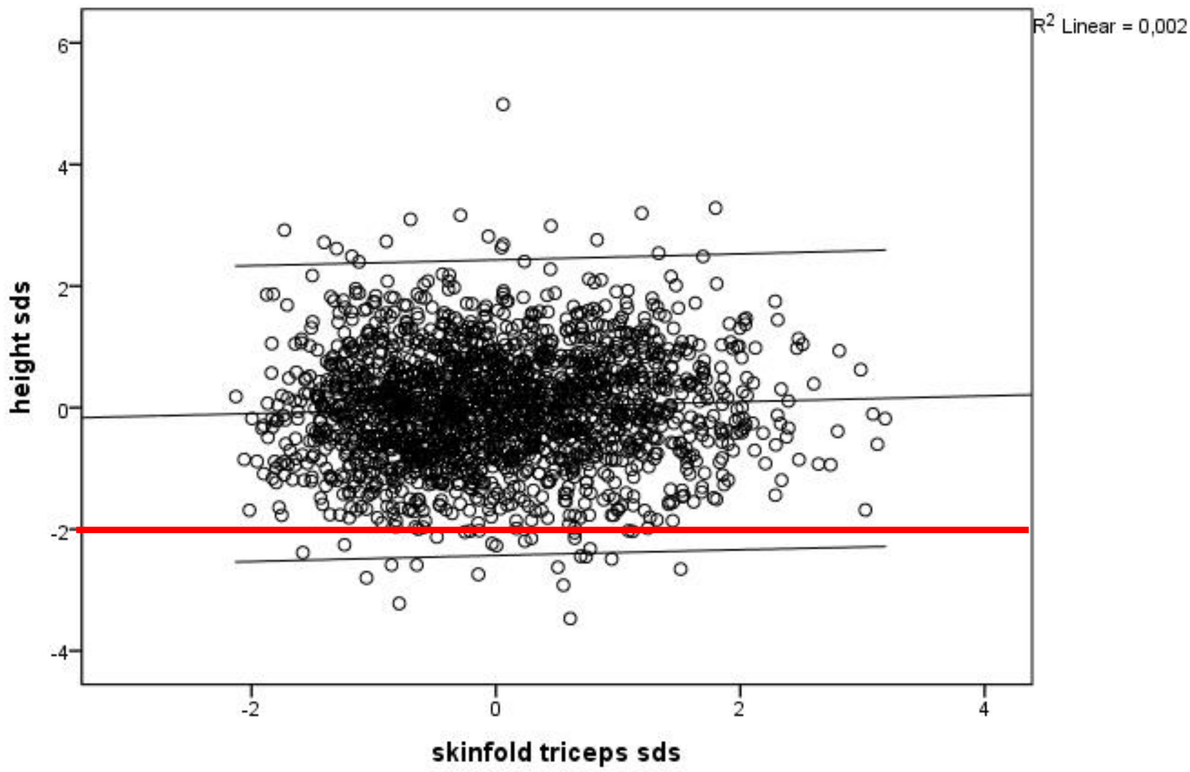

Figure 2 Association of skinfold thickness on triceps (SDS, Indian reference) and height (SDS, reference WHO) of 1,900 Indian boys 2011 (Multiple Regression, CI (99%): -0.011/0.106, p > 0.001). Measurements below the red line indicate stunting.

1.90; BMI_SDS = -1.25). A total 53% of the boys in Soe and 46% of the girls in Soe were stunted. Mean skinfold thickness ($\bar{x}$SF: boys 5.50 mm, girls 6.72 mm) was significantly less than in the urban children of Kupang, the capital of West-Timor ($\bar{x}$SF: boys 7.65 mm, girls 8.75 mm). Even though the very thin children of Kupang were slightly shorter, they were still significantly taller than the children of Soe. The correlation between $\bar{x}$SF and hSDS ranged

