Anthropol. Anz. 74/5 Supplement (2018), 403–411
J. Biol. Clin. Anthropol.
Published online March 2018

No association between fat tissue and height in 5019 children and adolescents, measured between 1982 and in 2011 in Kolkata/India

Christiane Scheffler[1], Louisa-Marie Krützfeldt[2], Parasmani Dasgupta[3], and Michael Hermanussen[4]

[1] University of Potsdam, Institute of Biochemistry and Biology, Human Biology, Am Neuen Palais 10, 14469 Potsdam, Germany
[2] University of Potsdam, Institute of Biochemistry and Biology, Bioinformatics, Potsdam, Germany
[3] Biological Anthropology Unit, Indian Statistical Institute, Kolkata, India
[4] Aschauhof, Altenhof, Germany
Corresponding author: christiane.scheffler@uni-potsdam.de

With 1 figure and 4 tables

Abstract: Body height has traditionally been looked upon as a mirror of the condition of society, short height being an indicator of poor nutritional status, poor education, and low social status and income. This view has recently been questioned. We aimed to quantify the effects of nutrition, education, sibship size, and household income, factors that are conventionally considered to be related to child growth, on body height of children and adolescents raised under urban Indian conditions. *Sample and methods:* We re-analyzed several anthropometric measurements and questionnaires with questions on sibship size, fathers' and mother's education, and monthly family expenditure, from two cross-sectional growth studies performed in Kolkata, India. The first Kolkata Growth Study (KG1) took place in 1982–1983, with data on 825 Bengali boys aged 7 to 16 years; and the second Kolkata Growth Study (KG2) between 1999 and 2011 with data of 1999 boys aged 7 to 21 years from Bengali Hindu families, and data of 2195 girls obtained between 2005 and 2011. *Results:* Indian children showed positive insignificant secular trends in height and a significant secular trend in weight and BMI between 1982 and 2011. Yet, multiple regression analysis failed to detect an association between nutritional status (expressed in terms of skinfold thickness), monthly family expenditure and sibship size with body height of these children. The analysis only revealed an influence of parental education on female, but not on male height. *Conclusion:* We failed to detect influences of nutrition, sibship size, and monthly family expenditure on body height in a large sample of children and adolescents raised in Kolkata, India, between 1982 and 2011. We found a mild positive association between parental education and girls' height. The data question current concepts regarding the impact of nutrition, and household and economic factors on growth, but instead underscore the effect of parental education.

Keywords: body height; nutrition; social growth adjustment

Introduction

Growth has traditionally been looked upon as a mirror of the condition of society (Tanner 1990) and hence been used as a measure of the circumstances of life, not only in human biology, but also in economic history, demography, public health, and for various political motives. Short height has been associated with poor nutritional status, poor education, and low social status and income (Bogin 1999; Bogin 2001; Perkins et al. 2016; Varela-Silva et al. 2016; World Health Organization 2012; NCD Risk Factor Collaboration (NCD-RisC) 2016). Yet, this view has recently been questioned. Goudet et al. (2016) showed that out of 22 nutrition intervention studies only 6 interventions had a small positive effect on height, weight and fat increased in 9, and all other studies showed no beneficial effect on body height or body mass. Historical observations further support these findings (Hermanussen et al. 2018). Multiple studies published in central European countries shortly after the First World War fail to detect significant effects of nutrition on child growth (summarized by Schlesinger 1925, and Keys et al. 1950). On the other hand, it is trivial knowledge that there is no growth without food. Children who are severely undernourished finally stop growing. But they show very marked effects of

DOI: 10.1127/anthranz/2018/0827
E. Schweizerbart'sche Verlagsbuchhandlung, 70176 Stuttgart, Germany, www.schweizerbart.de

re-feeding on height that by far exceed those observed in modern nutrition intervention studies in stunted populations. Stunted German children sent to Switzerland shortly during and after World War I for re-feeding, showed sizable catch-up growth in height of on average 3 cm within 6 to 8 weeks (Bloch 1920; Abderhalden 1920).

At the end of the last century more than 183 million of young children living in developing countries were considered underweight and 226 million were considered stunted (UNICEF 1998). Particularly the Indian subcontinent has a long history of recurrent famine. India has about half the world's undernourished children despite reduction of poverty in the country (Patwary 2013). The nutritional situation in India has changed during the last 40 years, with a decline of the proportion of underweight children below 3 years, from 52 % in 1990 down to about 33 % in 2015 (Rao et al. 2012; Patwari 2013). But still in 2010, malnutrition has been claimed responsible for 50% of child's death in India [http://timesofindia.indiatimes.com/india/Malnutrition-reason-for-50-of-child-deaths/articleshow/5913976.cms]. Half of all pre-school children suffered from undernutrition (Biswas & Bose 2011). Comparative data on childhood malnutrition in India and China at three time-points, viz. 1992–1993, 1998–1999, and 2005–2006 also showed that the prevalence of malnutrition was much higher in India and with slower rates of improvements (Svedberg 2007).

