Abstract

Objectives: Human body height differs within a wide range and has conventionally been associated with genetic, nutritional, and environmental conditions. In this study, we try to broaden this perspective and add the evolutionary aspect of height differences.

Sample and Method: We revisited height from archeological data (10 000–1000 BC), and historical growth studies (1877–1913). We analyzed height, weight, and skinfold thickness of 1666 Indonesian schoolchildren from six representative rural and urban elementary schools in Bali and West Timor with a stunting prevalence of up to 50%.

Results: Stature in the Holocene prehistory of the Near East and Europe varied with maxima for women usually ranging below 160 cm, and maxima for men between 165 and 170 cm. Stature never rose above 170 cm. European and white US-American schoolchildren of the 19th and 20th century were generally short with average height ranging between −1.5 and −2.2 hSDS, yet in the absence of any evidence of chronic or recurrent undernutrition or frequent illness, poverty, or disadvantageous living conditions. The same is found in contemporary Indonesian schoolchildren.

Conclusion: Stunting is frequently observed not only in the poor, but also in affluent and well-nourished social strata last 10 000 years. Only in very recent history, and only in a few democratic, modern societies, stature has increased beyond the long-lasting historic height average. Viewed from an evolutionary perspective, and considering adaptive plasticity of and community effects on growth, competitive growth and strategic growth adjustments, stunting appears to be the natural condition of human height.

1 | INTRODUCTION

Modern Europeans are characterized by an average body height that is significantly taller than the body height of most human populations had ever been. Conventionally this is considered to result from optimum nutrition, associated with affluent socioeconomic conditions, good maternal health and nutrition, absence of illness, and appropriate infant and young child feeding and care in early life that allows children to reaching their full physical and cognitive potential.

This fundamental vision has fueled hundreds of studies presenting “normal values” for child and adolescent growth. In 2006, the World Health Organization (WHO) launched their new Child Growth Standards and claimed that these growth charts “are standards; they are based...
on affluent contemporary children of the United States, Norway, and four (India, Brazil, Ghana, and Oman) low- and middle-income countries (LMIC) (WHO Multicentre Growth Reference Study Group, 2006), and identify how children “should grow when provided optimal conditions” (Centers for Disease Control and Prevention [CDC], 2010). Today, over 140 countries have adopted these standards (Zorlu, 2011). Yet, child growth varies. Even today, average adult human stature may differ by up to 30 cm between populations of different geographical regions (NCD Risk Factor Collaboration [NCD-RisC], 2016; Perkins et al., 2016), and has differed by up to 20 cm in the last 100 years. As being short is not restricted to the poor people in the poor countries, but also applies for the wealthy strata of these countries, and being tall is not restricted to the wealthy people of the wealthy countries, but also applies for the less affluent people of these countries (Bommer et al., 2019; Da Silva et al., 2018; Wong et al., 2017), many researchers seriously question that so-called global standards are globally applicable (Thompson, 2021). In countries with tall populations, global standards lead to misclassification and misdiagnosis of clinically relevant causes of short stature (Christesen et al., 2016; Saari et al., 2013) whereas underweight and stunting are likely to be over-diagnosed in short, but apparently healthy children in the LMIC such as Indonesia (Beal et al., 2018) and India (Khadilkar & Khadilkar, 2011).

Thus, what is normal? The meaning of the term “normal” is poorly defined. (1) Being normal is an emotional statement—nobody wants to be abnormal. Human social behavior is influenced by social identity and the sense of belonging to the own social group (Tajfel & Turner, 1986). The own social group is usually considered normal by members of that group. Characteristic features of that group are frequently shared by their members. Thompson (2021) wrote that “What we define as “normal” is a historical and statistical artifact shaped by the referent group chosen and the social, political, and economic context of the included samples.” (2) Being normal is a statistical statement—growth references describe frequency distributions of anthropometric variables in reference populations. (3) Being normal may be a medical statement associated with physical fitness, absence of illness, well-being, life expectancy, or any other parameter related to health. Events that are statistically not frequently observed do not automatically imply a state of unhealthiness or a health risk (Hermanussen, 2013). Graves nicely discussed the significant confusion associated with modern Eurocentric notions of the normal that still persist in both the lay public and various professions such as biomedical research and clinical practice (Graves, 2021).

