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Stunting, starvation, and refeeding - a review of forgotten 19th and early 20th century literature

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Key notes

Background: Stunting is commonly associated with poor living conditions, inappropriate nutrition and poor health. Late 19th and early 20th century Europeans independent of social strata, were stunted according to WHO standards.

Main findings: Already shortly after World War I, German paediatricians concluded that: *"the child's longitudinal growth is largely independent of the extent and nature of the diet".* Height catch-up after starvation was significantly greater, and allowed for unimpaired adult height, than height catch-up reported in modern nutrition intervention studies.

Interpretation: The appropriateness and effect size of modern nutrition interventions on child growth need revision.

ABSTRACT

Background: Stunting is a major global issue in child health, and commonly associated with poor living conditions, inappropriate nutrition and poor health.

Aim: To scrutinize to what extent modern ideas on nutrition effects on growth are supported by historic observations in European populations.

Method: We reviewed 19th and early 20th century paediatric journals in the Staatsbibliothek zu Berlin, the third largest European library with an almost complete collection of the German medical literature. During a three-day visit, we inspected 15 bookshelf meters of literature not available in electronic format.

Results: Late 19th and early 20th century breastfed European infants and children, independent of social strata, grew far below World Health Organisation (WHO) standards and 15-30% of adequately-fed children would be stunted by the WHO standards. Historic sources indicate that growth in height is largely independent of the extent and nature of the diet. Height catch-up after starvation was greater, and allowed for unimpaired adult height, than catch-up reported in modern nutrition intervention studies.

Conclusion: Historical studies are indispensable to understand why stunting does not equate with undernutrition and why modern diet interventions frequently fail to prevent stunting. Appropriateness and effect size of modern nutrition interventions on growth need revision.

INTRODUCTION

Stunting is a major global issue in child care, and is commonly associated with poor living conditions, inappropriate nutrition and poor health. Good nutrition is considered crucial to both individual and national development. Electronic searches in PubMed using the terms “child and nutrition and intervention and review” meanwhile result in more than 4,000 entries published since the mid-1960s. Series of papers published in the Lancet in 2008 and 2013, summarised the evidence base that good nutrition is a fundamental driver of a wide range of developmental goals (1). In 2016 Dewey (2) reviewed the complex and context-specific background to linear growth restriction and stunting as well as more recent efforts to reduce stunting by improving maternal, infant and young child nutrition. The effect of food and nutrient interventions is, at best, modest. Dewey suggested a more comprehensive approach, including intervention packages to improve nutrition during both pregnancy and the post-natal period, prevention and control of prenatal and post-natal infection and subclinical conditions that restrict growth, care for women and children and stimulation of early child development.

The biological importance of food on growth is unquestionable – no food, no growth. But the efficacy of nutrition interventions in low-income stunted populations appears questionable. Uauy et al (3) observed that providing food to these populations may be beneficial for some, but “it may be detrimental for others” and induce obesity especially in urban areas. In a 2005 Cochrane Database Systematic Review, Sguassero et al (4) reported a positive effect on length (cm) in a nutrition-supplemented group compared to controls (mean difference 1.3cm, CI (0.03cm–2.57cm) 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 (5) carried out a meta-analysis of community-based supplementary feeding in children under 5 years of age in low-income and middle-income countries and concluded that

supplementary feeding has a negligible impact on child growth. Even socioeconomically disadvantaged children, when supplemented, only grew an average of 0.27cm more over 6 months than those who were not supplemented (6). The data did not question that severe starvation coincides with growth inhibition, but the net effect of nutrition on body height was generally small (7). Goudet et al (8) reviewed interventions to tackle malnutrition and its risk factors in children living in urban slums. The authors found 22 intervention studies of which 10 increased weight, mostly body fat, and 6 increased length or height. The typical length increase was less than 1cm, and often close to measurement error.

Nutrition interventions in low-income and middle-income countries are laudable. But why are these efforts so disappointing? We aimed to scrutinize to what extent the modern ideas on nutrition effects on growth are supported by historic observations in European populations. We started approaching this question by studying the situation of mass starvation and refeeding in the recent European history, and re-read medical literature published in German at the end of the 19th and in the beginning of the 20th century that focused on the nutritional situation before, and during the period of starvation and subsequent refeeding after World War One, and is not available electronically. We considered the severely undernourished historic European populations an appropriate natural control for comparison with modern stunted Third World populations. For this purpose, we reviewed 15 shelf meters of 19th and early 20th century paediatric journals, and literature published by school doctors.

We did not only intend to read and republish parts of this forgotten material, but also to encourage efforts to fully digitalise and translate this material to make it accessible for electronic search engines, and the English speaking scientific community.

MATERIAL

Comprehensive collections of literature are available on starved and refed early 20th century central European populations. Based on two seminal reviews on child growth and development published after World War One by Koch (9) and Schlesinger (10), we first generated a list of journals that were most frequently mentioned as publication outlets for manuscripts on child growth and development, with particular preference to manuscripts on child nutrition. Co-authors MH and CS performed this literature research in the Staatsbibliothek zu Berlin, Unter den Linden 8, 10117 Berlin, Germany, the third largest European library with an almost complete collection of the German medical literature. We limited our approach to a three-day intensive working visit and browsed 15 bookshelf meters.

We searched for: material on child growth and nutrition. We included publications that presented data obtained from healthy children and children who suffered from undernutrition due to war, or from other environmental constraints. We excluded most case studies, and studies on pathological conditions as these conditions did not meet modern diagnostic criteria. Publications on general considerations based on outdated concepts in biology were also excluded. We visited some 25,000 pages in 16 pediatric and school doctors' journals. We detected 66 publications of primary interest in 9 of these journals. Most of the 19th century material was visited page by page. Later material was partially visited by title as in the later years it became common practice to also publish lists of titles. Table 1 summarizes basic information including short comments of those publications that were primarily selected and photographed. Twenty-six studies contained unknown details on child growth (including individual growth patterns, seasonality of growth, social influences on growth and particular patterns of growth during starvation and refeeding) from which we took some 2,500 photographs. Historic scientific literature differs from modern literature in many ways. None of the 26 publications are "studies" in the modern sense. They were written in the style of a novel, mostly without clear design, often without information on sample size, and usually without quality assessments. None of these studies are electronically available, none are translated into English, and therefore are not just forgotten, but may truly be considered lost

for the international scientific community. As we report on historic literature, there was no need for ethics committee approval.

RESULTS

Nineteenth and early 20th century auxology

Newborn and infant nutrition and growth was the priority among the early auxological contributions both in number of publications and their size in pages. Amazingly detailed case histories, often including daily measures of breastmilk quantities, were frequently published (11-14). In those days, infant growth was remarkably poor, even the majority of the breastfed infants of the upper social class (15) grew below modern World Health Organisation (WHO) standards (16).

In parallel with trajectories of individual growth (17), people became interested in the general patterns of growth. In 1869 Schuller (18) reviewed one of the first German scientific books on human growth (19). He republished several tables that, however, contained rather dubious material. A few years later, some scientifically more sound American papers, e.g. the work of Bowditch in Boston (20), and Porter in St. Louis (21) became known and was also cited in the German literature on child growth.