In view of these data, we aimed to further quantify the effects of nutrition, and also of education, sibship size, and household income, factors that are considered to be related to child growth, on body height. As we still consider Indian children an appropriate example to test the hypotheses, that a better nutritional status coincides with taller stature, we re-analysed data of children and adolescents raised under urban Indian conditions, and re-analyzed a large carefully measured late 20th century and an early 21st century sample of Kolkata children. The data included skeletal, and body fat measurements and additional information on social backgrounds. Measures of skinfold thickness were used as indicators of the nutritional status instead of mid- upper circumference (MUAC) that comprises the very similar information and has also often been used in nutritional intervention studies (Gibson 2005; Cheah et al. 2012; Lazzerini et al. 2013; Gera et al. 2017).

Sample and method

We re-analyzed several anthropometric measurements and questionnaires with questions on sibship size, fathers' and mother's education, and monthly family expenditure, from two cross-sectional growth studies performed in Kolkata, India. The first Kolkata Growth Study (KG1) took place in 1982–1983, with data on 825 Bengali boys aged 7 to 16 years; and the second Kolkata Growth Study (KG2) between 1999 and 2011 with data of 1999 boys aged 7 to 21 years from Bengali Hindu families, and data of 2195 girls obtained between 2005 and 2011.

Detailed descriptions of samples and methods were published by Das et al. (2016) with 14 tables and 10 figures. The present analyses were based on those 26 parameters that had been obtained in all three studies, and included various socio-economic factors. Skinfold measures were considered indirect measures of the nutritional status of the children. All data were checked for plausibility. Continuous data such as height, weight, subcutaneous fat measures, various body circumferences, but also household income were transformed into Standard Deviation Scores (SDS). Doing so, we the data were not referred to external references, but to mean values and variances of the respective samples. Nonparametric correlations were checked, and we applied principal component analysis (PCA) with Oblim-rotation on each cohort (excluding age as a variable). The Kaiser-Meyer-Olkin-criteria were checked (KMO > 0.75). Using scree plots and eigenvalue criteria six (in girls five) principal components (PC) were chosen respectively. We determined the variables with the highest loading value in each PC and used these (excluding body height, including age) in multiple regressions against body height SDS values. Because of large sampling sizes significance levels of 0.01 were chosen and 99 % confidence intervals calculated. All statistical analyses were performed using the statistical software R. For PCA the R package "psych" (Revelle 2017) was used.

Results

Indian children and adolescents showed positive secular trends in weight and BMI between 1982 and 2011, but no significant secular trend in height. Table 1 exemplifies the trends in the 16-year-old male participants.

We failed to detect associations between nutritional status (expressed in terms of skinfold thickness), monthly family expenditure and sibship size with body height of these children.

Figure 1 exemplifies the lack of association between body height SDS and SDS of three skinfolds. Dashed lines mark the –2 SDS cut-offs for height, and show that stature is not related to fat tissue thickness.

Principal Component Analyses (PCA) were performed in the boys of 1982–1983, in the boys of 1999–2011, and

Table 1. Mean height, weight and BMI of 16-year-old males participating in two Kolkata Growth Studies (KG) (double side t-test, significance level $p < 0.05$).

	KG1 (1982–1983)	KG2 (1999–2011)	*p*-values
Height [cm]	165.7	167.7	0.0691
Weight [kg]	48.97	56.43	0.0001*
BMI [kg/m²]	17.76	20.05	0.0003*