There is no trivial definition of “normal growth.” We decided to approach this question from an evolutionary perspective. We revisited data on human growth of the last 10 000 years (Rosenstock et al., 2019) including information on growth in the leading social strata, data on growth in the wealthier social classes of contemporary LMIC (Bommer et al., 2019; Da Silva et al., 2018; Wong et al., 2017), and add a reanalysis of growth data obtained in recent studies in clinically healthy Indonesian school children with a stunting prevalence of up to 50% (Scheffler et al., 2019; Scheffler et al., 2021). We consider a “natural state of human height” as that state that is most frequently observed during recent evolution, and an exceptional capability for phenotypic plasticity in body height that is characteristic for the human species.

Phenotypic plasticity is defined as the ability of the organism to react to internal and external environmental conditions, and allows for adjusting to changing natural and social environments (Pigliucci, 2001; West-Eberhard, 2003). Phenotypic plasticity is considered as (Little, 2018) an “adaptation along with reproduction, growth, organization, mobility, and energy capture ... fundamental properties of life.” In 2012, Kuzawa and Bragg (Kuzawa & Bragg, 2012) discussed the notable variation across contemporary human populations in life-history traits such as growth rate, body size, reproductive scheduling, and even life span. Studying the life history of contemporary humans has shown that much of this variation can be explained as the outcome of phenotypic or developmental plasticity triggered in response to social, nutritional, demographic, and other environmental conditions.

The contemporary literature on the variation in human height largely ignores this aspect and almost unfailingly attributes the currently existing worldwide differences in body height to differences in diet, economy, water, sanitation, and hygiene (WASH), and health, with diet being claimed the prime factor in union.

These claims lead to skyscraping estimates of the prevalence of undernutrition mainly in the LMIC. According to WHO 148.9 million (21.9%) children under 5 years are affected by food insecurity and undernutrition (WHO, 2019). This view is commonly shared by most governments of wealthy countries and non-governmental charity organizations (NGOs) and has fueled innumerable health interventions to improve diet, economy, WASH, and the overall health situation of children in LMIC. These interventions certainly improve the general living conditions of these children, but most of them are disappointing in respect to growth, with positive effect on body height that are at best marginal (Goudet et al., 2017). We do not question that growth inhibition accompanies undernutrition (Keys et al., 1950). We focus
on the question to what extent being shorter than a modern growth reference, is still being within the frame of the “normal” human phenotypic plasticity, and thus a natural condition of human height, or only a matter of pathology due to chronic or recurrent undernutrition, poor socioeconomic conditions, poor maternal health and nutrition, frequent illness, and/or inappropriate infant and young child feeding and care in early life.

Rather than asking, why are people in LMIC quite regardless of wealth and social status, shorter than modern global growth reverences, we discuss the role of phenotypic and developmental plasticity as a primary means of adjustment to environmental changes. We ask, what may have caused the modern industrialized democratic European population to so extraordinarily exceed the millennia-old historical frame of human body size. Given the widespread assertion that diet is the main cause of short stature, we focused particularly on the clinical signs of food shortage and micronutrient deficiency.

Undernutrition is characterized by a number of clinical features (Behrman, 1999), by anthropometric signs such as low values of body mass index (BMI), skinfold thickness, and mid-upper arm circumference, and by poor cognitive development and school performance (Dewey & Begum, 2011; Gardner & Halweil, 2000).

In view of the conventional modern understanding of the pathophysiology of stunting, we formulate the first hypothesis:

1. Stunting is frequent in historic populations. Stunting in history is prevalent irrespective of social status, economic wealth, and living conditions, and is usually not accompanied by clinical signs of protein-energy undernutrition or signs of micronutrient deficiency.

