Anthropol. Anz. 73/4 (2016), 265–274
J. Biol. Clin. Anthropol.
Published online 9 September 2016, published in print November 2016

Article

Stature signals status: The association of stature, status and perceived dominance – a thought experiment

Michael Hermanussen[1,*] and Christiane Scheffler[2]

[1] Aschauhof 3, 24340 Altenhof, Germany
[2] University of Potsdam, Human Biology, Am Neuen Palais 10, 14469 Potsdam, Germany
* Corresponding author: michael.hermanussen@gmail.com

With 1 figure and 1 table

Summary: *Background:* There is a common perception that tall stature results in social dominance. Evidence in meerkats suggests that social dominance itself may be a strong stimulus for growth. Relative size serves as the signal for individuals to induce *strategic growth adjustments*.

Aim: We construct a thought experiment to explore the potential consequences of the question: is stature a social signal also in humans? We hypothesize that (1) upward trends in height in the lower social strata are perceived as social challenges yielding similar though attenuated upward trends in the dominant strata, and that (2) democratization, but also periods of political turmoil that facilitate upward mobility of the lower strata, are accompanied by upward trends in height.

Material and methods: We reanalyzed large sets of height data of European conscripts born between 1856–1860 and 1976–1980; and annual data of German military conscripts, born between 1965 and 1985, with information on height and school education.

Results: Taller stature is associated with higher socioeconomic status. Historic populations show larger height differences between social strata that tend to diminish in the more recent populations. German height data suggest that both democratization, and periods of political turmoil facilitating upward mobility of the lower social strata are accompanied by a general upward height spiral that captures the whole population.

Discussion: We consider stature as a signal. Nutrition, health, general living conditions and care giving are essential prerequisites for growth, yet not to maximize stature, but to allow for its function as a lifelong social signal. Considering stature as a social signal provides an elegant explanation of the rapid height adjustments observed in migrants, of the hitherto unexplained clustering of body height in modern and historic cohorts of military conscripts, and of the parallelism between changes in political conditions, and secular trends in adult human height since the 19th century.

Keywords: community effect on height; secular trend; body height; social signals; strategic growth adjustment

Introduction

Across the Animal Kingdom the association of stature and status is intuitive. There is a common perception that large body size and tall stature result in social dominance (Cinnirella & Winter 2009). This also applies for humans. 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 & French1996; Judge & Cable 2004; Cinnirella & Winter 2009). Also children are able to recognize cues that predict dominance (Lourenco et al. 2016). They recognize physical size of the individual members of the group and numerical alliances.

Evidence in meerkats suggests that social dominance itself may be 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". Dominant group members further increase in size when they feel challenged by subordinate group members that experience additional extrinsic growth stimulation. Dominants do not want to lose their edge over their position. The authors discuss competitive growth strategies and *strategic growth adjustments* in view of a "threat of being displaced". Huchard et al. have not only

DOI: 10.1127/anthranz/2016/0698
www.schweizerbart.de
0003-5548/2016/0698 $ 2.50

raised the idea of a social target for growth; they explicitly discuss the possibility that "competitive growth may occur in many other social species, possibly including domestic mammals, non-human primates and humans".

Dominance status determines male mating success in many non-human primates (de Waal 1986; Bercovitch & Clarke 1995; Cowlishaw & Dunbar 1991). The evolutionary advantage of an association between stature, social status and dominance seems to also apply for humans (Marsh et al. 2009) even though recent population statistics lack evidence for an association between dominance status and number of children in modern Western populations.

Humans differ in size (Eveleth & Tanner 1990). Pygmy populations of Central Africa, the shortest human populations, are known to suffer from reduced GH and GH receptor gene expression (Meazza et al. 2011). This is possibly true for a few other very short human populations. The body height of European and Asian populations with no known genetic pathology spans over a wide range. Maximum average height of 179.5 cm has been recorded in Late Upper Paleolithic male populations, and minimum average height of 161.4 cm for Mesolithic males (Formicola & Giannecchini 1999). Considering the tallest ever measured average height of 184 cm in recent Dutch males (Fredriks et al. 2000) and one of the shortest measured average height of 156 cm in Japanese men at the end of the Edo period (www.sumitomo.gr.jp/english/discoveries/special/84_02.html), the framework for population height spans over 30 cm. A similarly broad framework has been shown for female height. The NCD Risk Factor Collaboration (2016) summarizes currently known empirical data on a century of trends in global adult human height from 1914 to 2014 and reports variation between and within populations of up to 20 cm.

Contrasting the animal studies linking size and social status, conventional wisdom tends to link human size to genetics and the physical environment, rather than to social circumstances. A Pubmed search using the keywords "genome+child+growth+development+review", resulted in almost 9.000 entries underscoring the general interest in genetic effects on growth. Recently Tyrrell et al. (2016) stated that the 396 height genetic variants they investigated explained 12.3% of the variance in adult height. The interest in nutrition, but also of clean water, sanitation and hygiene on growth is even higher. A Pubmed search using the keywords "child+growth+development+nutrition+review" resulted in more than 23.000 entries, the keywords "child+growth+development+developing+countries+nutrition+review", resulted in more than 8000 entries; the keywords "human+height+growth+health+water+sanitation+hygiene+review", in more than 500 entries. Ngure et al. (2014) discussed the role of malnutrition on child growth, and stated that "dietary interventions alone have not normalized growth or hemoglobin levels in children from low-income contexts". They added that "a recent review of 38 efficacy studies utilizing nutrient-dense foods and supplements with or without nutrition education showed an approximate 0.7 z-score gain in height for age (HAZ) at best; this is only one-third of the average deficit in Asian and African children (−2.0 z-scores)". They emphasized that the importance of water, sanitation and hygiene (WASH) is "associated with 6.6% of the global burden of disease and disability, and 2.4 million deaths annually due to diarrhoea, subsequent malnutrition, and their consequences". The association of stature, poverty, hunger, health impairment and the historic and economic background of the European populations has thoroughly been reviewed by Fogel (2004).