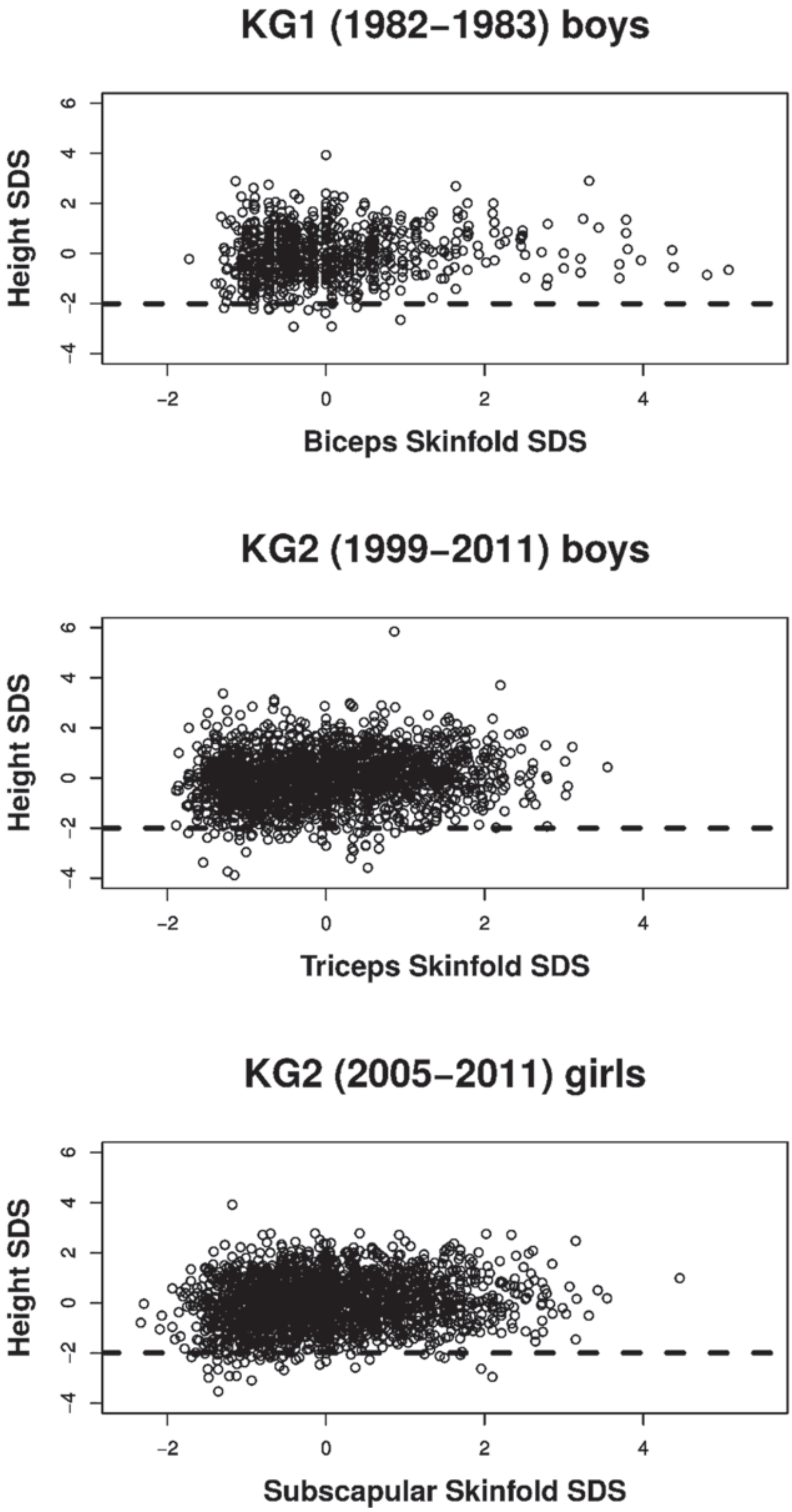

Fig. 1 Association between height SD-scores plotted against skinfold SD-scores of Kolkata Growth studies (KG1: boys 1982–1983, KG2: boys 1999–2011 and girls 2005–2011). Dashed lines optically divide into two groups: participants with height SD-scores ≤ 2 below (stunted children) and the rest above.

Table 2. Overview of contribution of variables to Principle Components (PC).

PC	Variables that contribute to PC (variables in braces contribute to mulitiple PC's)
Body height	stature, sitting height, biacromaial diameter, biiliocristal diameter, total arm length, leg length, (bicondular femur), (morphological facial height)
Nutritional status	triceps skinfold, biceps skinfold, subscapular skinfold, suprailiac skinfold, upper arm circumference, calf circumference, body weight, (bicondular femur)
Head size	head circumference, head breadth, head length, bizygomatic breadth, (morphological facial height)
Sibship size	sibship size, parity
Parent's education	father's education, mother's education, (family expenditure)
Economic factor	household are, (family expenditure)

in the girls of 2005–2011 (Table 3). Most of the variance was explained by 5 or 6 Principal Components that may best be described as (1) "body height", (2) "nutritional status", (3) "head size", (4) "sibship size", (5) "parents' education", and (6) "economic factor", according to that variable that contributed the most to the respective component (Tables 2, 3). For instance, the component named "head size" consisted of the parameters head circumference, head breadth, head length, bizygomatic breadth and morphological facial height.

We also performed multiple regression analyses in the three samples (Table 4). We detected significant associations between body height and head size ($p < 0.0001$) in all cohorts, and between body height and parental education in the girls of KG2 ($p = 0.00014$). Parental education did not exhibit significant influence on male height, neither in 1982–1983 nor in 1999–2011.

We detected no statistical influence of the nutritional status expressed as skinfold thickness, on body height. This was true for all three cohorts, and contrasts current understanding. The variables sibship size, economic factor and age also showed no influence on body height.

Discussion

The present study re-analysis data on various anthropometric and socio-economic parameters obtained in boys from Kolkata, in 1982–1983 and in 1999–2011, and in girls from Kolkata in 2005–2011 (Das et al. 2016). The data show a mild, but insignificant increase in body height, a significant positive trends in weight and body mass index (BMI) in boys. We assume that similar trends exist in girls, but the 1982 data set lacks female data. In contrast earlier Indian studies, e.g. by Rao et al. (2012) described mild positive height trends in preschool children. Mamidi et al. (2016) showed overall improvements in 18 year old boys and girls of 3.1 and 1.0 cm, over a period of 35 years. The increments in height were highest for both boys (7.4 cm) and girls (4.8 cm) in the state of Kerala followed by Tamil Nadu (boys, 7.3 cm and girls, 3.8 cm). Under-5 stunting rates decreased from 82% in the baseline survey to 45.7% in the final survey at a rate of 1.35% per year in the pooled states and were similar in both boys and girls. The recovery in stunting was highest in Tamil Nadu (1.63% per year) followed by Kerala (1.46% per year). These trends are commonly explained by improvements in nutrition, better education, and higher social status and income (Tanner 1990; Bogin 1999; Bogin 2001; Perkins et al. 2016; NCD Risk Factor Collaboration (NCD-RisC) 2016).