In view of the rapidity at which the modern industrialized democratic European population had changed in body size in the very recent history we formulate the second hypothesis:

2. The prevalence of stunting in non-starving and economically non-deprived LMIC populations depends on the connectedness with and the absorption of the Western lifestyle, and reflects the degree of social transition.

2 | SAMPLE AND METHODS

Data bases, participants and design

1. We revisited archeological material published by Rosenstock and coworkers (Rosenstock et al., 2019). We analyzed nine historic female growth studies performed between 1880 and 1904 from Germany (Jaeger, personal communication 1997; Freudenberg, 1924; Karstädt, 1888; Kotelmann, 1879; Pirquet, 1913), Austria (Igl, 1906), Switzerland (Combe, 1886), Sweden (Broman et al., 1942), United Kingdom (Aitken et al., 1957), and United States (Bowditch, 1891), Roberts (Anon, 1877), and 17 historic male growth studies performed between 1877 and 1913 from Germany (Jaeger, personal communication 1997; Freudenberg, 1924; Karstädt, 1888; Kotelmann, 1879; Pirquet, 1913), Austria (Igl, 1906), Switzerland (Combe, 1886), The Netherlands (Van Wieringen, 1972), Lithuania (Makower, 1914), Sweden (Broman et al., 1942), United Kingdom (Aitken et al., 1957), and United States (Bowditch, 1891). One of the female and nine of the male studies were based on schoolchildren explicitly mentioning “upper social classes.” We considered these studies are representative for affluent, non-starving, and economically non-deprived historic populations.

2. We reanalyzed own data from stunted Indonesian schoolchildren. In 2013, the prevalence of child stunting in Indonesia was 37.2% (BADAN PENELITIAN DAN PENGEMBANGAN KESEHATANKEMEN TERIAN KESEHATAN RI, 2013). Indonesia ranks seventh out of 190 countries in the World Bank list of Gross domestic product (GDP) (Wikipedia, 2021) and is not a poor country. Due to the geographic situation of many islands, we have a population with subpopulations of different social experience. (a) The people of the densely populated and economically prosperous “tourist island” Bali with a nominal per capita GDP of US$3791 have contact to Western tourists (Wikipedia, 2020), and they are the tallest Indonesians (Pulungan et al., 2018). (b) The shortest population of Indonesia lives in West Timor (East Nusa Tenggara) (Pulungan et al., 2018), the poorest province of Indonesia with a nominal per capita GDP of US$1288 (Wikipedia, 2020), and almost no contact to Western culture. West Timor has a rather homogeneous population except for refugees from nearby East-Timor, with little migration from other islands in recent history. Most people (300 000 inhabitants) live in the capital Kupang, with different social background. More than 95% of the households the schoolchildren were raised in, possess television, 82% have a refrigerator, 99% receive tap water, either within their own house (33.4%), or from a nearby private source (50%) or a public sanitary facility. A typically rural population with 40 000 inhabitants lives in the village of Soe 110 km apart from Kupang. As reported from our local coworkers, the economic conditions were similar to the urban Kupang conditions,
yet, we did not receive detailed data from the children. We considered both the rural population of Soe and the urban population of Kupang as non-starving and economically non-deprived. The schoolchildren of both locations appeared healthy, most parents had undergone at least 9 years of school education suggesting an appropriate economic potential. Flourishing subsistence culture with poultry, pig farming, and extensive gardening was prevalent in rural Soe.

We obtained data of body height, weight, and skinfold thickness (subscapular, triceps) of 1666 school children aged 5.8–13.9 (mean 9.5) years in two separate studies, 2018 and 2020 (Scheffler et al., 2019; Scheffler et al., 2021). The data were obtained under standardized conditions (Knussmann, 1988).

Altogether, the study populations consisted of 1666 schoolchildren of six elementary state schools: (1) rural Soe (West Timor), (4) urban Kupang (West Timor), and (1) urban Ubud (Bali) with average socioeconomic background (Table 1). As the connectedness with and absorption of the modern Western lifestyle differs from almost no contact in the case of the rural children of Soe, West Timor, some minor contact in the case of the urban children of Kupang, West Timor, and up to major contact with the Western tourist culture in the case of the urban children of Ubud, Bali, we considered the trend in living conditions from rural West Timor to urban Bali an appropriate example to illustrate the increasing degree of social transition in the Indonesian school children.