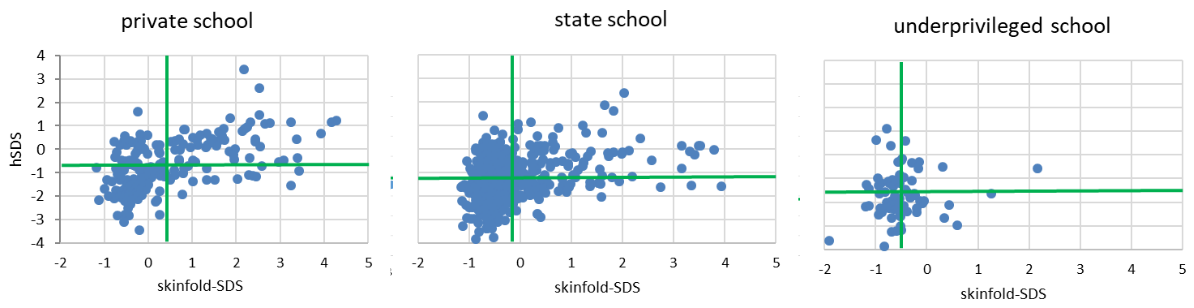

Figure 3 Height (hSDS, reference WHO) and mean skinfold thickness [(subscapular + triceps)/2; skinfold-SDS, reference these data set] of 723 children from urban Kupang/West-Timor, Indonesia. 196 children from a Catholic private school, 452 children from public state schools, and 75 children from an underprivileged school of the suburban region. Green horizontal lines indicate mean hSDS, green vertical lines indicate mean skinfold-SDS of each school.

from r = 0.12 to r = 0.38, explaining a maximum of 14.4% of the hSDS variance.

Even though the prevalence of stunting was up to 53% in the Indonesian population and thus much higher than in the Kolkata study, the association between body height and nutrition-related anthropometric measurements was negligible. This was also the case for BMI and MUAC.

A second study in Kupang in 2020 highlighted the impact of the social strata on body height and skinfold thickness (Scheffler et al. 2021a). Figure 3 shows that affluent children from a Catholic private school were significantly taller than disadvantaged children from the underprivileged school, and they had higher subcutaneous fat layers. The prevalence of stunting in boys was 8.5%, 26.4%, and 46.8% (private school, state schools, and underprivileged school). The prevalence of stunting in girls was 10.4%, 20.3%, and 25.5%, respectively. At first glance, these data appear to confirm the current perception that higher BMI, higher skinfold thickness, and larger MUAC yield better growth. Yet, figure 3 highlights that the association between body height and skinfold thickness becomes negligible when studied within each group of children separately. Stunted children are found in all social strata, regardless of skinfold thickness.

The lack of association between body length, weight, and body mass index is well known. Figure 4 was obtained from (Prentice et al. 2013) and shows early infant patterns of weight for age, weight for length, and length for age in 54 studies from LMIC. Whereas infants significantly drop in length-for-age up to age 2 years, they remain appropriate in weight-for-length.

Recently published data from India (Subramanian et al. 2020) support that anthropometric failure is not strongly associated with measures of 31 nutritional indicators. The stunting rate of different regions in India does not coincide with the inadequate diet (Fig. 5). Districts with high prevalence of stunting, e.g., West Bengal and the Western provinces of India, do not always show highest prevalence of inadequate diet.

In summary, there is strong evidence that stunting and malnutrition are different entities. Stunting is often associated with but not specific for poverty, poor health, and malnutrition. Malnutrition can lead to stunting, but the reverse equation is not true: Stunting is not a synonym of malnutrition.

But why are the children in the LMIC (Black et al. 2013) so frequently stunted?