Based on large sets of cross-sectional data, laws of human growth were developed (22). Height and weight differences between children of the different social strata were observed by Schmidt and Lessenich (23) and extensively discussed in view of previous literature. The authors confirmed observations by Porter (21) on the positive relation between physical development (height and weight) and learning achievements.

'Big data' on up to several tens of thousands of children and adolescents from official urban school investigations were regularly published by the authorities from various German, Swiss and Austrian cities (24-26) to evaluate the nutritional situation. For this purpose, Bartsch (27) used mid-upper-arm circumferences that had earlier been introduced by Oppenheimer (28). Seasonal variation in growth was studied by Schmid-Monnard (29) and discussed in the light of earlier Danish publications (30). He observed that the greatest gains in weight between September and January coincided with the least gains in body height. He considered the discrepancy between weight gain and height gain as evidence that growth in height is independent of nutrition. Similar findings were reported some 90 years later in 5.0 to 6.9-year-old children from very high SES, attending the American School of Guatemala. They were very well-fed throughout the year, but about 70% of the sample of 48 boys and girls grew fastest in height during the dry season and slowest in the rainy season when their mean gain in weight was greatest (31,32).

Papers on nutrition

In 1916, the German paediatrician Meinhard von Pfaundler (33) summarised body mass studies in children before World War One. He discussed differences in developmental tempo, the differential onset of puberty, and its effect on height variance at mid-adolescence. It was known that children raised under affluent conditions, were taller and matured earlier.

Even though Pfaundler considered food as a potentially influencing factor, he 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".* And regarding infant growth, he stated: *"Moreover, we find that the degree of short stature among healthy poor children is very minor in the first year of life".* He proposed that the deficit in body length also of the poor children did not occur

before the second year of life. In those days, infants of both the wealthy and the poor grew considerably below modern standards.

In order to further scrutinise social differences in body height, Pfaundler introduced Livi's (ponderal) index. Livi's index (100 * $\sqrt[3]{weight}$ / *body height*) relates the cube root of weight to height, and was considered to better mirror the nutritional state than body weight alone with arguments similar to those used today to recommend the Body Mass Index (BMI). The fact that Livi's index of the short lower-class school children were some 2% larger than the index of wealthy children (33) was used as proof against a potential role of nutrition on growth before World War One. Even though he later recognised that undernutrition during the 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's index)*. 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"*.

Shortly after World War One, the American Quaker Children's Aid Mission offered additional meals to undernourished German schoolchildren and requested from the German pediatricians to better define undernutrition and to develop criteria for classifying the degree of undernutrition of a given child. In view of this request, Pfaundler (34) recommended another index that had recently been introduced by Pirquets. The index ignored leg length and thus appeared to better mirror the nutritional status.. This "pelidisi" (($\sqrt[3]{10 * weight}$) / *sitting height, Pondus dEcies LInear DIviso SedentIs altitudo*) was then thoroughly discussed and appreciated by Wagner in his work on the numerical assessment of the nutritional status (35). Wagner stated that "the precondition for the usability of a body fullness index (Wagner discussed possibilities to better define a state of undernutrition) is that it represents an unnamed ratio derived from the division of equidimensional quantities". He rejected indices

such as weight-for-height because they divide a three-dimensional size, the weight, by a one-dimensional length, which results in an area. Yet, in spite of these thoughts, the pelidisi was never widely accepted and eventually disappeared from the literature presumably due to arithmetic clumsiness at a time when computers did not exist. In 2015, Burton (36) presented similar thoughts recommending that BMI be replaced by an index of body build that is less dependent on relative leg length and age in children and adults than are the BMI and the Rohrer Index, and proposed Weight/Sitting Height^3. Shortly after World War One, Schlesinger (37) summarised growth of children and adolescents during the war stating: *"The child's longitudinal growth is largely independent of the extent and nature of the diet ... Even during severe dietary restrictions, impairments of infant growth are markedly small, and occur slowly and delayed. Only during severe infectious nutritional disorders of the infant ... Stolte and others (38) observed a temporary growth inhibition... Malnourished infants show an inhibition of longitudinal growth only, and especially during periods of reparation, when food supplies, e.g. breast milk, was low in protein and minerals, but they quickly recovered when given protein rich milk".*

Impairment of body height is not a sudden event, but occurs during long-term starvation. Regarding school children Schlesinger wrote: *"In the second year of the war, 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.

In the following years, Schlesinger realised that due to the war the number of very tall adolescents temporarily decreased, and that the onset of the pubertal growth spurt tended to be later than before. Nevertheless, his final conclusion was that: *"the whole growth disturbance described here is to be regarded as a simple inhibition; the type of growth, the growth curve did not undergo any significant change in its form, except for the slight delay in*

the pubertal drive, the onset of puberty". Based on measurements of the loss in body fat, both in absolute terms and related to body height, he again argued that: *"even more regular is the deficit in weight in 1916 versus 1913, when taking into account the length of the body, which in this period has partly shifted in the opposite direction"*.

In summary, these studies were in line with common understanding: Undernutrition leads to weight loss and reduces growth velocity. But what happens when starving children are being refed?

Recovery from starvation is a different topic. Refeeding is usually characterised by marked catch-up in height, and in weight, both at the individual and at the population level. Schlesinger (39) summarised his observations on length and weight changes in school children after the war: *"The years 1921 and 1922 are marked by a significant improvement, an increase of average body height at almost all ages, especially in the elementary school in working class children; particularly in view of the shortest stature in 1919 and 1920, we may sometimes talk about saltatory height increments with average values surpassing those of previous years sometimes by 3 or 4, or even 5cm".* He stated that: "*with improving nutritional conditions, especially in the sense of quality, with more abundant contents of fat, protein, and supplements, the improvement in longitudinal growth … is generally more pronounced than the elevation in body weight*. *The young organism uses the nutritional components now available … to first recover the growth deficit, and much later to fill up the fat deposits. The organism presses to recover the inhibition which is by no means irreparable; on the contrary, it is very accessible to reparation".*

It is important to emphasise that Schlesinger observed that first the deficit in height recovers, and second the deficit in weight. Immediate catch-up in height was pathognomonic for preceding growth impairments.

Goldstein (40) analysed case studies and general patterns of weight and height gain of severely undernourished Berlin school children during refeeding. Catch-up growth in height of on average 3cm within 6 weeks was reported (41) in children from Jena who were sent for refeeding to Switzerland. The historic sources outlined that catch-up growth during refeeding was characterised by a short period of excessive, sometimes saltatory growth of up to several centimetres within a few weeks. Catch-up in height usually terminated when the height deficit was corrected, with no further increments even when abundant feeding was continued, catch-up in weight may continue beyond the previous state. Goldstein demonstrated this with individual weight curves. He considered added fatness to be the reason for the continuing weight increases.

Apart from the lack of evidence of associations between food and growth, we also detected interesting observations focused on the impact of chronic illness on child growth. School children who recovered from rickets, were not shorter than unaffected children. Measles, scarlet fever and pneumonia were listed among those illnesses that after recovery promoted, rather than impaired, overall growth, contrary to what the modern paediatrician would expect. These observations were not singular, we found multiple mentioning that particularly tuberculosis appears to stimulate growth. Schiötz (42) summarised much of this work and quantified the growth stimulation by tuberculosis mentioning an average height of 175cm for male Norwegian tubercular adults versus 170cm for healthy non-tubercular adults. Interestingly, Schiötz discussed the possibility of a higher susceptibility to tuberculosis of tall people and thus, introduced very modern aspects of life history theory treating this as trade-off between growth versus immune function.