The recruitment of the children was done by the local pediatricians. They chose representative schools with different social background. We measured complete school cohorts. Parental informed consent was given. Ethical approval was provided by the Medical and Health Research Ethics Committee, Faculty of Medicine. Gadjah Mada University, Dr. Sardjito General Hospital Yogyakarta, Ref. no. KE/FK/0175/EC/2018 and Ref. no: KE/FK 1440/EC/2019. All individual data were anonymized. In 2018, we excluded one child with trisomy 21, one child with hydrocephalus, one child with club feet, and one child with gait disorder. Seven children refused being measured. All measurements were performed in the presence of the children’s teachers, and supervised and accompanied by local physicians, pediatricians, and medical residents.

All children appeared appropriately nourished with no clinical signs of undernutrition and malnutrition (edema, Bitot’s spots, goiter, hair, skin, and general appearance (Behrman, 1999)). The local markets visited at the time of the study, showed rich varieties of fruit, vegetables, meat mainly of poultry, and in the city of Kupang, daily large quantities of fish. The children’s teachers, the local physicians, pediatricians, and the medical residents living in West Timor, negated that in recent years there was any relevant food shortage in this province. Further detailed information about the study procedure is given by Scheffler et al. (2019) and Scheffler et al. (2021).

### 2.1 Statistics

We calculated mean values and standard deviation scores (SDS) for body height, weight, and BMI based on the CDC reference (NCHS, 2021) and standard deviation (SD) for the mean of subscapular and triceps skinfold thickness. We used CDC references because WHO references do not allow for calculating SDS beyond the age of 10 years. For each location, we tested the density distributions of BMI SDS, height SDS (hSDS), weight SDS (wSDS), and mean of skinfold thickness for normality by Shapiro Wilk Test. T-tests were used for evaluating differences.

The statistics were performed with the programming language “R” (R-version 3.6.12019).

### 3 RESULTS

1. Based on 6098 published prehistoric skeletons consisting of long bone lengths from which stature was estimated according to different methods, Rosenstock

| Location | Year | n schools | n boys | n girls | Age (years) | Mean | Range |
|----------|------|-----------|--------|---------|-------------|------|-------|
| Soe      | 2018 | 1         | 107    | 113     | 9.75        | 5.4–13.7 |
| Ubud     | 2018 | 1         | 317    | 274     | 9.77        | 6.3–13.2 |
| Kupang   | 2018 | 2         | 205    | 198     | 9.52        | 5.8–13.9 |
| Kupang   | 2020 | 2         | 222    | 230     | 9.54        | 5.8–13.8 |

Note: For statistical analysis, we later combined the four elementary state schools of urban Kupang visited in 2018 and 2020.
and coworkers (Rosenstock et al., 2019) reported on the tempo-spatial variance of stature in the Holocene prehistory of the Near East and Europe. They showed a robust general northwest-southeast gradient in stature, with tallest stature in Eurasia and declining stature in Iberia. Transition to farming showed stable, decreasing, or increasing stature depending on the region and the mode of Neolithization. Particularly, Northern Europe experienced a rise in stature after the fourth millennium BC. Yet, maxima for women usually ranged below 160 cm, and maxima for men between 165 and 170 cm, and never rose above 170 cm between the years 10,000 and 1000 BC.

Until World War I, European and white US-American School children were short (Boyd, 1980). Most of the studies on child growth above age 6 years show hSDS of more than one SD below contemporary global references, and further declining hSDS to minus two SDs at mid-adolescence.