These and similar observations are plausible. The explanatory dilemma starts when merging trends in global adult human height of up to 20 cm within one century, with a 12.3% genetic contribution to the variance in adult height. Also the catch-up in height following nutrition interventions in stunted populations appears small in view of the historic height trends. And poor sanitation fails to serve as an explanation for the shortness of the wealthy urban Europeans before World War I who already in these days enjoyed almost modern sanitary conditions and economic prosperity. Short stature was epidemic in the 19th and in the early 20th century, very few Europeans reached average height of their modern descendants. Height clustered significantly below WHO growth standards (www.who.int/childgrowth/en/; www.who.int/growthref/en/).

Height clustering is the major paradox. Children and adults from similar historic and ethnic background are similar in height, quite regardless of the mean value of height. For example, in 1863 the average Dutch conscript reached 165 cm – also conscripts from the upper class were short. Less than 1% of them reached the mean body height of modern Dutch men of 184 cm (Fredriks et al. 2000). Thirty percent of the historic conscripts failed to reach 157 cm, which is less than the 1st centile of the modern Dutch growth charts (van Wieringen 1972). Conscript height distributions are narrow and tend to shift *in toto*, with little overlap between historic and modern height. The same phenomenon was noted in other countries, e.g. Switzerland (Staub et al. 2013), Germany, Italy (Hermanussen et al. 1995), and Portugal (Padez 2002). The fact that the secular trend in height affects all social strata regardless of nutrition and general living conditions, already puzzled school doctors and paediatricians in the 1920s (Koch 1935).

We construct a thought experiment to explore the potential consequences of the question: is stature a social signal also in humans?

We consider stature as a signal. Let us imagine stature being similar to a lighthouse serving as a navigational aid, though not for maritime but for social purposes. A lighthouse needs electricity, light bulbs, a certain height and the right physical position at the seashore to fully exhibit its function. There are tall lighthouses and small lighthouses, but nobody would seriously argue that the size of a lighthouse depends on the availability of construction material. So it is with stature. For fully growing up, an individual needs normal genetics, appropriate nutrition, good health, sanitation and a number of other conditions that are required for growth. But analogue to a lighthouse, growth and final size of a person do not so much depend on the availability of "construction material" but on their social function. Stature is a lifelong social signal. Recent support for a social determinant in the regulation of growth was provided by Aßmann & Hermanussen (2013). Using a Bayesian modelling approach and data from a longitudinal study of school children and adolescents from Zurich, Switzerland, the authors find that in addition to well-known predictors of adult height, such as bone age and Tanner stages of puberty, there is evidence for a new parameter that operates during the adolescent growth period to adjust the growth rate of an individual toward the average height of her/his immediate community already in children and adolescents. The authors write, ". . . the smaller the adolescent is compared with past mean average height (of the community), the more the adolescent grows during puberty". Conversely, taller than average adolescents will grow less. The net outcome is that the distribution of heights of members of a community (or a social network) is narrow and will cluster toward the mean value which was previously defined as a "community effect on height". People may simply be short because their friends and neighbors are short; or tall because their friends and neighbors are tall. A recent analysis of 3 to 6 year old kindergarten children confirms this impression. The variability in height decreases after children enter the kindergarten. Height starts to cluster around average height of their respective play groups whereas height variance of the whole kindergarten remains unchanged (Czernitzki pers. comm. 2016).

Children recognize cues that predict dominance (Lourenco et al. 2016). They recognize physical size as social signals and transmit social hierarchies. Groups of children from dominant background are educated both formally and by social experience to anticipate future dominance (Clark & Cummins 2014); others anticipate subordination.

In contrast to meerkats that can individually respond to social challenges by immediate growth adjustments at any age, humans only grow during a certain number of years and reach final height at early adulthood. Time for growth is limited. Children and adolescents who want to perform strategic height adjustments need to do so early. Yet, anticipating one's own future is difficult, at least at the individual level. We consider *strategic growth adjustments* as probabilistic assessments at the group level. Members of the same social groups/strata are aware of their social strata, and collectively generate appropriate lifelong signals of their putative future positions.

Stature as a signal has dynamic implications. Whereas meerkats individually respond to social challenges, humans can only do so at the group level. Whenever social groups/strata change in height, they challenge other groups that, in turn, again will change in height. Modern democratic systems and also demagogues during political turmoil promise equal opportunities and upward social mobility to the lower class. Children and adolescents receive these signals and can adjust in height towards the new and "better" target. Stimulated growth of the lower classes challenges the upper classes signalling "threats of being displaced". In turn upper class children uplift their height targets initiating a general upward height spiral that captures the whole population.

We hypothesize that

1. upward trends in height in the lower social strata are perceived as social challenges yielding similar though attenuated upward trends in the dominant strata
2. democratization, but also periods of political turmoil that facilitate upward mobility of the lower strata, are accompanied by upward trends in height

We test the hypotheses by reference to published historic data, by recent meta-analyses of height and weight, and by conscript data.