Irrespective of our focus on war and starvation, we also came upon several sources on birth measures and infant growth (table 1). Birth weight was close to that of modern Europeans, but the subsequent length and weight increments of infants and children were less. The

developmental tempo appeared slower than today, and puberty was late (43). The average child was short and stout. Figure 1 illustrates mean height and BMI z-scores of two growth references of, presumably, adequately-fed children and youth that were often cited in the late 19th and early 20th century: the Boston study published in 1877 by Bowditch (20), and the German data originally published by Camerer in 1893 (44) and reviewed by Pirquet in 1913 (45). Z-scores refer to the WHO Multicentre Growth Reference Study (16) and the WHO growth reference for school-aged children and adolescents (46). Even though historic data on height variance are missing, we may assume that height was normally distributed and roughly estimate that 15-20% of the healthy Boston children in 1877 and 25-30% of the healthy German children in 1893 were stunted at age six, according to the WHO references.

DISCUSSION

Science forgotten, science lost

During the three-day working visit to the Staatsbibliothek zu Berlin, we screened medical literature published at the end of the 19th and in the beginning of the 20th century that focused on the nutritional situation before, and during the period of starvation and subsequent refeeding after World War One. We detected comprehensive material on child growth and the nutritional situation during these decades. The abundance of food in the wealthy strata of Imperial Germany before World War One is well documented, so is the disastrous undernutrition of a large portion of the civilian population after 1916, and the slow recovery in the early 1920s, summarising in detail the clinical signs of child starvation and refeeding. Among thousands of paediatric publications, we identified 26 papers that appeared of interest for the modern reader. All the material reviewed is not electronically available, it is in the German language, and not cited in the current literature on child stunting.

At first view the historic observations seem to support the popular perception that starving negatively affects child growth, and refeeding results in catch-up. But the historic sources provide much more detail. The studies highlighted the temporariness of the effects of starving on growth, in particular, the suddenness and great magnitude of the almost saltatory catch-up following refeeding (41), and the absence of permanent effects on adult height. Shortly after World War One, Schlesinger (37) explicitly stated: *"The child's longitudinal growth is largely independent of the extent and nature of the diet*. This statement diametrically opposes modern statements such as Prendergast and Humphrey (47) who summarized in 2014: *"Linear growth failure is the most common form of undernutrition globally"*.

This contradiction is a dilemma and it is difficult to explain. On the one hand, one may consider undernourished historic European populations being inappropriate natural controls for comparison with modern stunted Third World populations. One the other hand, one may blame a lack of familiarity and understanding of the historic literature. The majority of the ample and well-documented historic material on European child growth is stored in libraries, but few researchers make physical visits to library shelves these days. The non-English historic studies may be difficult to access directly, but many early growth studies were summarised by James Tanner (48) and Edith Boyd (43) in their books covering the history of the study of human growth. More recent data on starvation studies reviewed by Keys et al in 1950 (49) also questioned the association of food and growth in height. This material is rarely cited by those people designing and promoting the efficacy of modern food and nutrient interventions. The result is that most of lessons of the past appear lost, forgotten, and the non-English material is generally unavailable for the English-speaking researcher.

We detected a final reference to the lack of association between weight and height in a German paper published by de Rudder in 1960 (50) referring to the well-fed but short upper-class children of Munich at the beginning of the 20th century versus the malnourished

children shortly after the monetary reform in 1948 that were much taller. After 1960, no more scientific work was found on the lack of association between food and growth. Instead, American publications now focused on height deficits in Third World countries and again started to link short stature to undernutrition. We note especially the seminal articles by Seoane and Latham in 1971 (51) and by Waterlow (52). These articles provided a medical classification of malnutrition based on height-for-age. The diagnosis of "stunting" became a synonym for "chronic malnutrition". This purely anthropometric definition of nutritional status was discussed in detail in a World Health Organization 1971 report (53) and became quite broadly accepted after publication of a Nestlé nutrition workshop in 1988 (54). Evidence is mounting, however, that this late-20th century wisdom is not accurate. Dr Noel Solomons recently presented a review of contradictory research and concluded that any essential, "…nutrient deficiencies can cause growth impairment, but not all growth impairment in humans is attributable to a nutrient deficiency problem" (55).

History of science and medicine is too often considered a field separate from the current practice of epidemiology and public health. Some public health and medical researchers may consider 'history books' irrelevant to their research. A more realistic appreciation of that literature would correct this artificial and inappropriate distinction and show that in many ways 19th and early 20th century Europe and the United States were developing nations. There was poor sanitation, unreliable food supply and food storage to be sure, but there was also great economic inequality, undemocratic politics, lack of education for the poor, and exposure to much violence for poor and rich. Similar in many essential ways to least developed nations today. All of these physical, social and political factors are associated with shorter height for the people who most suffer, and shorter average height for the population as a whole (56). We return to this point later in this Discussion.

Not only the classic studies of the late 19th century, but also the later studies on height and weight patterns during war and other times of food constraints in affluent Western societies are barely cited. The common knowledge of European paediatricians at the beginning of the 20th century, that body height is an invalid measure of nutritional status and that severe long-term nutrition constraints lack effects on adult height, was simply lost after World War Two. Quite in contrast to current-day perception, height is in fact remarkably resilient. German and Japanese conscripts (57-59) may serve as excellent examples: even those cohorts who experienced exceptionally severe and long-lasting undernutrition during and particularly after World War Two, lacked evidence of persistent height impairments. The secular trend for the height of 20-year-old Japanese men and women shows the steepest upward slope for birth cohorts between 1940 and 1950 (59).

Discussing the truth content of scientific data is difficult. Recently we debated the problem of perception (60). The current understanding of the impact of starvation, stunting and refeeding on growth was largely developed by scientists who never personally experienced war and severe nutritional deprivation in their home country. In other words, this understanding is limited to observations that were done in Third World low-income and middle-income countries by people who were raised under wealthy conditions in the First World. The confinement of personal perception of scientists who never made first-hand observations at home among friends and family members similar to those published in Germany during and after the two great wars, seems important to us.

Let us talk about knowledge. Young children take up much of their parents' concepts of life. Common parental concepts are based on traditional perception and popular knowledge. They match most other people's concepts and do not reflect scientific evidence. Children eat and children grow. This is trivial popular wisdom. Also the opposite linking lack of food and lack of growth, is trivial. Remember when you did not clean your plate, our mothers said: "Eat", otherwise "you will not grow". But what about the inversion of this link? When you

finally grew up and travel through the world, and when you see a Third World child who looks a little short, can you truly know: “this child did not eat well”? Is it legitimate to state that *short stature is due to food constraint?*

Instead of a commodity which is transported from one mind into another, knowledge, that is “truth” in the sense of a true picture of a reality that exists independent of us, can be viewed as a property of an individual. The individual links up specific interpretations of experiences and ideas with his own reference of what is possible and viable. Radical constructivism as defined by Glasersfeld (61) replaces the term “truth” by “viability” within the world of personal experience -- one's own experience made by one's own sensory perception. Individuals can never exceed the limits of personal experience. The process of constructing knowledge, of understanding, thus depends on the individual's subjective interpretation, not only on what "actually" occurs. Understanding and acting are circularly conjoined. Even if people use the same scientific knowledge successfully for themselves, it does not make it objectively true.