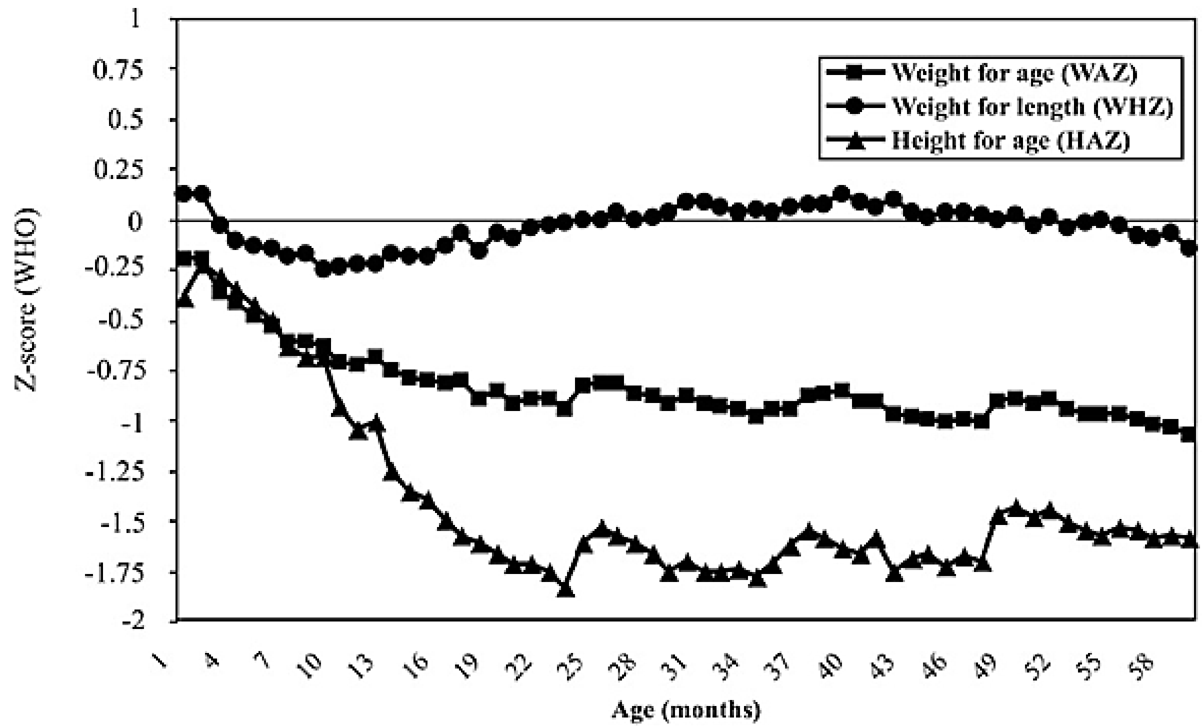

Figure 4 Mean anthropometric z-scores (hSDS-HAZ, wSDS-WAZ, height-for-length SDS-WHZ) for 54 studies from low- and middle-income countries relative to the WHO standard (Prentice et al. 2013) (reprinted with kind permission of Oxford University Press, November 30th 2020)

Stunting is a synonym of social disadvantage and poor parental education

Humans are social, they have a species-specific basic pattern of growth (Bogin et al. 2018b; Bogin 1999; Bogin 2020) as an outcome of the four- to seven-million-year evolutionary history of the hominins. The bio-cultural nature of our species includes a prolonged childhood and allows for intense learning and adapting social behavior from adults. Children and adolescents are capable of recognizing their own social position among their peers and within society. Social, political, and emotional interactions are not limited to structuring living conditions and the psychosocial environment but also have an important influence on physical growth, development, and cognitive maturation. Panter-Brick (1998), Bogin (Bogin 1999; Bogin 2020; Bogin 2021), and numerous other authors addressed that psychosocial well-being and stress are dimensions of an individual's health with physiological responses in behavior and also in endocrine regulation. Stress hormone levels are negatively associated with social strata (Ursache et al. 2015; Zilioli et al. 2017).