Material and methods

Large sets of height data of European conscripts were listed and analyzed by Hatton & Bray (2010). The lists summarize conscript height at 5-year birth cohorts from 15 countries born 1856–1860 to 1976–1980. For political and economic reasons, Hatton and Bray divided their material into three major eras: birth cohorts born before 1911–1915 (prewar), birth cohorts 1911–1915 to 1951–1955 (transwar) and birth cohorts 1951–1955 to 1976–1980 (postwar).

We follow Hatton and Bray's argument of three major eras, but in view of our hypothesis of growth adjustments anticipated at young age, we adapted the time cut-offs. We considered "prewar" cohorts those cohorts born before 1891–1895. The adaptation assures that all "prewar" cohorts reached adult age before World War I. Cohorts born 1891–1895 to 1941–1945 were considered "transwar" as they experienced both World Wars. Cohorts born since 1941–1945 were considered "postwar". Postwar cohorts were born and raised under postwar conditions, except for the first that reached postwar conditions in late childhood. Table 1 summarizes data from Germany, France, Belgium, Denmark, Spain, Italy, Norway, Sweden, Netherlands, and the UK. Austria was excluded because of major territorial changes. Finland, Ireland, Portugal and Greece are not shown as Hatton and Bray's data were incomplete.

Annual data of German military conscripts, born between 1965 and 1985, with information on height

Table 1. Height increases (mm/10 years) of European men since the mid-19th century. Numbers in brackets indicate the national height trends in percent of the European average (Hatton & Bray 2010).

	"prewar"	"transwar"	"postwar"
Birth cohort	**1861–1865 to 1891–1895**	**1891–1895 to 1941–1945**	**1941–1945 to 1976–1980**
European average (mm/10 years)	6.2	10.6	14.4
National height trends in mm/10 years (percent of European average)			
Belgium	2.5 (40)	13.1 (123)	15.9 (110)
Germany	**2.8 (45)**	**14.0 (132)**	**13.7 (95)**
France	3.1 (49)	6.6 (63)	15.0 (104)
Denmark	3.5 (57)	14.2 (134)	15.6 (108)
Italy	4.7 (75)	8.5 (81)	17.0 (118)
Spain	5.2 (83)	5.2 (49)	25.9 (180)
Norway	6.0 (96)	15.2 (144)	4.6 (32)
Netherlands	10.3 (166)	11.3 (107)	19.2 (133)
Sweden	10.3 (166)	8.3 (78)	11.4 (79)
UK	10.7 (172)	10.2 (96)	7.1 (49)

and school education were obtained from the Institut für Wehrmedizinalstatistik und Berichtswesen, 56626 Andernach, Germany, by courtesy of Dr. Kai Uwe Spaniol. As military conscription was compulsory, the data were considered representative for all German males aged 19 years. Up to birth cohort 1972 (conscripted before re-unification in 1989), the data comprised West German conscripts, thereafter East and West Germans. East Germans were shorter than West Germans (Hermanussen 1995). As it was not possible to disentangle East and West (Spaniol, personal communication 2016), we excluded the first two post-re-unification cohorts (1973, 1974).

Linear regressions were calculated using Excel (Microsoft Office 2010).

Results

Hypothesis 1. Upward trends in height in the lower social strata are perceived as social challenges yielding similar though attenuated upward trends in the dominant strata

In developed counties, taller stature is associated with higher socioeconomic status and better health (Tyrrell et al. 2016). Magnusson et al. (2006) showed that height at age 18 years is a strong predictor of attained education later in life in Swedish men. This is to an even greater extent, true for historic populations. Kouche (1996) presented data of Japanese students and the general Japanese population since 1870. Whereas the general population increased in height by more than 14 cm (males) respectively 8 cm (females), the height advantage of end-19th century students of some 3 cm over the general population, vanished in the recent cohorts. Öberg (2014) published similar observations in the Swedish population. Sons of fathers with white collar occupations were 4 cm taller than sons of low-skilled manual workers in the first half of the 19th century, but only 2 cm taller in the mid-20th century.

Figure 1 illustrates annual mean height values of German military conscripts born between 1965 and 1985. Even though the secular trend has almost vanished in these recent cohorts, with an average height increase of 2.2 mm/decade, height increments still differ between educational levels. Conscripts from special need schools (lowest educational level) increased by 4.3 mm/decade, conscripts with no final school diploma by 1.9 mm/decade, conscripts with elementary school diploma by 2.2 mm/decade, and conscripts with high school diploma by only 1.2 mm/decade. It is obvious that height increments of high school graduates are attenuated.

Already in 1966 Grimm (1966) considered the improved physical development of apprentices in the former German Democratic Republic after World War II as a signal of overcoming the social differences. In line with current wisdom however, he explained his findings by assuming better food in the working class yet without scientific evidence for truly effective nutritional or health improvements.