We realised that at least since the Nestlé nutrition workshop in 1988, where the terms “wasted, stunted, or wasted and stunted” were established as criteria of malnutrition (52), the modern literature has started to use the terms “stunting” and “undernutrition” synonymously. Modern concepts of the “double-burden of malnutrition”, that is short stature plus obesity within the same community highlight that more food does not prevent from stunting. We are afraid that ignoring the absent associations between food and stature in modern nutrition science, may be a convenient denial of the more direct causes of stunting.

There are some limitations to our considerations. Historic literature significantly differs from modern literature. Not before the mid-20th century, articles lacked the usual structure, but were written more or less in the form of a novel. Some monographs comprised more than 100 pages, others were just short comments without mentioning an author. Data collection methodologies and sampling protocols were not always appropriate. Even so, the sheer

numbers of school children these observations were based upon – Schlesinger reported on more than 10,000 male children and adolescents from Strasbourg/Alsace – provide strong observational evidence. Ronald Fisher published his work on statistical hypotheses and testing in 1925 (62). Consequently, the older literature does not make use of modern statistics, and the comparability of modern studies and historic studies may be problematic for technical reasons. As it was not the intent of this study to write on medical history, we deliberately refrained from providing lists on study design, exposure, and outcomes, and except for providing table 1, decided not to present this review in the usual form of a meta-analysis. In addition, modern nutrition interventions in stunted populations have mostly been performed in the rural areas of low- and middle-income countries, whereas the historic studies usually report from urban regions.

In support of the older literature, it needs to be considered that US studies, published in the late-19th and early and mid-20th century, often focused on low-income people and on recent immigrants, even within their countries of birth, such as rural-to-urban immigrants. Poor housing conditions, poor water and sanitation, lack of food safety and of medical care were certainly problems. Living conditions for these low-income people were similar to Third World countries today. With these similarities, the interpretation differences between the older and the modern intervention studies are surprising. The historic studies concluded that more food would only allow for catch-up growth, but not more. The modern studies interpret the, often, negligible effects of food supplementation as either a small success or as a failure of the intervention, and not as the normal biology of human growth. If scientists, clinicians, policy makers, and politicians understood better the normal biology, as revealed from the old literature, there would need to be a major change in the approach to the causes of growth stunting. We expect that this shift of theory and application would be along the lines proposed by Subramanian et al (63), who recommend that we look to the upstream, structural factors of the social-economic-political systems that systematically deprive lower class families of hope, dignity, and a belief that they can better themselves economically and

socially. Subramanian and colleagues propose that we move away from growth-mediated strategies to prevent stunting and move toward support-led strategies that offer integrated policies to reduce risks for stunting. To do this requires changing the upstream factors to create, *"… equitable public policies and provisions that matter…*" to improve sanitation, health care, food quality and distribution, and, especially, education and economic opportunities. This is what happened in Europe and the USA where environmentally induced stunting is virtually non-existent.

Considering cost-effectiveness of the time we spent in the library, and the scientific outcome, it appears prudent to substantially stimulate similar activities in other large non-Anglo-American libraries, and to rigorously translate historic articles, and to post them unabridged to the World Wide Web.

CONCLUSION

In the late 19th and early 20th century, growth of European infants was remarkably poor. Even breastfed infants of the upper social class usually grew below modern World Health Organisation (WHO) standards.

The historic literature lacks evidence of a strong association between food, child growth and adult height. Even in view of mass starvation during and shortly after World War One, German paediatricians concluded that the shorter stature of those children affected was an inhibition, that is a delay in growth tempo. It was explicitly stated that *"the child's longitudinal growth is largely independent of the extent and nature of the diet"* (37). Even prolonged starvation during childhood did not affect adult height.

With on average 3cm within 6 weeks, catch-up growth in height of severely undernourished school children during refeeding, was significantly greater than any catch-up reported in modern nutrition intervention studies.

A sharper research focus on appropriateness and effect size of modern nutrition interventions is needed. Historical studies are indispensable to understand why modern diet interventions often fail to prevent stunting. It appears prudent to substantially stimulate activities in the large non-Anglo-American libraries to rigorously identify and translate important historic articles, and to post them unabridged to the World Wide Web.

Abbreviations used:

WHO	World Health Organisation
UNICEF	United Nations International Children's Emergency Fund
BMI	Body Mass Index

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Table 1:

Basic information including short comments of those publications that were primarily selected and photographed.

[please see additional file]

Figure 1:

Mean height and BMI of adequately-fed Boston and German children, published in 1877 by Bowditch (20), and by Camerer in 1893 (44,45), given as z-scores referred on the WHO Multicentre Growth Reference Study (16) and the WHO growth reference for school-aged children and adolescents (46). Assuming a normal distribution for height, some 15-20% of the Boston and some 25-30% of the apparently healthy German children were stunted at age six.

[please see additional file]