Figure 1 illustrates that upper-class Boston boys of a Latin school, upper-class Dutch boys from Utrecht, and upper-class girls from Berlin were tallest at the end of the 19th century, but still significantly shorter than the modern global average. Upper-class boys from Breslau, Germany (1888), and Hamburg, Germany (1879) ranged in average height between −1.5 and −2.2 hSDS, that is, depending on age, more than 50% of these boys should be considered stunted. The respective literature does not mention any chronic or recurrent undernutrition or frequent illness in these children, but presents the data as data from wealthy and socially privileged background. Maternal health and nutrition, and infant and young child feeding and care in early life were considered appropriate for that time.

A particularly relevant growth description of upper-class urban boys was provided by Kotelmann (1879). Kotelmann was a school physician from Hamburg, Germany, who routinely studied affluent boys of an elite urban Latin school. He wrote that “the annual increments of the height of boys were not uniform in childhood, as Quetelet had assumed, but increased in magnitude from 2.17 cm in the 9th–10th year of age to a maximum of 7.46 cm in the 15th–16th year of age, or from a relative increment of 1.68% to one of 4.83%.”

These boys were delayed in physical maturation by on average more than 2 years, and roughly one-third of the boys were stunted. Up to the end of the 19th century, upper-class high school (Gymnasium) boys remained some 10 cm shorter than modern boys, the height of elementary school boys was some 15–16 cm shorter (Rietz, 1904). Due to tempo delay, average hSDS in historic children declined from some −1SD to some −2SD between school-entry at age 6 years, to mid-adolescence, with a trough at age 12–13 years in girls, respectively at age 14–15 years in boys.

The historic literature lacks any evidence suggesting that the majority of the end 19th, and early 20th century European children and adolescents who corresponded to the conventional definition of stunting (low height-for-age) had demonstrably suffered from clinical signs of protein-energy undernutrition or signs

![Figure 1](image-url)
of micronutrient deficiency. Stunting was prevalent irrespective of economic wealth and living conditions. Even though in those days, the clinical signs of protein-energy undernutrition, anemia, rickets, and hypothyroidism were well known (Gerhardt, 1881), they were not mentioned in the meticulously documented health reports of those school children. Thus, we accepted the first hypothesis.

2. Indonesian schoolchildren are short and thin (Beal et al., 2018). Figure 2 and Table 2 depict body hSDS of the 6–13-year-old schoolchildren. The shortest children were found in rural Soe. The tallest children lived in the touristic town of Ubud (t(2255) = −12.319, p < .001, 95% CI[−0.54, 0.74]). The sub-populations of urban Ubud, urban Kupang, and rural Soe showed symmetrical Gaussian hSDS distributions (Ubud [Shapiro–Wilk Test, p = .1085], Kupang [p = .1388], Soe [p = .4137]) each with SDs close to 1.0 (Figure 2).

Soe children were thinnest in skinfold, with the lowest weight and BMI SDS (Table 2). Yet, we failed to detect any plausible reason for their thinness. Neither did we detect any clinical signs of malnutrition or chronic disease, nor did we find any correlation between the degree of thinness and measures of the family’s economic potential such as parental education. Rural children from Soe with higher educated parents (mean of education years of father and mother >12 years, n = 111) are not heavier (t(198) = 0.462, p = .6442, 95% CI[−0.21, 0.36]), do not have higher BMI_SDS (t(198) = 0.909, p = .3645, 95% CI[−0.16, 0.43]), nor higher skinfold values (t(198) = 1.018, p = .3101, 95% CI[−0.27, 0.86]) than children raised by lower educated parents (mean of education years of father and mother <12 years, n = 89).

The state schoolchildren of Kupang were significantly heavier (p < .001), with higher BMI (p < .0001) and higher skinfold thickness (p < .0001), but also without any association between skinfold thickness and parental education. The children of Ubud were heaviest, with the highest prevalence of overweight (29.8%) and obesity (8.5%).

Figures 3 and 4 visualize the body wSDS and the BMI_SDS distributions. Except for the rural Soe children (Shapiro–Wilk Test, wSDS p = .14; BMI_SDS p = .414) the distributions of wSDS were skewed (Ubud, Shapiro–Wilk Test, wSDS p = .009; BMI_SDS p < .001; Kupang, wSDS p = .001; BMI_SDS p < .001) highlighting the significant prevalence of overweight and obesity in Ubud and Kupang.