Hypothesis 2. Democratization, but also periods of political turmoil that facilitate upward mobility of the lower strata, are accompanied by upward trends in height

European men increased in height by approximately 10 mm/decade since the mid-19th century (Table 1), prewar samples by 6.2 mm/decade, transwar samples by 10.6 mm/decade,

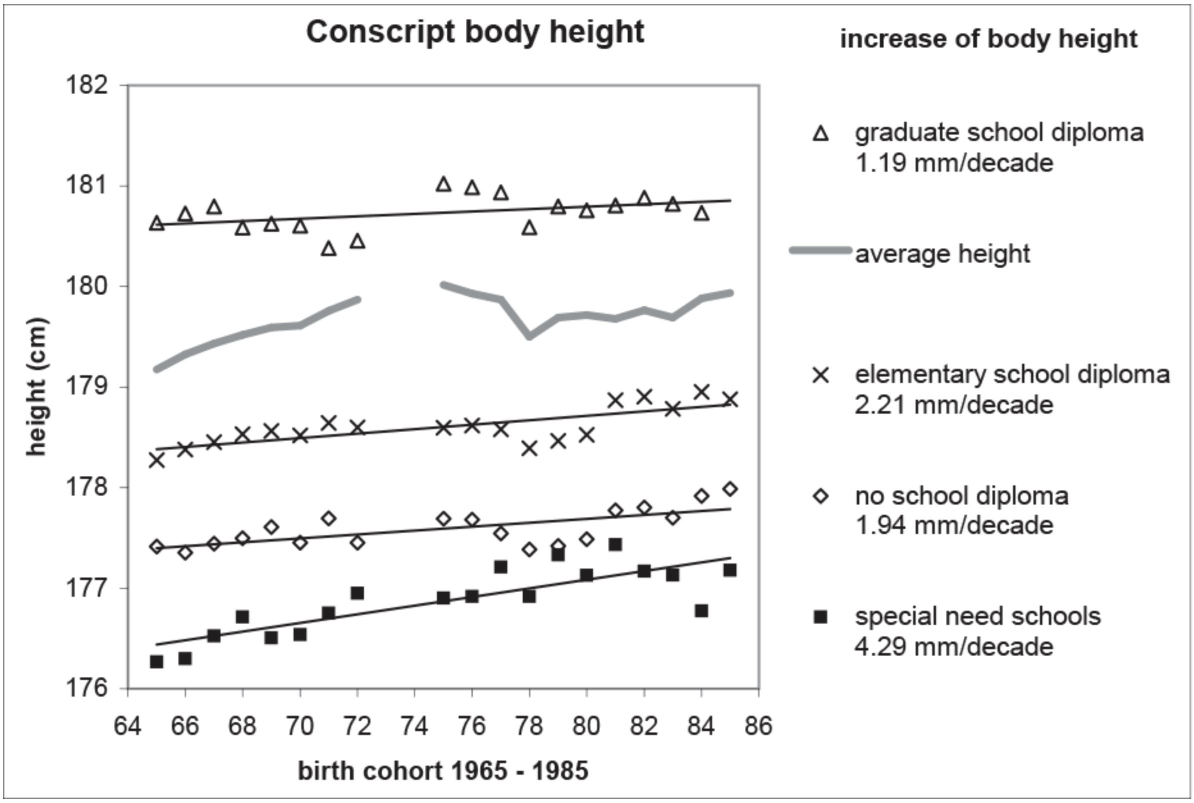

Fig. 1. Annual mean height values of German military conscripts born between 1965 and 1985. Average height increased by 2.2 mm/decade. Conscripts from special need schools (lowest educational level) increased by 4.3 mm/decade, conscripts with no final school diploma by 1.9 mm/decade, conscripts with elementary school diploma by 2.2 mm/decade, and conscripts with high school diploma by 1.2 mm/decade. As it was not possible to disentangle East and West cohorts after re-unification, the first two post-re-unification cohorts (1973, 1974) are excluded.

and postwar samples by 14.4 mm/decade. But the countries differ markedly, even though Europeans may be considered similar in culture, life style and economic conditions. The average increase in height appears to roughly coincide with the gradual changes of political systems. Maximum height increases in the late 19th century were found in the almost modern constitutional monarchies of the United Kingdom, Sweden, and the Netherlands. The picture changed in the first half of the 20th century. Particularly in countries that did not suffer from significant political riots, such as the UK and Sweden, height increases dropped. But as a detailed analysis of the political and economic circumstances of 20th century Europe are beyond the scope of our manuscript, we focus on German data.

After 1850, the states of Germany had rapidly become industrialized, with particular strengths in coal, iron (and later steel), chemicals, and railways. In 1871 the German Empire had a population of 41 million people, and by 1913 this had increased to 68 million. During its 47 years of existence, the German Empire operated as an industrial, technological, and scientific giant. But quite in contrast to the economic prosperity, the political structure was rigid. The German constitutional monarchy was a façade masking the continuation of authoritarian policies. A highly restrictive three-class voting system in which the richest third of the population could choose 85% of the legislature, effectively prevented social mobility (Kühne 1994). During these years, male citizens of the German Empire increased in height by 2.8 mm/decade (45% of the prewar European average).

In 1918 the German Empire collapsed. The following years were characterized by repeated upheavals and severe economic failure. Politics focussed on the working class, and particularly after 1933 fuelled national hubris culminating in megalomaniac slogans like “today we own Germany, and tomorrow the whole world” (popular Nazi song, H. Baumann 1935 (https: //de.wikipedia.org/wiki/Hans_Baumann)). In these years, the secular height trend multiplied by a factor of five: German men increased by 14.0 mm/decade, i.e. 32% above the European average – in spite of severe post World War I starvation and disastrous economic failure. English men increased by 10.2 mm/decade and French by only

6.6 mm/decade during the same historic period. After World War II, European height trends generally increased, but the German trend – in spite of rapid economic recovery – barely reached the European average.

Discussion

We consider stature as a signal and constructed a thought experiment. Thought experiments gain new information by rearranging or reorganizing already known empirical data, and look at these data from a different and often unusual perspective. Thought experiments challenge prevailing explanatory patterns, they try to identify flaws in the line of traditional arguments, to correct misapprehension, and to generate ideas to avoid past failures. Scientists have used thought experiments when particular experiments were difficult or impossible to conduct, such as Einstein's thought experiment of one observer midway inside a moving train and another observer standing on a platform as the train passes by to emphasize essentials of the relativity theory (Einstein 1917).