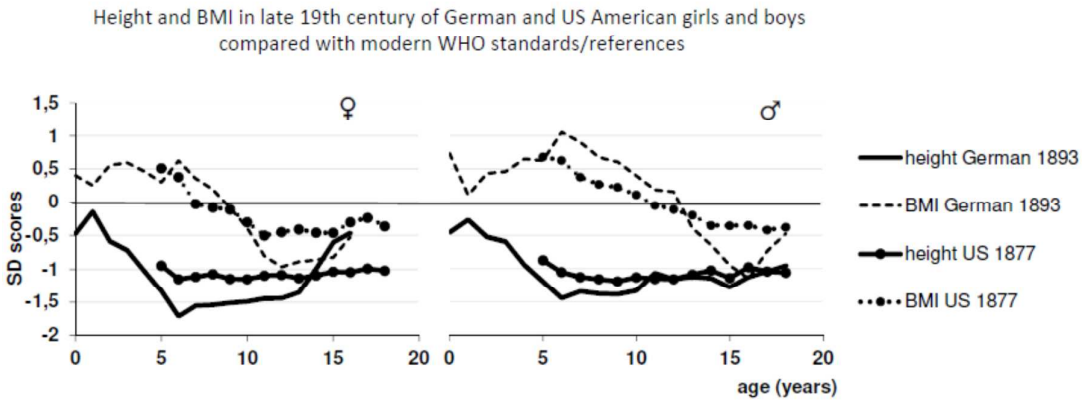


Table 1

Summary on 66 historic publications revisited in the Staatsbibliothek zu Berlin

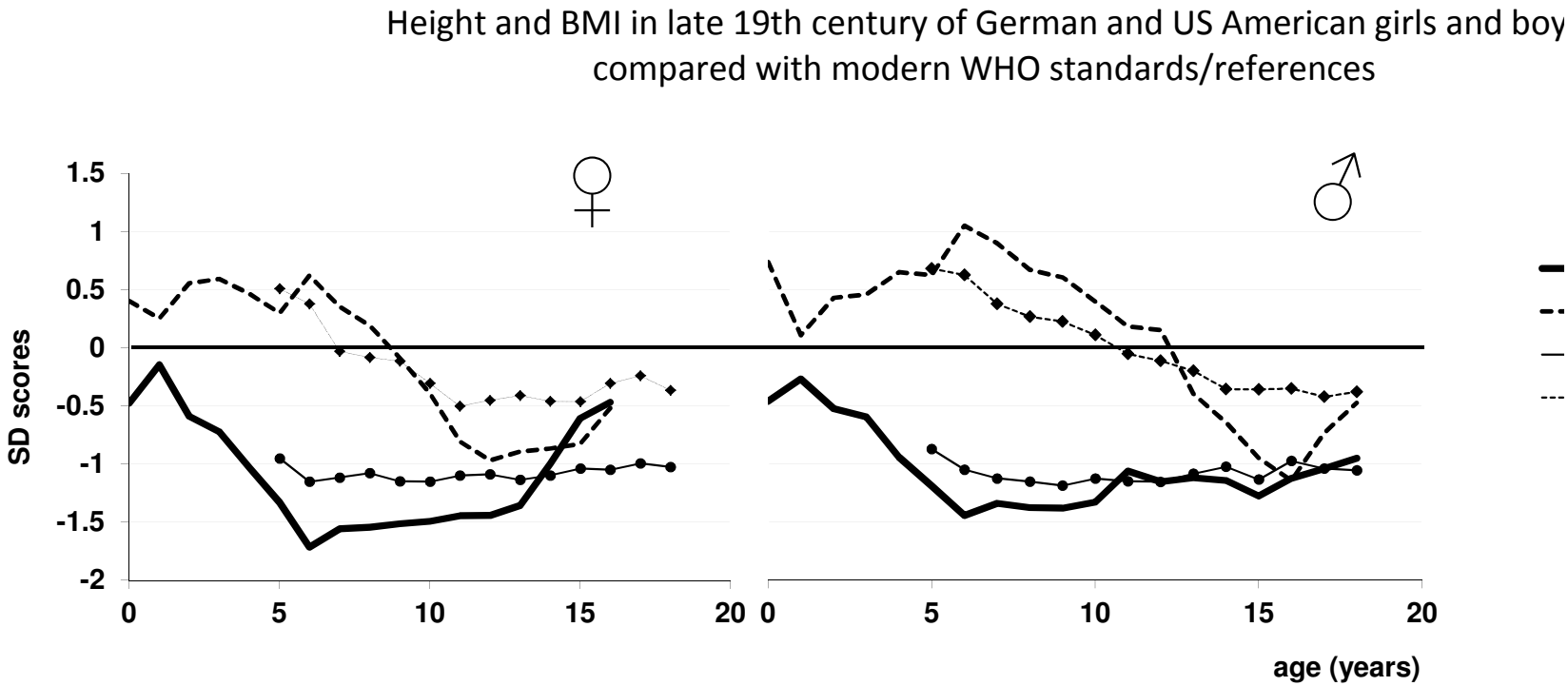
year	volume	author	title	page	comments
Jahrbuch der Kinderheilkunde					
1858	2	Schreber	zur physische Erziehung des Kindes		on child education
Jahrbuch der Kinderheilkunde Neue Folge					
1869	2	Liharzik F	Das Gesetz des menschlichen Wachstums	25-33	laws of growth with partially very obscure ideas on growth
1880	15	Haehner H	Über die Nahrungsaufnahme des Kindes an der Mutterbrust und das Wachsthum im ersten Lebensjahre	23-78	very precise longitudinal study of breast-fed infants during the first 12 months of life
1881	16	Russow A	Vgl. Beobachtungen über den Einfluss der Ernährung	86-132	case reports
1882	18	Camerer W	Gewichtszunahme von 21 Kindern im ersten Lebensjahre	254-264	very precise longitudinal study of infants during the first 12 months of life
1883	19	Pfeiffer D	Bemerkungen betreffend Wachstum und Körperwägungen	142-147	infant weight reference values
1893	36	Camerer W	Untersuchungen über Massenwachstum und Längenwachstums der Kinder	249-293	longitudinal study, first 12 months, some comments on later growth
1895	40	Schmid-Monnard K	Ueber den Einfluss der Jahreszeit und der Schule auf das Wachstum der Kinder	84-106	seasonal growth
1899	49	Schmid-Monnard K	Ueber die Nahrungsmengen normaler Flaschenkinder	67-76	antiquated ideas on nutritional needs
1903	57	von Lange	Die Gesetzmässigkeit im Längenwachstum des Menschen	261-324	mathematical approaches to growth of infants, longitudinal data
1902	56	Beuthner	Beobachtungen über die Nahrungsmengen von Brustkindern unter Berücksichtigung des Energiequotienten	446-471	three case studies

1902	56	Nordheim	Beobachtungen an einem natürlich genährten Kinde	86-104	case study
1902	56	Neumann N	Körpergewicht der Säuglinge nach socialer Gruppirung	719-724	considerations on growth and SES
1905	61	Orgler A	Über Entfettungskuren im Kindesalter	106-113	on the need of weight loss diets in children
1908	67	Kassowitz M	Die Ursachen des grösseren Stoffverbrauches im Kindesalter	551-588	child metabolism
1908	68	Karnitzky AO	Zur Physiologie des Wachstums und der Entwicklung des kindlichen Organismus	562-474	case study on his own child
1910	72	Schloss E	Zur Pathologie des Wachstums im Säuglingsalter	575-598	antiquated comments on growth pathologies
1912	75	Rietschel H	Zur Technik der Ernährung der Brustkinder in den ersten Lebenswochen	403-434	case studies on infant nutrition, and infant care
1921	95	Hammann R	Über das Gedeihen von Brustmilchkindern in und nach der Kriegszeit	242-249	growth of breast-fed infants during and after the war
Monatsschrift Kinderheilkunde					
1908	7	Schütz A	Über die Schwächen der statistischen Beweisführung von Ernährungsversuchen	597-601	statistics in nutrition studies
Zeitschrift für Kinderheilkunde					
1912	4	von Reuss A	Über die Bedeutung der Unterernährung in der ersten Lebenstzeit	499-525	importance of undernutrition and risks of obesity
1911	2	Risel H	Adipositas und exsudative Diathese	325-344	case studies on obesity
1913	6	Pirquet C	Eine einfache Tafel zur Bestimmung von Wachstum und Ernährungszustand bei Kindern	253-262	reference tables for growth and nutrition status
1913	8	Engel I, Samelson S	Der Energiequotient des natürlich und des künstlich genährten Säuglings	425-442	case studies on food intake and weight in infants
1916	13	Guttmann M	Einige Beispiele individueller körperlicher Entwicklung	248-256	longitudinal growth, case studies
1916	13	Schiötz C	Wachstum und Krankheit - schulhygienische Studien	393-434	illness as growth stimulus
1914	10	Samelson S	Über mangelnde Gewichtszunahme bei jungen Brustkindern	19-35	case studies of breast-fed infants