Body height (next to age at menarche) has traditionally been considered a measure of the quality of living conditions (Tanner 1987). It has become common practice in economic history, demography, public health, and political policy inquiry to take body height as an appropriate measure of living conditions. Shorter height is associated with less education (Fig. 6, lower social status, and income (Bogin 1999; Bogin et al. 2002; Hermanussen and Scheffler 2016; NCD Risk Factor Collaboration 2016). These associations suggest positive feedback between greater height and better living conditions. Nevertheless, what is the

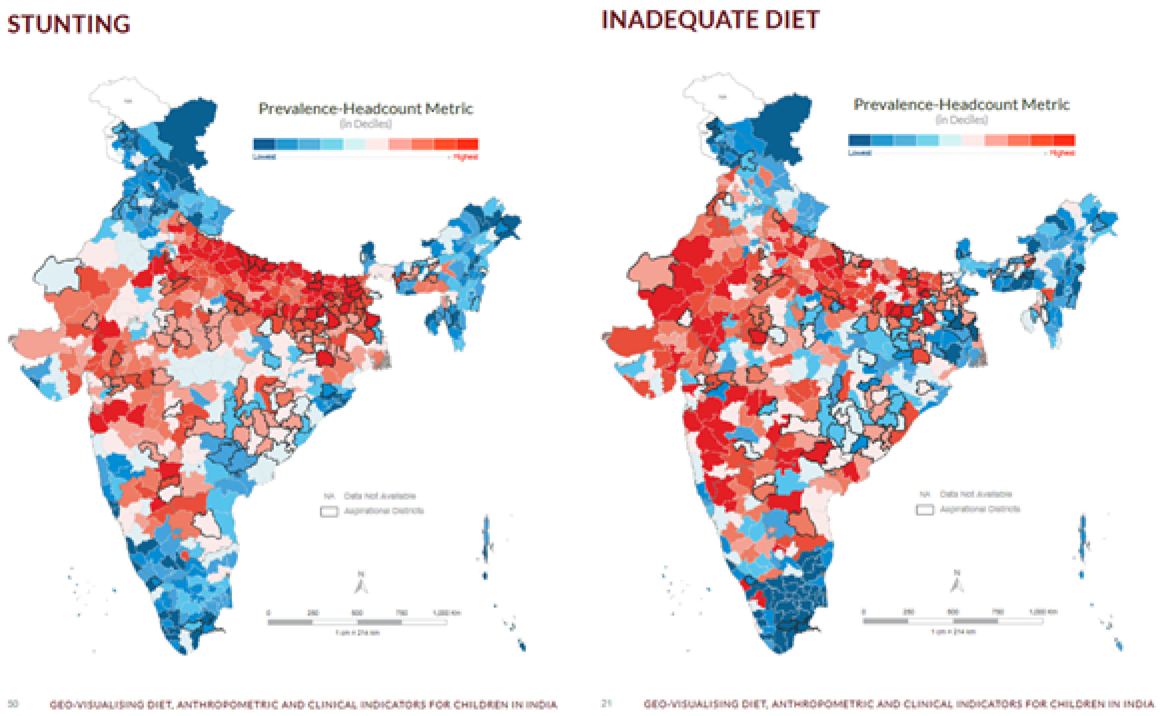

Figure 5 Prevalence of stunted children and inadequate diet in the different districts of India. Prevalence-headcount-metric included prevalence and absolute headcount number. (Subramanian et al. 2020) (General permission: CCO 1.0 Universal (CCO 1.0) Public Domain Dedication)

implication of better living conditions on body height?

In many social species, size is associated with social position within the group and mating success. This has, for example, been shown for baboons, deer, and meerkats (Bercovitch and Clarke 1995; Cowlishaw and Dunbar 1991; Huchard et al. 2016; Waal 1986). Stature itself is a lifelong social signal. Social interactions and group behavior are modulated by body height and, in turn, are able to modulate body height, allowing competitive growth and strategic growth adjustments similar to what has been shown in meerkats (Huchard et al. 2016). There is a common perception that large body size and tall stature result in social dominance (Cinnirella and Winter 2009; Hermanussen and Scheffler 2016). This also applies to humans. Humans are able to perceive physical size as a signal of social dominance. Huang et al. (2002) have described the greater influence of humans perceived as taller in a negotiation task. Taller men are perceived as more competent and authoritative (Cinnirella and Winter 2009; Judge and Cable 2004). Also, children are able to recognize cues that predict dominance (Lourenco et al. 2015). They recognize the physical size of individual members of a group and numerical alliances as signals of social hierarchies. Groups of children from socially dominant backgrounds are educated both formally and by social experience to anticipate future dominance (Clark and Cummins 2014) while others anticipate subordination (Hermanussen and Scheffler 2016).