The nutritional situation in India has changed with a significant decline of the proportion of underweight children in recent years (Rao et al. 2012; Patwari 2013). Kanade et al. (1999) described an increase in developmental tempo. In a longitudinally study of Indian stunted and underweight children, the authors found retardation in the age at take-off and the age of peak pubertal height velocity of about 2 years compared to well-fed children. Our data confirm the increase in average weight.

Data on the nutritional situation of the Kolkata study population was not available. Instead, we used skinfold thickness and considered this parameter an estimate of the "cumulated nutritional situation". As the majority of the study population was raised from urban middle-class families one may assume that the nutritional situation was not critical, neither in the 1980s nor in the early 2000s. Particularly during the last decades, when the economic situation of this strata had significantly improved (https://data.worldbank.org/country/india), our analysis nicely illustrates the concomitant rise in body weight and BMI. Sixteen year old male adolescents had risen in weight by more than 7 kg, and in BMI from 17.76 kg/m² to 20.05 kg/m², with analogue increases in skinfold thickness indicating significant gains in body fat. Yet, the population did not grow much better, the 16 year old boys were only 2 cm taller in 2011. When referred to WHO reference, average BMI of the 16 year old boys rose from –1.22 SDS to –0.17 SDS, whereas height only mildly increased from –0.93 SDS to –0.67 SDS. Our statistical analysis failed to show meaningful associations between the various measures of fat tissue and body height. The thin children were not the stunted children, and the normal and overweight children were not the tall children. At first view this finding was amazing as it contrasts current opinion. However, the lack of a trivial association between food intake and growth is well known. The regulation of the growth plate (Lui et al. 2014) includes integrated processes of chondrocyte differentiation, proliferation, cartilage matrix secretion, cell death, and of vascular and bone cell invasion that are regulated and coordinated by a complex array of paracrine signaling molecules,

Table 3. Principal Component Analysis of the three cohorts of the two Kolkata Growth Studies.

	Boys 1982–1983						Boys 1999–2011						Girls 2005–2011				
	Height	**Nutrition***	**Siblings**	**House size**	**Head**	**Education**	**Height**	**Nutrition***	**Siblings**	**House size**	**Head**	**Education**	**Height**	**Nutrition***	**Siblings**	**Head**	**Education**
Height SDS	0.952						0.922						0.909				
Sitting height SDS	0.871						0.816						0.800				
Biacromial diameter SDS	0.850						0.760						0.760				
Bi-iliocristal diameter SDS	0.784						0.736						0.647	0.604			
Total arm length SDS	0.903						0.898						0.897				
Upper arm circumf. SDS	0.517							–0.879						0.925			
Bicondylar femur SDS	0.810						0.693	–0.585					0.568	0.713			
Calf circumference SDS	0.663	0.648					0.514	–0.816						0.871			
Triceps skinfold SDS		0.903						–0.933						0.836			
Biceps skinfold SDS		0.908						–0.908						0.795			
Subscapular skinfold SDS		0.855						–0.928						0.894			
Suprailiac skinfold SDS		0.891						–0.851						0.856			
Bizygomatic breadth SDS	0.599				0.583						–0.676					0.672	
Morphol. facial height SDS	0.514																
Head circumference SDS					0.929						–0.927					0.952	
Head breadth SDS					0.604						–0.701					0.763	
Head length SDS					0.812						–0.758					0.786	
Body weight SDS	0.855				0.535						–0.511		0.577	0.877		0.518	
Leg length SDS	0.818						0.844						0.860				
Father's education						0.864						0.872					0.826
Mother's education						0.843						0.864					0.795
Family expenditure										–0.798							0.696
Sibship size			0.933						0.911						0.895		
Parity			0.935						0.915						0.872		
Household area				0.863						–0.792							

Rotation: oblim with Kaiser-Normalization; only eigenvalues > 0.5; * nutrition = anthropometric variables depending on nutrition (skinfolds, circumferences)

Table 4. Results (*p*-values and 99 % confidence intervals (CI), linear regression estimates β and R2) from multiple regression against height SDS on three cohorts of two Kolkata Growth Studies. Asterisks represent significant *p*-values.

Factor represented by the relevant variable	Cohort	*p*-value	[99% CI]	β	R2
Age	KG1 boys	0.806	[–0.03 , 0.03]	0.003	0.00006
	KG2 boys	0.989	[–0.01 , 0.01]	–0.00007	0.0000003
	KG2 girls	0.736	[–0.01 , 0.01]	–0.002	0.000001
Head size	KG1 boys	< 2e–16 *	[0.31 , 0.48]	0.40	0.16
	KG2 boys	< 2e–16 *	[0.25 , 0.37]	0.31	0.11
	KG2 girls	< 2e–16 *	[0.29 , 0.40]	0.34	0.13
Nutritional status	KG1 boys	0.293	[–0.05 , 0.12]	0.04	0.01
	KG2 boys	0.035	[–0.01 , 0.11]	0.05	0.02
	KG2 girls	0.094	[–0.02 , 0.09]	0.04	0.02
Sibship size	KG1 boys	0.211	[–0.11 , 0.39]	–0.04	0.004
	KG2 boys	0.771	[–0.11 , 0.12]	–0.01	0.04
	KG2 girls	0.551	[–0.07 , 0.11]	0.02	0.0004
Parents' education	KG1 boys	0.012	[–0.003 , 0.20]	0.10	0.01
	KG2 boys	0.089	[–0.03 , 0.12]	0.05	0.007
	KG2 girls	0.00014 *	[0.03 , 0.11]	0.10	0.02
Economic factor	KG1 boys	0.445	[–0.16 , 0.30]	0.007	0.0006
	KG2 boys	0.199	[–0.000007 , 0.000021]	0.000007	0.005
	KG2 girls	0.310	[–0.00004 , 0.00010]	0.00003	0.002