1917	16	Bernstein F	Bemerkungen zur Abhandlung "Körpermassstudien an Kindern" von Pfaundler	78-84	considerations on the studies of von Pfaundler
1917	16	von Pfaundler M	Notiz zu Körpermaßstudien	85-89	notes on Bernstein's notes
1916	14	Pirquet C	Sitzhöhe und Körpergewicht	211-228	introduction of pelidisi index
1916	14	von Pfaundler M	Körpermaß-Studien an Kindern	1-148	basics on growth in children
1919	19	Neurath R	Geschlechtsreife und Körperwachstum	209-224	pubertal development
1919	20	Bergmann E	Zur Frage der Beeinflussung der Brustkinder durch die Kriegsernährung der Mütter	75-111	notes on the influence of war nutrition on breast-feeding
1919	21	Davidsohn H	Die Wirkung der Aushungerung Deutschlands auf die Berliner Kinder mit besonderer Berücksichtigung der Waisenkinder der Stadt Berlin	349-410	the effect of starvation in Germany on Berlin children
1920	26	Baltz H	Ein Beitrag zur Variation der Körpermaße	327-330	variability of growth measures
1919	22	Schlesinger E	Wachstum, Gewicht und Konstitution der Kinder und der heranwachsenden Jugend während des Krieges	80-123	basics on growth in children
1921	28	Wagner R	Die zahlenmäßige Beurteilung des Ernährungszustandes durch Indices	38-50	justification of various indices for defining the state of nutrition
1921	29	von Pfaundler M	Über die Indices der Körperfülle und über "Unterernährung"	217-244	body indices and undernutrition
1922	32	Goldstein F	Klinische Beobachtungen über Gewichts- und Längenwachstum unterernährter schulpflichtige Kinder bei Wiederauffütterung	178-198	catch-up after re-feeding, Swiss data
1924	37	Schlesinger E	Wachstum, Ernährungszustand und Entwicklungsstörungen der Kinder nach dem Kriege bis 1923	311-324	catch-up after re-feeding
1925	39	Eriksson Z	Über die Körperverfassung von Anstaltskindern	347-363	growth of institutionalized children
1923	36	Kistler H	Individualmessungen in der Zeit des Pubertätswachstums	157-163	case studies on body proportions
1929	48	Kornfeld W	Zur Bewertung von Größe und Gewicht bei Knaben und Mädchen aller Altersstufen	188-207	basics on growth in children

1930	49	Kornfeld W	Über Durchschnittswerte und Bewertungsgrundlagen einiger weiterer Körpermaße bei Kindern (Kopfumfang, Sitzhöhe und relative Stammlänge)	64-78	basics on growth in children
1931	50	Rosenstern J	Über die körperliche Entwicklung in der Pubertät	1-25	pubertal development
1920	26	Schlesinger E	Das Wachstum der Knaben und Jünglinge vom 6. bis 20. Lebensjahr	265-304	basics on growth in children, circadian growth, community effects on height, independence of slimness from food supply
Zeitschrift für Schulgesundheitspflege					
1888	1	Carstädt F	Über das Wachstum der Knaben vom 6. bis zum 16. Lebensjahr	65-69	basics on growth in children
1896	9	Schmid-Monnard K	Gewichts- und Längenzunahme bei Kindern	317-323	case studies on weight and length gains, seasonal variation
1896	9	Combe	Körperlänge und Wachstum der Volksschulkinder in Lausanne	567-589	growth references
1905	18	Quirsfeld E	Zur physischen und geistigen Entwicklung des Kinds während der ersten Schuljahre	127-185	physical and mental development of school children
1905	18	Koch-Hesse A	Ein Beitrag zur Wachstumsphysiologie des Menschen I	293-319	basics on growth in children, comments on social growth regulations
1905	18	Koch-Hesse A	Ein Beitrag zur Wachstumsphysiologie des Menschen II	400-416	basics on growth in children
1905	18	Koch-Hesse A	Ein Beitrag zur Wachstumsphysiologie des Menschen III	457-492	basics on growth in children, references for growth velocity
Der Schularzt					
1906	4	Oebbecke	Die Wägungen und Messungen in den Volksschulen zu Breslau im Jahre 1906	588-594	growth in school children
1906	4	Igl	Die Wägungen und Messungen in den Volksschulen zu Brünn	753-760	community effects on growth, growth during holidays
1909	22	Oppenheimer K	Über eine Methode zur ziffermäßigen Bestimmung des Ernährungszustandes	880-891	circumferences for determining the state of nutrition

1914	27	Makower AA	Untersuchungen über Wachstum	97-120	reference values, growth during holidays
1914	12	Bartsch H	Über die Bestimmung des Ernährungszustandes bei Schulkindern	465-469	considerations on growth in children
Gesundheit und Erziehung					
1932	45	Wolff G	Krieg und Wirtschaftskrise in ihrem Einfluss auf das Schulkindwachstum	501-506	effects of war and economic crisis on growth of school children
Ärztl. Jugendkunde					
1974	65	Legner C, Richter J	Zum Problem der Akzeleration im wissenschaftlichen Schrifttum der UdSSR	93-98	literature on acceleration
1967	58	Valsik JA	Ein Akzelerationsphänomen - Wachstumsabschluß bei 16 jährigen Mädchen	129-132	literature on acceleration
1967	58	Beckert H	Bemerkungen über die Entwicklung des Längenwachstums	117-128	literature and considerations on secular trends in height
1964	55	Grimm	Welche Endgröße erreicht gegenwärtig das Längenwachstum in Mitteleuropa	355-359	literature and considerations
1965	56	Cappieri M	Bilanz eines Jahrhunderts: Die Körpergröße der Italiener nimmt zu	124-131	literature and considerations
1965	56	Grimm H	Untersuchungen über Wachstum und Entwicklung in der Deutschen Demokratischen Republik	196-204	literature and considerations
1965	56	Scholz E	Eine auf die Körperlänge bezogene Tabelle von Mittelwert und Variationsbreite des Körpergewichtes für das Schulalter	8 bis 13	literature and considerations


Height and BMI in late 19th century of German and US American girls and boy
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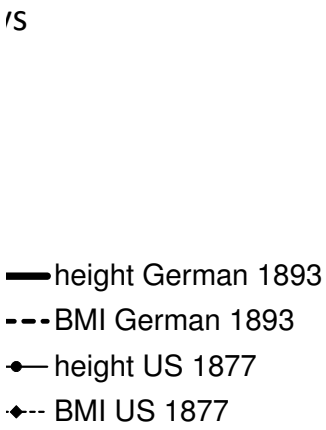
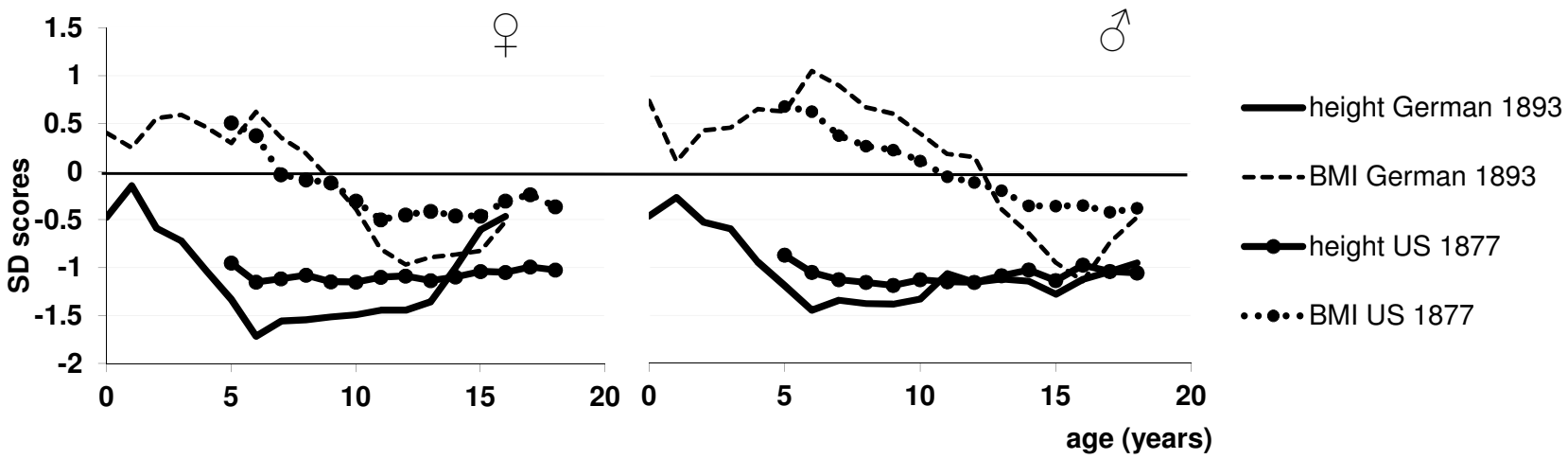