![Figure 2](image)

**Figure 2** Density plots of height standard deviation score (hSDS) of Indonesian 6–13-year-old children from different representative elementary state schools. All plots show normal distributions. Vertical lines indicate mean hSDS. Reference CDC (NCHS, 2021)

|                | hSDS | BMI_SDS | wSDS | Mean_sf |
|----------------|------|---------|------|---------|
|                | Mean | SD     | Mean | SD      | Mean | SD    |
| Soe rural      | −2.00| 1.02    | −1.47| 1.11    | −2.36| 1.22  |
| Kupang urban   | −1.19| 1.00    | −1.03| 1.56    | −1.47| 1.49  |
| Ubud urban     | −0.36| 0.97    | 0.19 | 1.25    | −0.03| 1.28  |

Note: Reference CDC (NCHS, 2021).
The broad and markedly skewed distribution of skinfold thickness (Ubud [Shapiro–Wilk Test, \( p < .001 \)], Kupang [\( p < .001 \)], [Figure 5]) underscores the prevalence of overweight and obesity in the urban children of Ubud and to a lesser degree, in the children of Kupang with great numbers of overweight and obese individuals.

No relevant association exists between height and skinfold thickness in either one of the groups of schoolchildren. The apparent mild growth advantage in the overweight and obese children of Ubud and Kupang. Only 13.4% (\( p < .001 \), Ubud) and 12.5% (\( p < .001 \), Kupang) barely indicate any meaningful associations between body fat depots and height (Figure 6).

In view of the increasing height, and at the same instant, increasing prevalence of obesity associated with the increasing connectedness with and absorption of the Western lifestyle from essentially no contact for the school children from Soe, sporadic contact for the children of Kupang and the unmissable influences of everyday tourism on the children of Ubud, we accepted our second hypothesis.

### DISCUSSION

Throughout the Holocene, average adult human body height varied between 150 and 160 cm in women, and between 160 and 170 cm in men (Rosenstock et al., 2019). Since that time, men's average body height had surpassed the upper limit of 170 cm, nor women's
height the limit of 160 cm. This was true even for the people of the upper social strata of advanced European and Western Asian civilizations (Rosenstock et al., 2019). Height of skeletons of different burial grounds from Merovingian (around 400–750 AD) to the medieval time differed from 167.7 ± 1.2 cm to 170.7 ± 5.0 cm in males and from 155.3 ± 1.4 cm to 159.7 ± 3.9 cm in females. In the fifth/sixth century a height difference of skeletons of poorly and richly endowed graves was documented, the aristocracy reached a body height 3 cm taller than the normal population in early medieval time (Siegmund, 2010). Estimates of mean body mass ranged between 60 to 70 kg in male adults and 52 to 55 kg in female adults in the Mesolithic (15 000–5000 BC) to the Medieval time period (5th–late 15th century) (Macintosh et al., 2016). They described also a reduction of mean body height from 173 cm in males resp. 158 cm in females in the Mesolithic period to 165 cm resp. 151 cm to Iron Age (800 BC–500 AD) and an increase in the Medieval age. Minimum average height of 161.4 cm was recorded for Mesolithic males (Formicola & Giannecchini, 1999). Periods of shorter height have occasionally been reported from Medieval and early modern European populations (Koepke & Baten, 2005; Komlos & Cinnirella, 2005; ScienceDaily, 2021; Staub et al., 2013) and from Japan shortly after the Edo-period (Kouchi, 2018).