which includes insulin-like growth factors (IGFs), fibroblast growth factors (FGFs), Indian hedgehog (IHH) and parathyroid hormone related protein (PTHrP), bone morphogenic proteins (BMPs), WNTs, and vascular endothelial growth factors (VEGFs). In addition, the rate of endochondral bone formation at the growth plate is regulated by an array of endocrine signals, including growth hormone (GH), IGF-I, thyroid hormone, glucocorticoids, androgens, and estrogens. GH and intracellular STAT 5 signaling is an old regulatory system. GH may be viewed as the primary anabolic hormone during stress and fasting. GH exerts anabolic effects directly and through stimulation of IGF-I, insulin, and free fatty acids. When subjects are well nourished, the GH induced stimulation of IGF-I and insulin is important for anabolic storage and growth of lean body mass (LBM), adipose tissue, and glycogen reserves. A prominent metabolic effect of GH is a marked increase in lipolysis and free fatty acid levels (Møller & Jørgensen 2009). Yet, the connections between growth hormone, its growth releasing hormone (GHRH) and somatostatin hypophysiotropic neurons and the integration between regulators of food intake/metabolism and growth hormone release is complicated (Steyn et al. 2016). Complex intra- and extrahypothalamic neuronal networks are involved in its regulation in which also nutrition is a necessary element, but the assumption that shortness is an indicator of undernutrition is simplistic. Nonetheless – and this was the primary motive for our analysis – common wisdom largely ignores this evidence. Stunting is commonly associated with poor living conditions, poor health and inappropriate nutrition. Nutrition has been considered crucial to both individual and national development. Series of papers published in the Lancet in 2008 and 2013, conclude that good nutrition is a fundamental driver of a wide range of developmental goals (http://www.thelancet.com/pb/assets/raw/Lancet/stories/series/nutrition-eng.pdf).

Yet this view has been challenged. In 2016, Dewey (2016) reviewed recent efforts to reduce stunting by improving maternal, infant and young child nutrition, and found that the efficacy of nutrition interventions in low-income stunted populations appears questionable. In a 2005 Cochrane Database Systematic Review, Sguassero et al. (2005) reported a positive effect on length in a nutrition-supplemented group compared to controls (mean difference 1.3 cm [0.03–2.57]) after 12 months of an intervention conducted in Jamaica, but no similar benefit in growth after 12 months of supplementation in a trial from Indonesia. In 2012, the same authors (Sguassero et al. 2012) meta-analyzed community-based supplementary feeding in children under 5 years of age in low- and middle-income countries and concluded that supplementary feeding has a negligible impact on child growth. Goudet et al. (2016) reviewed interventions to tackle malnutrition and its risk factors in children living in slums, again with negligible effects on length/height. Imdad et al. (2011) showed that provision of appropriate complementary foods (± nutritional counseling) resulted in an extra gain of 0.25 kg (± 0.18) in weight and 0.54 cm (± 0.38) in height in children aged 6–24 months, and considered overall quality grades for these estimates to be of 'moderate' level.

Stunting is not new, and it is not a phenomenon limited to populations of the developing countries. Stunting was ubiquitous among the European populations of the 19th and early 20th century. Also starvation was ubiquitously present in the central European countries particularly after the First, and the Second World War. Historic evidence on child and adolescent growth before, during and after the great wars, has been summarized e.g. by Boyd (1980) and Keys et al. (1950). In addition, we find big data on up to several tens of thousands of children and adolescents from official urban school investigations that were regularly published by the authorities from various German, Swiss and Austrian cities (e.g. Combe 1896; Igl 1906; Oebbecke 1906) to evaluate the nutritional situation. In those days, the perception that child growth does not depend on nutrition was common. It was first discussed when studying seasonal variation in growth (Malling Hansen 1884; Schmid-Monnard 1895). The greatest gains in weight were observed between September and January, and coincided with the least gains in body height. Similar findings were reported some 90 years later in children from very high SES, attending the American School of Guatemala. They were very well fed throughout the year, but grew slower in height when they were growing faster in weight and they grew faster in height during the dry season (Bogin 1978; Bogin 1979).