Education is important. The educational level of parents has a positive influence on body height. The above-discussed an-

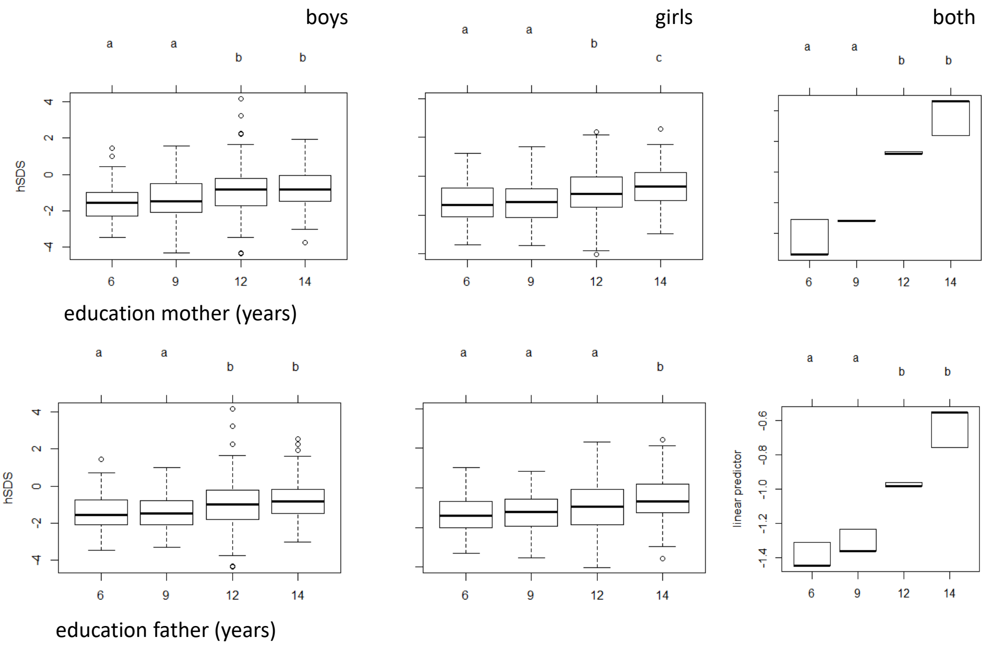

Figure 6 Body height (hSDS) of 6–13-year-old children of Indonesia depending on mothers' and fathers' education (years of education) and the linear prediction (ANOVA; mother F = 32.69, p < 0.000, father F = 24.06, p < 0.000; a, b, c indicate significant differences between adjoining groups)

thropometric studies of stunted children in India and Indonesia also provided information on social background and on parental education. Figure 6 shows that parental education (number of years spent in school and university) was positively associated with body height of the children from a study, which was conducted in different regions in Indonesia (Bali, West-Timor and Sumatra) in 2018 and included more than 1,700 primary school children aged between 6 and 13 years (Scheffler et al. 2020).