We presented a small selection of European and US-American child growth studies. Considering similar symmetrical Gaussian distributions of height (see e.g., Habicht et al., 1974) in affluent, and also in less affluent population (Eveleth & Tanner, 1990), an average deficit in hSDS of −1SD indicates that some 16% of that population is stunted. An average height deficit in hSDS of −2SD means that about half of that population is stunted. The selection of historic studies we present, explicitly mention the affluent social circumstances these children lived in. Thus illustrate that a 16%–50% prevalence of stunting in European and US American children of the end 19th and early 20th century did not coincide with chronic or recurrent undernutrition, poor socioeconomic conditions, poor maternal health and nutrition, frequent illness, and/or inappropriate infant and young child feeding and care in early life. These children were raised under optimum 19th-century circumstances, they certainly reached their full cognitive potential, and further, provide good evidence for accepting our first hypothesis.

Children of the LMIC still tend to be short (Mapping child growth failure across low- and middle-income countries, 2020). This is particularly true for the economically less advantaged strata in these countries. But, also the wealthy are short. Da Silva and coworkers (Da Silva et al., 2018) analyzed 217 nationally representative
surveys from 67 LMIC and reported that up to 50% of the children of the richest 60% of these populations were stunted. Wong and coworkers (Wong et al., 2017) listed 46 LMIC and found that in 15 out of 46 countries, more than 20% of the children of the wealthiest decile were stunted. In four out of 46 countries, more than 30%, and in Timor Leste, up to 40% of the children of the wealthiest decile were stunted. Bommer and coworkers (Bommer et al., 2019) derived household SES by calculating a survey-specific asset index from electricity, radio, television, refrigerator, bicycle, motorcycle, car, phone, as well as binary measures for floor quality, wall material, and roof material, including 416.181 observations from 72 countries, and showed the age-dependent prevalence of stunting with rates of up to 30% at age 2 years in the richest quartiles of these populations.

Da Silva and coworkers (Da Silva et al., 2018) also depicted the changes in stunting prevalence separately in the LMIC between 1993 and 2014. They reported that in the poorest 40% and in richest 60% portions of these populations the reduction in the rate of stunting was almost parallel though “both relative and absolute inequalities increased over time in low-income countries.” The statement underscores that the prevalence of stunting is independent of the economic conditions, and further support the hypothesis that stunting is frequently prevalent in human populations irrespective of economic wealth and living conditions. The findings strengthen the view that growth in height is grossly influenced by social interactions among people who live at close distances and know each other physically reflecting competitive growth and strategic growth adjustments (Hermanussen & Scheffler, 2016).

Indonesian children belong to the shortest children on earth (BADAN PENELITIAN DAN PENEGAKAN KESEHATAN KEMENTERIAN KESEHATAN RI, 2013). However, our previous studies in school children from West Timor and Bali (Scheffler et al., 2019; Scheffler et al., 2021) failed to confirm any association between shortness of body height and clinical signs of chronic food shortage. Neither BMI, nor weight, nor skinfold thickness were related with body height, not even in the shortest individuals within the rural cohorts with the highest prevalence of stunting. Quite in opposition to the common perception that stunted children are at greater risk of impaired motor capacities (Stunting in a nutshell, 2021), the most stunted children from rural Soe were physically fittest (Scheffler & Hermanussen, 2021). The data strongly support the second hypothesis that non-starving and economically non-deprived LMIC populations exist that depending on connectedness with the modern Western culture show patterns of child and adolescent growth that are similar to patterns published from affluent historic European societies.

Thus, why are these children so short? We decided to put the question differently: Is stunting an unnatural condition of human height?

Current wisdom associates small body size with food scarcity, disease, and impaired child development. Yet, this association though frequently observed has been questioned. Mumm et al. (2016) reanalyzed data from 833 growth studies from 78 different countries published between 1920 and 2013, and failed to find evidence supporting the vision of any inherent association between nutrition and growth in the majority of the populations living in the 20th century. Thompson (2021) reviewed anthropological, public health, and clinical literature on the nature of child growth and the applicability of WHO growth standards and concluded that “a single norm cannot represent healthy growth for all children in all locations at all times.” Thompson discusses size variability and whether the plasticity of human growth may represent an adaptive response suggesting that “plasticity is usually beneficial.”