The nutritional situation in Europe of the late 19th and early 20th century was apparently delicate, particularly among the lower social strata. Yet, it was explicitly stated *"that the under-nourishment of the children of the poor, with the exception of the fact that it certainly does not occur in the assumed extent, is probably over-estimated in its importance for the growth of body length"* (Pfaundler 1916). Even though Pfaundler later recognized that undernutrition during the First World War inhibited height growth, he stressed that this inhibition was temporary and mild, and less pronounced than the reduction in weight. He called this the "*dissociation of statural and ponderal growth*" and stated that *"this change of proportion is diametrically opposite to that found among the children of the poor* (again he refers to higher Livi indices). *For this reason too, it does not appear to me to address the problem of malnutrition as the decisive factor in the short stature of the poor"*. Physical growth appears to be a very stable phenomenon in child development. Even persistent nutrition impairment has no immediate effects on body height. In 1919 Schlesinger wrote: *"In the second year of the [First World] war (1916), there were more than a few groups of boys from the public, citizens' and advanced educational schools who were 1–2cm taller than in the year 1913 (before the war). This difference in the second year of the war was even more conspicuous, as at the same time there was a very clear and . . . not very small weight loss"*. Children became slimmer, but nevertheless, grew taller. Even though the number of very tall adolescents temporarily decreased, and the onset of the pubertal growth spurt tended to be later than before, Schlesinger concluded that *"the whole growth disturbance described here is to be regarded as a simple inhibition"*.

Refeeding of starved children is characterized by a short period of excessive, sometimes saltatory growth of up to several centimeters within a few weeks (Goldstein 1922). Bloch (1920) described catch-up growth in height of on average 3 cm within 6 weeks. Similar data were published by Abderhalden (1920). The observations contrast modern findings, e.g., published by Imdad et al. (2011) that provision of appropriate complementary foods resulted in an extra gain of 0.25 kg in weight and 0.54 cm in height in children aged 6–24 months.

The observation of European pediatricians at the beginning of the 20th century that even severe long-term nutrition constraints lack effects on adult height, and that body height rapidly returns to its former pattern after refeeding, resulting in the perception that body height is an invalid measure of nutritional status, strongly contrasts the modern perception of stunting being the most important anthropometric indicator for child nutrition (Black et al. 2013).

Our data (Das et al. 2016) support the historic findings. The prima vista impression of positive trends in height and Body-Mass-Index suggesting some relation between nutrition and height is deceptive. Multiple regression analyses failed to provide evidence for any substantial association between subcutaneous fat as a mirror of the nutritional status, and body height, neither in 1982–1983 nor in 1999–2011. Our findings might provide an explanation for the disappointing efficacy of many modern nutrition interventions on body height. The analysis supports the vision that also in Kolkata, short stature is not caused by nutrition constraints, and trends in height since 1982–1983 should be attributed to other than nutritional mechanisms. These may be better education, and higher social status (Tanner 1990; Bogin 1999; Bogin 2001; Perkins et al. 2016; NCDRisk Factor Collaboration (NCD-RisC) 2016).

We found associations between body height and head size, and body height and parental education in girls. The association between height and head size is explicable as head size is part of the measured length of the body. The association between body height and parents' education in the girls, but not in the boys, remains to be elucidated. Biswas & Bose (2011) described the influence of gender discrimination on height and weight of girls, depending on sib size and numbers of living rooms. Parental educational may mitigate or enhance gender discrimination and thereby, indirectly interact sex specifically on height and weight.

Body height mirrors social position. Humans are able to perceive physical size as a signal of social dominance. The greater influence of perceived taller humans in a negotiation task has been described by Huang et al. (Huang et al. 2002). Taller men are perceived as more competent and authoritative (e.g. Young & French 1996; Judge & Cable 2004; Cinnirella & Winter 2009). Also children are able to recognize cues that predict dominance (Lourenco et al. 2016). The link between social position and body size has extensively been studied in social mammals. Evidence in meerkats suggests that social dominance itself is a strong stimulus for growth (Huchard et al. 2016). Meerkats that "*acquire dominant status, show a secondary period of accelerated growth whose magnitude increases if the difference between their own weight and that of the heaviest subordinate of the same sex in their group is small*". The authors point out that not absolute, but relative size serves as the signal for "*individuals (to) adjust their growth to the size of their closest competitor"*. The authors discuss competitive growth strategies and strategic growth adjustments in view of a "*threat of being displaced*". Evidence from historic sources strongly suggests that competitive growth strategies and strategic growth adjustments exist in the human society and that also in the humans, size signals social status (Hermanussen & Scheffler 2016).

Conclusion

We failed to detect influences of nutrition, sibship size, and monthly family expenditure on body height in a large sample of children and adolescents raised in Kolkata, India, between 1982 and 2011. We found a mild positive association between parental education and girls' height. The data question current concepts regarding the impact of nutrition, and household and economic factors on growth, but instead underscore the effect of parental education.

Acknowledgements: Statistical analyses of data was conducted during the International Summer School *"Child and Adolescent Growth and Nutrition"* in Potsdam/Gülpe from the 3rd to 8th of July in 2017. This Summer school was supported by the Auxological Society (Gesellschaft für Auxologie), by the Society of Anthropology (Gesellschaft für Anthropologie). Publication of the manuscripts of this supplement volume has been made possible with grateful support of Lilly Deutschland GmbH. We also thank Rana Saha, Rituparna Das, and Sukana Das for collecting the data and the Neys-van Hoogstraten Foundation NHF for sponsoring the study.

References

Abderhalden, E. (1920): Der Erfolg der Schweizerfürsorge für deutsche Kinder. – Münchener Medizinische Wochenschrift 50: 1444.