Common wisdom associates human growth with physical factors, such as genetics, nutrition, health, water, and sanitation, and factors that are related to psychology and economic circumstances. Adult body height is interpreted as the cumulative action of these factors. Optimum/maximum nutrition, health, general living conditions and care giving, are considered essential prerequisites for achieving optimum/maximum height. We do not question that these factors are necessary for growth. But as much as electricity, light bulbs, a certain height and the right physical position at the seashore are needed for the lighthouse to properly exhibit its function, so are genetics, appropriate nutrition, good health, clean water and sanitation needed for child growth.

Stature itself is a lifelong social signal. Social interactions and group behaviour 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). In contrast to meerkats height adjustments in humans take place usually before their final social position is achieved. Height signals an anticipated position within social groups/strata of children and adolescents. Later adjustments of body size are restricted to adjustments in weight. When adolescents migrate and change their social environment, they usually target towards height of the new host population (Spier 1929; Bogin 2012). Bogin (1999; 2010) discussed the growth spurt as a signal of maturation sent to everyone about the changing sexual and social status of the adolescent.

Social interactions and group behaviour has long been studied. Turner & Oakes (1986) discussed social self-concepts of humans and showed that the system of cognitive representations of self is based upon comparisons with other people and relevant to social interaction. Group membership correlates with emotional, evaluative and other psychological parameters. The authors enrolled the concept of a 'self-categorization theory' to explain the social psychological basis of group phenomena, and to identify the mechanisms by which individuals become unified into a psychological group. Conflicts of group interests not only create antagonistic intergroup relations, but also heighten identification with, and positive attachment to, the in-group (Tajfel & Turner 1986). In relevant intergroup situations, individuals will not interact as individuals, on the basis of their individual characteristics or interpersonal relationships, but as members of their groups. If we assume that *strategic growth adjustment* is part of social interactions, the concept of 'self-categorization theory' suggests that members of the same group adjust in height.

Our thought experiment is limited to the interpretation of published retrospective material. Needles to say, this material already underwent critical analyses by their original authors, but we feel that in spite of decades of research, the effect of genetic, nutritional, health-related, and psychological and socio-economic influences on growth is too small to fully explain the trends in global adult human height between and within populations of up to 20 cm.

We take studies on nutrition as an example. Food is essential. People share food. Similarity in food choice, quality and quantity is common within social groups. If *strategic growth adjustment* is part of group behaviour, we expect that within-group similarity in growth relates to within-group dietary preference. In recent years, growth stunting has attracted much attention, as it has statistically been associated with poverty, hunger and health impairment (e.g. Fogel 2004). In line with the understanding that food is essential, food supplementation has become a widely accepted and globally practiced measure for improving growth and physical and psychosocial health of stunted populations. Yet, the conjunction of food and growth is far from being convincing. Already in 2001, Uauy et al. (2001) observed that providing food to low income stunted populations may be beneficial for some, but "it may be detrimental for others", and induce obesity especially in urban areas. In a 2012 Cochrane Database Systematic Review, 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 though the scarcity of available studies still made it difficult to reach firm conclusions supplementary feeding has a negligible impact on child growth. Kristjansson et al. (2015) showed in randomised controlled trials in socio-economically disadvantaged children aged three months to five years that even these children when supplemented, only grew an average of 0.27 cm more over six months than those who were not supplemented. In a meta-analysis of seven controlled before-and-after studies, they found no evidence of an effect on height, whereas meta-analyses of randomised controlled trials demonstrated benefits for weight-for-age z-scores. The observation that weight and height are not necessarily intertwined, is not new. In 1935 Koch (1935) explicitly stated: "physical exercises and more abundant food were quite handsome explanations for the increase in linear growth. But, **linear growth has been demonstrated to be almost independent of these two factors**. It has neither been possible to achieve height increases by physical exercises, nor does particular abundance of food appear to be a prerequisite for growth at all. Size recklessly increases even during marked undernutrition ... until the body has wasted its last depot. One might talk about ***parasitic growth in length***; and that "as far as the quality of the food is concerned, a certain increase in the consumption of fresh vegetables, fruit and fish must be assumed. But it appears doubtful if this overconsumption applies to all strata of the population (he mentions the unemployed). It is very unlikely that the type of diet has fundamentally changed in the rural population; nevertheless Hofmann et al. (1933) were able to show even in them, concordant length increments". Also a small recent pilot study in kindergarten children, aged 3–6 years, failed to detect any significant association between daily macro- and micro-nutrient intake and body height (Pospisil et al. 2016).

Mumm et al. (2016a) studied the within-population variation in height and weight in 833 recent and historic growth studies from 78 different countries and concluded that height gains and weight gains do not depend on each other, and are subject to different regulation. Mumm et al. (2016b) showed in a meta-analysis of 152 studies with data on infants and 287 studies with data on juveniles, from 71 countries published since 1974 that within-country body height variance is also independent from economic prosperity measured by GDP per capita in current US$ (gross domestic product divided by midyear population) and Gini coefficients as an indicator of income inequality. The study provides indirect evidence that height in 7-year old children does not depend on affluence.

Our thought experiment suggests that under usual conditions, body height is decoupled from energetic and socioeconomic variables. For reasons mentioned above, we also question the impact of heritability on height. It is self-evident that the genome plays a role in growth. Yet, contrasting common wisdom, we do not assume that a tall person is tall because he possesses particular "tall genes", we assume that the genome provides the framework for adaptive plasticity. A tall person is tall because adaptive plasticity allows strategic tallness within his social group.