Height and BMI in late 19th century of German and US American girls and boys compared with modern WHO standards/references



Stunting, starvation, and refeeding - a review of forgotten 19th and early 20th century literature

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Key words: stunting, child growth, undernutrition, refeeding, historic literature

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Key notes

Background: Stunting is commonly associated with poor living conditions, inappropriate nutrition and poor health. Late 19th and early 20th century ~~breastfed~~ Europeans ~~infants and children~~ independent of social strata, were stunted according to ~~grew far below~~ WHO standards.

Main findings: Already s~~S~~hortly after World War I, German paediatricians concluded that: *"the child's longitudinal growth is largely independent of the extent and nature of the diet ... "*.

H~~istoric h~~eight catch-up after starvation was significantly greater, and allowed for unimpaired adult height, than height catch-up reported in modern nutrition intervention studies.

Interpretation: The appropriateness and effect size of modern nutrition interventions on child growth need revision.

ABSTRACT

Background~~Aim~~: Stunting is a major global issue in child health, and ~~. Stunting is~~ commonly associated with poor living conditions, inappropriate nutrition and poor health.

Aim: ~~W~~To scrutinize to what extent modern ideas on nutrition effects on growth are supported by historic observations in European populations ~~hereas the biological importance~~

~~of food on growth is unquestionable, the efficacy of height for age to define undernutrition remains questionable~~.

Method: We reviewed 19th and early 20th century paediatric journals in the Staatsbibliothek zu Berlin, the third largest European library with an almost complete collection of the German medical literature. During a three-day visit, we inspected 15 bookshelf meters of literature not available in electronic format.

Results: Late 19th and early 20th century breastfed European infants and children, independent of social strata, grew far below World Health Organisation (WHO) standards and 15-30% of adequately-fed children would be stunted by the WHO standards. Historic sources indicate that growth in height is largely independent of the extent and nature of the diet. Height catch-up after starvation was ~~significantly~~ greater, and allowed for unimpaired adult height, than ~~height~~ catch-up reported in modern nutrition intervention studies.

Conclusion: Historical studies are indispensable to understand why stunting does not equate with undernutrition and why modern diet interventions frequently fail to prevent stunting. Appropriateness and effect size of modern nutrition interventions on growth need revision

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INTRODUCTION

Stunting is a major global issue in child care, and is commonly associated with poor living conditions, inappropriate nutrition and poor health. Good nutrition is considered crucial to both individual and national development. Electronic searches in PubMed using the terms “child and nutrition and intervention and review” meanwhile result in more than 4,000 entries published since the mid-1960s. Series of papers published in the Lancet in 2008 and 2013, summarised the evidence base that good nutrition is a fundamental driver of a wide range of developmental goals (1). In 2016 Dewey (2) reviewed the complex and context-specific background to linear growth restriction and stunting as well as more recent efforts to reduce stunting by improving maternal, infant and young child nutrition. The effect of food and nutrient interventions is, at best, modest. Dewey suggesteds a more comprehensive approach, including intervention packages to improve nutrition during both pregnancy and the post-natal period, prevention and control of prenatal and post-natal infection and subclinical conditions that restrict growth, care for women and children and stimulation of early child development.

The biological importance of food on growth is unquestionable – no food, no growth. But the efficacy of nutrition interventions in low-income stunted populations appears questionable. Uauy et al (3) observed that providing food to these populations may be beneficial for some, but “it may be detrimental for others” and induce obesity especially in urban areas. In a 2005 Cochrane Database Systematic Review, Sguassero et al (4) reported a positive effect on length (cm) in a nutrition-supplemented group compared to controls (mean difference 1.3cm, CI (0.03cm–2.57cm) 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 (5) carried out a meta-analysis of community-based supplementary feeding in children under 5 years of age in low-income and middle-income countries and concluded that

supplementary feeding has a negligible impact on child growth. Even socioeconomically disadvantaged children, when supplemented, only grew an average of 0.27cm more over 6 months than those who were not supplemented (6). The~~ir~~ data did not question that severe starvation coincides with growth inhibition, but the net effect of nutrition on body height was generally small (7). Goudet ~~and~~ et al (8) reviewed interventions to tackle malnutrition and its risk factors in children living in urban slums. The authors found 22 intervention studies of which 10 increased weight, mostly body fat, and 6 increased length or height. The typical length increase was less than 1cm, and often close to measurement error.

Nutrition interventions in low-income and middle-income countries are laudable. But why are these efforts so disappointing? We aimed to scrutinize to what extent the modern ideas on nutrition effects on growth are supported by historic observations in European populations. We started approaching this ~~dilemma~~ question by studying the situation of mass starvation and refeeding in the recent European history, and ~~. The aim of this investigation was~~ re-read~~ing of~~ medical literature published in German at the end of the 19th and in the beginning of the 20th century that ~~, and not available electronically, that~~ focused on the nutritional situation before, and during the period of starvation and subsequent refeeding after World War One, and is not available electronically. We considered the severely undernourished historic European populations an appropriate natural control for comparison with modern stunted Third World populations. For this purpose, we reviewed 15 shelf meters of 19th and early 20th century paediatric journals, and literature published by school doctors.

We did not only intend to read and republish parts of this forgotten material, but also to encourage efforts to fully digitalise and translate this material to make it accessible for electronic search engines, and the English speaking scientific community.

MATERIAL

Comprehensive collections of literature are available on starved and refed early 20th century central European populations. Based on two seminal reviews on child growth and development published after World War One by Koch (9) and Schlesinger (10), we first generated a list of journals that were most frequently mentioned as publication outlets for manuscripts on child growth and development, with particular preference to manuscripts on child nutrition. Co-authors MH and CS performed this literature research in the Staatsbibliothek zu Berlin, Unter den Linden 8, 10117 Berlin, Germany, the third largest European library with an almost complete collection of the German medical literature. We limited our approach to a three-day intensive working visit and browsed 15 bookshelf meters. ~~, searching for~~

We searched for: material on child growth and nutrition ~~that may be relevant for modern researchers~~. We included publications that presented data obtained from healthy children and children who suffered from undernutrition due to war, or from other environmental constraints. We excluded most case studies, and studies on pathological conditions as these conditions did not meet modern diagnostic criteria. Publications on general considerations based on outdated concepts in biology were also excluded.