Biswas, S. & Bose, K. (2011): Effect of number of rooms and sibs on nutritional status among rural Bengalee preschool children from Eastern India. – Collegium Antropologicum 35: 1017–1022.

Black, R.E., Victora, C.G., Walker, S.P., Bhutta, Z.A., Christian, P., de Onis, M., Ezzati, M., Grantham-McGregor, S., Katz, J., Martorell, R., Uauy, R. & Maternal and Child Nutrition Study Group (2013): Maternal and child undernutrition and overweight in low-income and middle-income countries. – Lancet 382 (9890): 427–451.

Bloch, H. (1920): Untersuchung an schwer unterernährten deutschen Kindern. – Münchener Medizinische Wochenschrift 37: 1062–1064.

Bogin, B. (1978): Seasonal pattern in the rate of growth in height of children living in Guatemala. – Am. J. Phys. Anthropol. 49 (2): 205–210.

Bogin, B. (1979): Monthly changes in the gain and loss of growth in weight of children living in Guatemala. – Am. J. Phys. Anthropol. 51 (2): 287–291.

Bogin, B. (1999): Patterns of Human Growth. 2nd ed. – Cambridge University Press, Cambridge, UK & New York.

Bogin, B. (2001): The growth of humanity. – Wiley, New York.

Boyd, E. (1980): Origin of the study of human growth. – University of Oregon Health Science Center Foundation, Oregon.

Cheah, W.L., Wan Muda, W.A., Mohd Hussin, Z.A. & Thon, C.C. (2012): Factors associated with undernutrition among children in a rural district of Kelantan, Malaysia. – Asia Pac. J. Public Health 24 (2): 330–342. doi: 10.1177/1010539510380737.

Cinnirella, F. & Winter, J. (2009): Size matters! Body height and labor market discrimination: a cross-European analysis. – CESifo Working Paper Series, pp. 1–29.

Combe, A. (1896): Körperlänge und Wachstum der Volksschulkinder in Lausanne. – Zeitschrift für Schulgesundheitspflege 9: 567–589.

Das, R., Das, S., Datta Banik, S., Saha, R., Chakraborty, A. & Dasgupta, P. (2016): Secular trends in physical growth and maturation in 7 to 21 year-old Bengali boys and girls from Kolkata, India, over six decades of time interval. – Int. J. Anthropol. 31: 185–226.

Dewey, K.G. (2016): Reducing stunting by improving maternal, infant and young child nutrition in regions such as South Asia: evidence, challenges and opportunities. – Matern. Child Nutr. 12 (Suppl. 1): 27–38.

Gera, T., Pena-Rosas, J.P., Boy-Mena, E. & Sachdev, H.S. (2017): Lipid based nutrient supplements (LNS) for treatment of children (6 months to 59 months) with moderate acute malnutrition (MAM): A systematic review. – PLoS ONE 12 (9): e0182096. doi: 10.1371/journal.pone.0182096.

Gibson, R.S. (2005): Principles of Nutritional Assessment. 2nd ed. – Oxford University Press, Oxford.

Goldstein, F. (1922): Klinische Beobachtungen über Gewichts- und Längenwachstum unterernährter schulpflichtiger Kinder bei Wiederauffütterung. – Zeitschrift für Kinderheilkunde 32: 178–198.

Goudet, S., Griffiths, P., Bogin, B. & Madise, N. (2016): Interventions to tackle malnutrition and its risk factors in children living in slums: A scoping review. – Ann. Hum. Biol. 44: 1–10.

Hermanussen, M. & Scheffler, C. (2016): Stature signals status: The association of stature, status and perceived dominance – A thought experiment. – Anthropol. Anz. 73 (4): 265–274. doi: 10.1127/anthranz/2016/0698.

Hermanussen et al. (2018): Stunting, starvation, and refeeding-a review of forgotten 19th and early 20th century literature. – Acta Paediatrica. in press