Indirect evidence for the impact of spatial connectedness on height was provided by Hermanussen et al. (2014) who investigated cohorts of Swiss conscripts conscripted in 1884–1891, in 1908–1910, and in 2004–2009. They showed that height within a district is related to height of physically connected neighboring districts. The correlations depend on the order of connectedness, and decline with increasing distance. Very similar data have been obtained from modern Polish military conscripts (Gomula et al. 2016) and from historic Norwegian military conscript data (Bents & Groth 2016). Recent Monte Carlo simulation of height further strengthens the concept of spatial connectedness being involved in the regulation of human height (Hermanussen et al. 2016). In additional simulations, Groth (2016) modelled possible contributions of asymmetric migration, with preferred migration of taller individuals into districts which are network hubs. He showed that trends in height similar to natural trends require network properties that are very different from the real world situation. Koziel & Gomula (2016) provided direct evidence of reduced variance of height and BMI in 14 year old girls who attended the same school classes. Similar data were obtained from kindergarten children. Except for the first weeks of life, height z-scores of kindergarten children attending the same play group within a kindergarten, vary less than expected (Czernitzki pers. comm. 2016).

The thought experiment raises new questions, in particular, regarding consequences of misfit between stature and status. Adjustments to body height are limited to the time span until early adulthood is reached. What happens when stature and status do not match? The "Napoleon complex" describing a theorized condition of aggressive misbehaviour occurring in people of short stature, has attracted much public attention (e.g. http://www.dailymail.co.uk/sciencetech/article-3125722/Are-short-men-little-Napoleons-s-said-smaller-men-tend-chippy-aggressive-s-scientific-evidence.html). After adolescence size adjustments are limited to weight. When considering that weight may also serve as a social signal of wealth, and specifically in women, of fertility, Rubens' voluptuous ladies, and the plump faces of baroque burgomasters and wealthy merchants depicted by local artists at all centuries, may be seen from a different perspective: obesity as a signal of preferences and social dominance in those who perceive themselves as in need for strategic size adjustments.

The endocrinology of *strategic growth adjustments* in humans is unknown. Several authors describe the association between social dominance, sex steroids, and size in non-human primates. Sapolsky & Spencer (1997) studied the association between acquisition of dominance and Insulin-like growth factor-1 (IGF-1) in baboons. IGF-1 has a fundamental role in the regulation of metabolism and growth of the human body (Blum & Schweizer 2003; Savage et al. 2010; Hwa et al. 2013). Prior to adulthood, a deficiency of GH, IGF-1, their cell receptors, or their signal transducers (JAK2, STAT5b, etc.) results in growth retardation and short stature. On the other hand, children and adolescents with pituitary gigantism have an excessive production of GH, with highly elevated IGF-1 levels (Bogin 2013). The central role of GH and IGF-1 in human growth is well studied. Unden et al. (2002) showed positive correlations between IGF-1 and psychosocial factors in humans representing quality of life and psychological well-being, better physical health and higher education. And in 2008, Kumari et al. (2008) showed that IGF-1 secretion is associated with social position measured by father's or own occupational class. Lower IGF-1 levels were associated with lower social position measured with father's occupational class at birth and own occupational class aged 42 years. Adult social position was associated with IGF-1 independently of social position at birth. Bogin et al. (2015) investigated the relationship between IGF-1, assessed via finger-prick dried blood spot, and elite level sport competition outcomes. They showed a statistically significant difference between winners and losers of a competition and discussed the relation to the action of the growth hormone/IGF-1 axis as a transducer of multiple bio-social influences into a coherent signal which allows the growing human to adjust and adapt to local ecological conditions.

Conclusions

Based on evidence of competitive growth strategies in meerkats suggesting that social dominance is a stimulus for growth, we explored the potential consequences of stature being a lifelong social signal also in humans. In a thought experiment we partially refute the prevailing theories of substantial influences of genetics, nutrition, health and socioeconomic circumstances on human growth and instead establish the hypothesis that growth is socially targeted. Stature is a lifelong social signal. Historic data on upward height trends during periods of equal opportunities, but also during periods of political turmoil facilitating upward social mobility, strongly support this vision. The fact that competitive growth strategies are examinable in meerkats suggests new ways for randomized prospective scientific trials in animals to study *strategic growth adjustments* and to elucidate the underlying mechanisms of social growth targeting and the height trends that are found in humans.

The physiological mechanism of social growth targeting is unknown. As vivid discussions have already occurred citing the concept of "Mind over matter", a phrase that has been used in several spiritual and philosophical contexts, we want to clearly stress that we consider *strategic growth adjustments* an important biological and not a spiritual concept. The "threat of being displaced" is ubiquitous and evolutionary relevant. Nobody wants to lose the edge over his position. Even though biological data supporting the interaction between group behaviour and physical growth are still speculative, competitive growth strategies appear to be a universal pattern in social mammals and may also be relevant in humans (Huchard et al. 2016). They may be responsible for the characteristics such as the amazing narrowness in height distributions of historic and modern cohorts of military conscript, and we assume that much of the 15 cm to 19 cm secular increment in European adult height since the mid-19th century results from *strategic growth adjustments* in societies that have increasingly been opened to upward social mobility and concomitant readjustments of target heights.