Already in Homo erectus, fossil discoveries have revealed extensive variation in the fossil signatures of life-history variation (Kuzawa & Bragg, 2012). Kuzawa and Bragg called into question previous assumptions regarding the evolution of size and shape in Homo and bring variation per se to the fore as an important focus of analysis. We consider this the quintessence of the discussion about stunting.

We may add at this point that the limited skeletal material dating back prior to some 15 000 years BP suggests that the Middle East and European hunter gatherer populations before they had shifted from nearly 100% foraging to a mix of foraging and farming were not only quite muscular but also taller with male height ranging close to 175–182 cm. They lived at very low population density with some 0.1 person/km² (Angel, 1984). With this shift from being independent and far roaming foragers to sedentary farmers and urban dwellers integrated into rigid feudal systems with dominant and subordinate social strata, the need for competitive growth and strategic growth adjustments may have risen resulting in elites that remained tall, and ordinary people of limited body size (Mathers & Henneberg, 1995; Ruff, 2002; Bogin, 2021a, pp. 316ff, 330ff).

The common notion that selection for small size is an advantageous evolutionary strategy when successfully dealing with limited physical resources (Little, 2020) fueling ideas like the old “small but healthy” hypothesis (Pelto & Pelto, 1989; Seckler, 1982), we instead consider the acquisition of the exceptional capability of the contemporary human species for adaptive phenotypic plasticity in growth the core achievement in our recent evolution. Under this aspect, being short does not result
from limited resources, but represents the lower end of a plastic spectrum of height allowing for stature to be a social signal (Hermanussen & Scheffler, 2016). Humans use stature as a signal to communicate their position within social hierarchies (Huang et al., 2002; Judge & Cable, 2004; Lourenco et al., 2015; Young & French, 1996). Being able to adjust in stature stands for being able to send physical signals for social communication. Adaptive plasticity in height appears to be greatest between the initiation of puberty and the approximate achievement of adult height (Haas & Campirano, 2006), and thus coincides with that developmental period within which major parts of the lifelong social networks are constructed (Bogin, 2021b). Competence for adaptive plasticity in height appears to be of major evolutionary advantage for developing the complex social structures and hierarchies that are typical for the human culture.

Being low-height-for-age according to contemporary growth references of the early 21st century, gives a false impression of sickness. Stunting can be, but is not necessarily an indicator of physical constraints. Stature that is shorter than contemporary standards and references suggest should be considered the short end of the exceptionally wide frame of physiological plasticity in growth reflecting the physical equivalent of the wide frame of options within social networks.

5 CONCLUSION

The evidence for the global agreement on the association between the prevalence of stunting and chronic undernutrition in modern and historic populations is weak. We find overwhelming evidence to support the vision that stunting is the natural condition of human height also in the affluent and well-nourished social strata of feudal rural and urban societies. Only the scattered independent groups of paleolithic hunter and gatherers, and again in the very recent history, and only in a few democratic, modern societies, human stature has increased far beyond the long-lasting historic average of some 165–170 cm for males, and less than 160 cm for females. Recent considerations upon community effects on growth, on competitive growth and strategic growth adjustments need further attention in order to better understand the complex regulation of human growth.

ACKNOWLEDGMENTS

We gratefully thank Prof. Arman Pulungan, Prof. Madarina Julia, and our Indonesian colleagues from West Timor for their cooperation and their great personal support. We also gratefully thanks the two anonymous reviewers of a former version of this article. Their comment had helped us to clarify which was the most important issue of our previous article version. Open Access funding enabled and organized by Projekt DEAL.

CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

AUTHOR CONTRIBUTIONS

Christiane Scheffler and Michael Hermanussen developed the study design and discussed the results. Christiane Scheffler calculated the data and wrote the first draft. Michael Hermanussen and Christiane Scheffler finished the manuscript.

DATA AVAILABILITY STATEMENT

The data are availability by the authors.

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**How to cite this article:** Scheffler, C., & Hermanussen, M. (2022). Stunting is the natural condition of human height. *American Journal of Human Biology, 34*(5), e23693. https://doi.org/10.1002/ajhb.23693