Huang, W., Olson, J.S. & Olson, G.M. (2002): Camera angle affects dominance in video-mediated communication. – In: Proceedings of the Conference on Human Factors in Computing Systems. – Association for Computing Machinery, New York, pp. 716–717.
Huchard, E., English, S., Bell, M.B., Thavarajah, N. & Clutton-Brock, T. (2016): Competitive growth in a cooperative mammal. – Nature 533 (7604): 532–534.
Igl, J. (1906): Die Wägungen und Messungen in den Volksschulen zu Brünn. – Der Schularzt IV: 753–760.
Imdad, A., Yakoob, M.Y. & Bhutta, Z.A. (2011): Impact of maternal education about complementary feeding and provision of complementary foods on child growth in developing countries. – BMC Public Health 11 (Suppl. 3): S25.
Judge, T.A. & Cable, D.M. (2004): The effect of physical height on workplace success and income: preliminary test of a theoretical model. – J. Appl. Psychol. 89: 428–441.
Kanade, A.N., Joshi, S.B. & Rao, S. (1999): Undernutrition and adolescent growth among rural Indian boys. – Indian Pediatr. 36 (2): 145–156.
Keys, A., Brozek, J., Henschel, A., Mickelsen, O. & Longstreet Taylor, H. (1950): The biology of human starvation. – The University of Minnesota Press, Minneapolis.
Lazzerini, M., Rubert, L.& Pani, P. (2013): Specially formulated foods for treating children with moderate acute malnutrition in low- and middle-income countries. – Cochrane Database Syst. Rev.6: CD009584. doi: 10.1002/14651858.CD009584.pub2.
Lourenco, S.F., Bonny, J.W. & Schwartz, B.L. (2016): Children and Adults Use Physical Size and Numerical Alliances in Third-Party Judgments of Dominance. – Front. Psychol. 6: 2050. doi: 10.3389/fpsyg.2015.02050.
Lui, J.C., Nilsson, O. & Baron, J. (2014): Recent research on the growth plate: Recent insights into the regulation of the growth plate. – J. Mol. Endocrinol. 53 (1): T1–T9. doi: 10.1530/JME-14-0022.
Malling Hansen, R. (1884): Tägliche Wägungen der 130 Zöglinge des Königlichen Taubstummen-Instituts in Kopenhagen. – http://www.malling-hansen.org/periods-in-the-growth-of-children.html.
Mamidi, R.S., Rajkumar, H., Radhakrishna, K.V. & Babu, J.J. (2016): Secular Trends in Heights and Weights in Boys and Girls Over 3 Decades in Rural India. – Food Nutr. Bull. 37 (3): 425–438. doi: 0379572116647579.
Møller, N. & Jørgensen, J.O. (2009): Effects of growth hormone on glucose, lipid, and protein metabolism in human subjects. – Endocr. Rev. 30 (2): 152–177. doi: 10.1210/er.2008-0027.
NCD Risk Factor Collaboration (NCD-RisC) (2016): A century of trends in adult human height. – eLife 5: e13410. doi:10.7554/eLife.13410.
Oebbecke, A. (1906): Die Wägungen und Messungen in den Volksschulen zu Breslau im Jahre 1906. – Der Schularzt IV: 588–594.
Patwari, A.K. (2013): Millennium Development Goals and Child Undernutrition. – Indian Pediatr. 50: 449–452.
Perkins, J.M., Supramanian, S.V., Smith, G.D. & Özaltin, E. (2016): Adult height, nutrition, and population health. – Nutr. Rev. 74: 149–165.
Pfaundler, M. (1916): Körpermaß-Studien an Kindern. – Zeitschrift für Kinderheilkunde 14: 1–148.
Rao, S., Kanade, A.N., Joshi, S.B. & Sarode, J.S. (2012): Secular Trends in Growth of Preschool Children from Rural Maharashtra, India. – J. Health Populat. Nutr. 30 (4): 420–430.
Revelle, W. (2017): psych: Procedures for Personality and Psychological Research, Northwestern University, Evanston, Illinois, USA. – https://CRAN.R-project.org/package=psych Version = 1.7.8.
Schlesinger, E. (1919): Wachstum, Gewicht und Konstitution der Kinder und der heranwachsenden Jugend während des Krieges. – Zeitschrift für Kinderheilkunde 22: 80–123.
Schlesinger, E. (1925): Das Wachstum des Kindes. – In: Kraus, F. et al. (eds): Ergebnisse der inneren Medizin und Kinderheilkunde. – Verlag von Julius Springer, Berlin.
Schmid-Monnard, K. (1895): Ueber den Einfluss der Jahreszeit und der Schule auf das Wachstum der Kinder. – Jahrbuch der Kinderheilkunde Neue Folge 40: 84–106.
Sguassero, Y., de Onis, M. & Carroli, G. (2005): Community-based supplementary feeding for promoting the growth of young children in developing countries. – Cochrane Database Syst. Rev. 2005: CD005039.
Sguassero, Y., de Onis, M., Bonotti, A.M. & Carroli, G. (2012): Community-based supplementary feeding for promoting the growth of children under five years of age in low and middle income countries. – Cochrane Database Syst. Rev. 2012: CD005039.
Steyn, F.J., Tolle, V., Chen, C. & Epelbaum, J. (2016): Neuroendocrine Regulation of Growth Hormone Secretion. – Compr. Physiol. 6 (2): 687–735. doi: 10.1002/cphy.c150002.
Svedberg, P. (2007): Child malnutrition in India and China.2020 FOCUS BRIEF on the world's poor and hungry people. – International Food Policy Research Institute, Washington, DC, pp. 1–5.
Tanner, J. (1990): Foetus into Man. 3rd ed. – Harvard University Press, Cambridge, Massachusetts.
UNICEF (1998): Nutrition Review 56 (4).
Varela-Silva, M.I., Bogin, B., Sobral, J.A.G., Dickinson, F., Monserrat-Revillo, S. & Healthy Birth, Growth, and Development – Knowledge Integration (HBGDki) Initiative (2016): Deep data science to prevent and treat growth faltering in Maya children. – Eur. J. Clin. Nutr. 70: 679–680.
World Health Organization (2012): WHO Global Nutrition Targets 2025: Stunting Policy Brief. – Available at: http://www.who.int/nutrition/topics/globaltargets_stunting_policybrief.pdf.
Young, T.J. & French, L.A. (1996): Height and perceived competence of US presidents. – Perceptual and Motor Skills 82: 1002.

Manuscript received: 24 October 2017
Revisions required: 25 January 2018
Revised version received: 06 February 2018
Accepted: 06 February 2018