Acknowledgements: Thanks are due to Prof. Barry Bogin, Loughborough, UK, for his magnificent and long-lasting support in discussing and constructing this manuscript. Thanks are due to Dr. Kai Uwe Spaniol, Institut für Wehrmedizinalstatistik und Berichtswesen, 56626 Andernach, Germany, who provided the German military conscript data. The study was supported by The Auxological Society (German Society for Auxology).

References

Aßmann, C. & Hermanussen, M. (2013): Modeling determinants of growth: evidence for a community-based target in height? – Pediatr. Res. 74: 88–95.

Bents, D. & Groth, D. (2016): Spatial conscript body height correlation of Norwegian districts in the 19th century. – Anthropol. Anz. doi:10.1127/anthranz/2016/0701.

Bercovitch, F.B. & Clarke, A.S. (1995): Dominance rank, cortisol concentrations, and reproductive maturation in male rhesus macaques. – Physiol. Behav. 58: 215–221.

Blum, W.F. & Schweizer, R. (2003): Insulin-like growth factors and their binding proteins. – In: Ranke, M.B. (eds): Diagnostics of Endocrine Function in Children and Adolescents. – Karger, Basel.

Bogin, B. (1999): Patterns of human growth. 2nd ed. – Cambridge University Press, Cambridge.

Bogin, B. (2010): Evolution of Human Growth. – In: Muehlenbein, M.P. (ed.): Human evolutionary biology. – Cambridge University Press, Cambridge.

Bogin, B. (2013): Secular changes in childhood, adolescent and adult stature. – Nestle Nutr. Inst. Workshop Ser. 71: 115–126.

Bogin, B., Hermanussen, M., Blum W.F. & Aßmann, C. (2015): Sex, Sport, IGF-1 and the Community Effect in Height Hypothesis. – Int. J. Environ. Res. Public Health 12: 4816–4832.

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

Clark, G. & Cummins N. (2014): Surnames and social mobility in England, 1170–2012. – Hum. Nat. 25: 517–537.

Cowlishaw, G. & Dunbar, R.I.M. (1991): Dominance rank and mating success in male primates. – Anim. Behav. 41: 1045–1056.

De Waal, F. (1986): The integration of dominance and social bonding in primates. – Quart. Rev. Biol. 61: 459–479.

Einstein A. (1917): Über die spezielle und allgemeine Relativitätstheorie. – Sammlung Vieweg Heft 38. – Vieweg, Braunschweig.

Eveleth, P.B. & Tanner, J.M. (1990): Worldwide variation in human growth, 2nd ed. – Cambridge University Press, Cambridge.

Fogel, R.W. (2004): The escape from hunger and premature death, 1700–2100. – Cambridge University Press, Cambridge, New York, Melbourne.

Formicola, V. & Giannecchini, M. (1999): Evolutionary trends of stature in upper Paleolithic and Mesolithic Europe. – J. Hum. Evol. 36: 319–333.

Fredriks, A.M., Buuren, S.v., Burgmeijer, R.J.F., Meulmeester, J.F., Beuker, R.J., Brugman, E., Roede, M.J., Verloove-Vanhorick, S.P. & Wit, J.M. (2000): Continuing positive secular growth change in the Netherlands 1955–1997. – Ped. Res. 47: 316–323.

Gomula, A., Koziel, S., Groth, C. & Bielicki, T. (2016): The effect of neighboring districts on body height of Polish conscripts. – Anthropol. Anz. doi:10.1127/anthranz/2016/0701.

Grimm, H. (1966): Grundriss der Konstitutionsbiologie und Anthropometrie. 3rd ed. – Volk und Gesundheit, Berlin.

Groth, D. (2016): Modeling a secular trend by Monte Carlo simulation of height biased migration in a spatial network. – Anthropol. Anz. doi: 10.1127/anthranz/2016/0703.

Hatton, T.J. & Bray, B.E. (2010): Long run trends in the heights of European men, 19th-20th centuries. – Econ. Hum. Biol. 8: 405–413.

Hermanussen, M. (1995): Die Körpergröße deutscher Wehrpflichtiger vor und nach der deutschen Wiedervereinigung. Ein Beispiel für den Einfluß politischer Veränderungen auf das Wachstum junger Männer. – Med. Welt 46: 395–396.

Hermanussen, M., Aßmann, C., Staub, K. & Groth, D. (2016): Monte Carlo simulation of body height in a spatial network. – Eur. J. Clin. Nutr. 70: 756. doi: 10.1038/ejcn.2016.71.

Hermanussen, M., Burmeister, J. & Burkhardt, V. (1995): Stature and stature distribution in recent West German and historic samples of Italian and Dutch conscripts. – Am. J. Hum. Biol. 7: 507–515.

Hermanussen, M., Scheffler, C., Groth, D. & Aßmann, C. (2015): Height and skeletal morphology in relation to modern life style. – J. Physiol. Anthropol. 34: 41.

Hofmann (1933): Zeitschrift für Gesundheitsverwaltung und Gesundheitsfürsorge. 4 vol. 7.

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.

Hwa, V., Fang, P., Derr, M.A., Fiegerlova, E. & Rosenfeld, R.G. (2013): IGF-I in human growth: Lessons from defects in the GH-IGF-I axis. – Nestle Nutr. Inst. Workshop Ser. 71: 43–55.

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.

Koch, E.W. (1935): Über die Veränderung menschlichen Wachstums im ersten Drittel des 20. Jahrhunderts. – Barth, Leipzig.

Kouche, M. (1996): Secular change and socioeconomic difference in height in Japan. – Anthropol. Sci. 104: 325–340.