Body height differs according to school type (Figure 3). On average, wealthy parents of private school children spent 12.35 years in school, whereas parents of state and underprivileged school children only spent 11.15 and 8.7 years respectively. The influence of parental education on growth and educational performance (school grades) was strongest in the girls of the underprivileged school, weaker in state schoolchildren of both sexes, and weakest in the private school boys. This strongly underlines the significance of parental education, particularly in the girls of the poorest socio-economic strata. The findings are in line with evidence that maternal and paternal education were independently associated with 0.37 (95% CI 0.33 to 0.41) and 0.20 (95% CI 0.16 to 0.24) higher hSDS, and 0.31 (95% CI 0.29 to 0.34) and 0.16 (95% CI 0.14 to 0.18) higher Early Childhood Development Index z-scores, respectively (comparing secondary or higher to no education), as summarized by Jeong et al. (2018). The factor household prosperity, even though associated with parental education (Vaivada et al. 2020), appeared to have no direct impact on height in either school type. In 2020, in the study of Kupang, additional information on water supply as well as television and refrigerator access was condensed to a "household score". The household score of children attending the private school is significantly better than of those attending the underprivileged school ($p < 0.000$). Additionally, poor children are physically fitter. They showed the best results in standing jump.Their high skeletal robusticity (high Frame index: elbow breath/height) (Scheffler and Hermanussen 2021) suggested persistent high levels of daily ph ysical activity (Rietsch et al. 2013).

The shortness of the children of the underprivileged school was neither associated with clinical signs of malnutrition nor with thinness nor with delay in physical development, indicating that the shortness in height of underprivileged children is not associated with poor nutrition (Scheffler et al. 2021a). We only found significant though small associations between body height and indicators of the state of nutrition, such as BMI, MUAC, and skinfold thickness, in the wealthy children. It seems that it is not the poor nutrition that inhibits growth but the abundant nutrition that leads to accelerated developmental tempo (Hermanussen and Scheffler 2022) and, in consequence, to taller-than-average body height.

Bogin (Bogin 2020; Bogin 2021) summarized non-nutritional impact on growth in the Social-Economic-Political-Emotional (SEPE) factors. SEPE factors refer toprestige, dominance-subordination, social identity, and ego motivation of individuals and groups in a society. The underprivileged children are socially, economically, politically, and emotionally disadvantaged (Adriany and Tesar 2022). This is in line with their lower educational possibilities. A test of self-confidence was also a part of the above-mentioned study in Indonesia in 2020. We set out to test the self-confidence as well as the subjective feeling of inferiority of father's social position as an emotional influence on growth with the MacArthur Scale of Subjective Social Status (SSS) but failed, as our Western cultural concepts appear inappropriate when testing schoolchildren in West Timor, Indonesia (Boeker et al. 2021).

The perception of one's own social, economic, and emotional position depends on one's cultural and time-specific role within society. The influence of self-perception and of social status becomes particularly evident when people leave one and integrate into another social network. Migrants are challenged by their new host society and its specific social roles. Besides the cultural (acquisition of knowledge and skills), the structural (degree of education, employment), and the social dimension (social relationships) emotional aspects become increasingly important for their integration (Esser 2006). The emotional dimension includes emotional integration and identification in line with a personal sense of belonging to society. This is a challenge for migrant children and they react with phenotypic plasticity in growth and maturation. Migrant children and adolescents of lower social status rapidly adjust in height towards the average height of their hosts (Scheffler et al. 2021b). They also tend to mature earlier and are prone to overweight (Bogin et al. 2018a). Observations on intergenerational upward and downward social mobility reflect the strong association between social position and body height: Upward social mobility results in taller stature, whereas children from "upper class" families who lose their social advantage tend to end up shorter (Koziel et al. 2019). Recent evidence links social competition and its effect on hierarchies in social structures with the neuronal networks of the ventromedial hypothalamus and body size; the link between size and status permits adaptive plasticity, competitive growth, and strategic growth adjustments also in humans (Hermanussen et al. 2022).

Conclusion

Stunting is not a synonym of under- or malnutrition. Stunting in the modern sense has been the natural condition of human height for more than 10.000 years. Already historic observations on children of starving populations in Europe emphasized the lack of association between starvation and long-term growth. Modern studies in low-and-middle-income countries similarly fail to provide evidence of an association between stunting and malnutrition. Being shorter than average reflects poor social, economic, political, and emotional circumstances and reflects social disadvantage and poor parental education. Parental education has a positive effect on the body height of children. The concept of SEPE is a modern concept explaining the regulation of body height.

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