Koziel, S. & Gomula, A. (2016): Variation of height and BMI within school classes in 14-year-old children. – Anthropol. Anz. doi: 10.1127/2016/0702.

Kristjansson, E., Francis, D.K., Liberato, S. et al. (2015): Food supplementation for improving the physical and psychosocial health of socio-economically disadvantaged children aged three months to five years. – Cochrane Database Syst. Rev. 3: CD009924.

Kühne, T. (1994): Handbuch der Wahlen zum Preußischen Abgeordnetenhaus. 1867–1918. Wahlergebnisse, Wahlbündnisse und Wahlkandidaten (Handbücher zur Geschichte des Parlamentarismus und der politischen Parteien 6). – Droste Verlag, Düsseldorf.

Kumari, M., Tabassum, F., Clark, C., Strachan, D., Stansfeld, S. & Power, C. (2008): Social differences in insulin-like growth factor-1: Findings from a British birth cohort. – Ann. Epidemiol. 18: 664–670.

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.

Magnusson, P.K., Rasmussen, F. & Gyllensten, U.B. (2006): Height at age 18 years is a strong predictor of attained education later in life: cohort study of over 950,000 Swedish men. – Int. J. Epidemiol. 35: 658–663.

Marsh, A.A., Henry, H.Y., Schechter, J.C. & Blair, R. (2009): Larger than life: humans' nonverbal status cues alter perceived size. – PLoS ONE 4: e5707.

Meazza, C., Pagani, S. & Bozzola, M. (2011): The pygmy short stature enigma. – Pediatr. Endocrinol. Rev. 8: 394–399.

Mumm, R., Ipsen, M.J. & Hermanussen, M. (2016a): The association of weight, weight variability and socioeconomic situation among children. – Eur. J. Clin. Nutr. 70: 650–652.

Mumm, R., Czernitzki, A.F., Bents, D. & Musalek, M. (2016b): Socioeconomic situation and growth in infants and juveniles. – Anthropol. Anz. doi: 10.1127/2016/0706.

NCD Risk Factor Collaboration (NCD-RisC) (2016): A century of trends in adult human height. – eLife2016;5: e13410. DOI: 10.7554/eLife.13410.

Ngure, F.M., Reid, B.M., Humphrey, J.H., Mbuya, M.N., Pelto, G. & Stoltzfus, R.J. (2014): Water, sanitation, and hygiene (WASH), environmental enteropathy, nutrition, and early child development: making the links. – Ann. N.Y. Acad. Sci. 1308: 118–128.

Öberg, S. (2014): Long-term changes of socioeconomic differences in height among young adult men in Southern Sweden, 1818–1968. – Econ. Hum. Biol. 15: 140–52.

Padez, C. (2002): Stature and stature distribution in Portuguese male adults 1904–1998: the role of environmental factors. – Am. J. Hum. Biol. 14: 39–49.

Pospisil, C., Czernitzki, A.F. & Scheffler, C. (2016): No association between nutrition and body height in German kindergarten children – a pilot study. – Anthropol. Anz. doi: 10.1127/anthranz/2016/0704.

Sapolsky, R.M. & Spencer, E.M. (1997): Insulin-like growth factor I is suppressed in socially subordinate male baboons. – Am. J. Physiol. 273 (4 Pt 2): R1346–51.

Savage, M.O., Burren, C.P. & Rosenfeld, R.G. (2010): The continuum of growth hormone-IGF-I axis defects causing short stature: Diagnostic and therapeutic challenges. – Clin. Endocrinol. (Oxf.) 72: 721–728.

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. 6: CD005039.

Spier, L. (1929): Growth of Japanese children born in America and in Japan. – University of Washington Publication in Anthropology, Vol. 3 No 1.

Staub, K., Rühli, F. & Woitek, U. (2013): Impact and Pitfalls of Conscription data. – In: Hermanussen, M. (ed.): Auxology: Studying Human Growth and Development. – Schweizerbart, Stuttgart, pp. 146–147.

Tajfel, H. & Turner, J.C. (1986): The social identity theory of intergroup behaviour. – In: Worchel, S. & Austin, W.G. (eds): Psychology of intergroup relations. 2nd ed. – Nelson-Hall, Chicago, pp. 7–24.

Turner, J.C. & Oakes, P.J. (1986): The significance of the social identity concept for social psychology with reference to individualism, interactionism and social influence. – Brit. J. Soc. Psychol. 25: 231–252.

Tyrrell, J., Jones, S.E., Beaumont, R., Astley, C.M., Lovell, R., Yaghootkar, H., et al. (2016): Height, body mass index, and socioeconomic status: mendelian randomisation study in UK Biobank. – BMJ 352: i582. doi: 10.1136/bmj.i582.

Uauy, R., Albala, C. & Kain, J. (2001): Obesity Trends in Latin America: Transiting from Under- to Overweight. – J. Nutr. 131: 893S–899S.

Unden, A.L., Elofsson, S., Knox, S., Lewitt, M.S. & Brismar, K. (2002): IGF-I in a normal population: relation to psychosocial factors. – Clin. Endocrinol. (Oxf). 57: 793–803.

van Wieringen, J.C. (1972): Secular changes of growth. 1964–1966 height and weight surveys in the Netherlands in historical perspective. – Netherlands Institute for Preventive Medicine TNO, Leiden.

Young, T.J. & French, L.A. (1996): Height and perceived competence of US presidents. – Perceptual and Motor Skills 82: 1002.

Manuscript received: 16 August 2016

Accepted: 22 August 2016