We visited some 25,000 pages in 16 pediatric and school doctors' journals. We detected 66 publications of primary interest in 9 of these journals. Most of the 19th century material was visited page by page. Later material was partially visited by title as in the later years it became common practice to also publish lists of titles. ~~Jahrbuch der Kinderheilkunde from 1858 to 1921; Zeitschrift für Kinderheilkunde from 1910 to 1920; Zeitschrift für Schulgesundheitspflege from 1888 to 1908, and Der Schularzt from 1906 to 1914. Our inclusion criterion was: material on child growth and nutrition that may be relevant for modern researchers. We included publications that presented data obtained from healthy children and children who suffered from undernutrition due to war, or from other environmental constraints. We excluded most case studies, and studies on pathological conditions as these~~

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~~conditions did not meet modern diagnostic criteria. Publications on general considerations based on outdated concepts in biology were also excluded.~~

Table 1 summarizes basic information including short comments of those publications that were primarily selected and photographed. ~~We detected 25~~Twenty-six studies contained unknown details on child growth (including individual growth patterns, seasonality of growth, social influences on growth and particular patterns of growth during starvation and refeeding)~~that appear worth mentioning to modern readers~~ from which we took some 2,500 photographs~~.~~. Historic scientific literature differs from modern literature in many ways. None of the 26 publications are “studies” in the modern sense. They were written in the style of a novel, mostly without clear design, often without information on sample size, and usually without quality assessments. None of these studies~~m~~ are electronically available, none are translated into English, and therefore are not just forgotten, but may truly be considered lost for the international scientific community. As we report on historic literature, there was no need for ethics committee approval.

RESULTS

Nineteenth and early 20th century auxology

Newborn and infant nutrition and growth was the priority among the early auxological contributions both in number of publications and their size in pages. Amazingly detailed case histories, often including daily measures of breastmilk quantities, were frequently published (11-14). In those days, infant growth was remarkably poor, even the majority of the breastfed infants of the upper social class (15) grew below modern World Health Organisation (WHO) standards (16).

In parallel with trajectories of individual growth (17), people became interested in the general patterns of growth. In 1869 Schuller (18) reviewed one of the first German scientific books on human growth (19). He republished several tables that, however, contained rather dubious material. A few years later, some scientifically more sound American papers, e.g. the work of Bowditch in Boston (20), and Porter in St. Louis (21) became known and was also cited in the German literature on child growth.

Based on large sets of cross-sectional data, laws of human growth were developed (22). Height and weight differences between children of the different social strata were observed by Schmidt and Lessenich (23) and extensively discussed in view of previous literature. The authors confirmed observations by Porter (21) on the positive relation between physical development (height and weight) and learning achievements.

'Big data' on up to several tens of thousands of children and adolescents from official urban school investigations were regularly published by the authorities from various German, Swiss and Austrian cities (24-26) to evaluate the nutritional situation. For this purpose, Bartsch (27) used mid-upper-arm circumferences that had earlier been introduced by Oppenheimer (28). Seasonal variation in growth was studied by Schmid-Monnard (29) and discussed in the light of earlier Danish publications (30). He observed that the greatest gains in weight between September and January coincided with the least gains in body height. He considered the discrepancy between weight gain and height gain as evidence that growth in height is independent of nutrition. Similar findings were reported some 90 years later in 5.0 to 6.9-year-old children from very high SES, attending the American School of Guatemala. They were very well-fed throughout the year, but about 70% of the sample of 48 boys and girls grew fastest in height during the dry season and slowest in the rainy season when their mean gain in weight was greatest (31,32).

Papers on nutrition

In 1916, the German paediatrician Meinhard von Pfaundler (33) summarised body mass studies in children before World War One. He discussed differences in developmental tempo, the differential onset of puberty, and its effect on height variance at mid-adolescence. It was known that children raised under affluent conditions, were taller and matured earlier.

Even though Pfaundler considered food as a potentially influencing factor, he 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".* And regarding infant growth, he stated: *"Moreover, we find that the degree of short stature among healthy poor children is very minor in the first year of life".* He proposed that the deficit in body length also of the poor children did not occur before the second year of life. In those days, infants of both the wealthy and the poor grew considerably below modern standards.

In order to further scrutinise social differences in body height, Pfaundler introduced Livi's (ponderal) index. Livi's index (100 * $\sqrt[3]{weight}$ / *body height*) relates the cube root of weight to height, and was considered to better mirror the nutritional state than body weight alone with arguments similar to those used today to recommend the Body Mass Index (BMI). The fact that Livi's index of the short lower-class school children were some 2% larger than the index of wealthy children (33) was used as proof against a potential role of nutrition on growth before World War One. Even though he later recognised that undernutrition during the 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's index)*. 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".*

Shortly after World War One, the American Quaker Children's Aid Mission offered additional meals to undernourished German schoolchildren and requested from the German pediatricians to better define undernutrition and to develop criteria for classifying the degree of undernutrition of a given child. In view of this request~~order to further improve the description of undernutrition~~, Pfaundler (34) recommended ~~introduced~~ another index that had recently been introduced by Pirquets. The index ignored leg length ~~(34~~and thus appeared to better mirror the nutritional status.~~,35)~~. This "pelidisi" ($(\sqrt[3]{10 * weight})$ / *sitting height, Pondus dEcies LInear DIviso SedentIs altitudo*) was then thoroughly discussed and appreciated by Wagner in his work on the numerical assessment of the nutritional status (35). Wagner stated that "the precondition for the usability of a body fullness index (Wagner discussed possibilities to better define a state of undernutrition) is that it represents an unnamed ratio derived from the division of equidimensional quantities". He rejected indices such as weight-for-height because they divide a three-dimensional size, the weight, by a one-dimensional length, which results in an area. Yet~~however~~, in spite of these thoughts, the pelidisi was never widely accepted and eventually disappeared from the literature presumably due to arithmetic clumsiness at a time when computers did not exist. In 2015, Burton (36) presented similar thoughts recommending that BMI be replaced by an index of body build that is less dependent on relative leg length and age in children and adults than are the BMI and the Rohrer Index, and proposed Weight/Sitting Height[23]. Shortly after World War One, Schlesinger (37) summarised growth of children and adolescents during the war stating: *"The child's longitudinal growth is largely independent of the extent and nature of the diet ... Even during severe dietary restrictions, impairments of infant growth are markedly small, and occur slowly and delayed. Only during severe infectious nutritional disorders of the infant ... Stolte and others (38) observed a temporary growth inhibition... Malnourished infants show an inhibition of longitudinal growth only, and especially during periods of reparation, when food supplies, e.g. breast milk, was low in protein and minerals, but they quickly recovered when given protein rich milk".*

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Impairment of body height is not a sudden event, but occurs during long-term starvation. Regarding school children Schlesinger wrote: *"In the second year of the war, 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.

In the following years, Schlesinger realised that due to the war the number of very tall adolescents temporarily decreased, and that the onset of the pubertal growth spurt tended to be later than before. Nevertheless, his final conclusion was that: *"the whole growth disturbance described here is to be regarded as a simple inhibition; the type of growth, the growth curve did not undergo any significant change in its form, except for the slight delay in the pubertal drive, the onset of puberty"*. Based on measurements of the loss in body fat, both in absolute terms and related to body height, he again argued that: *"even more regular is the deficit in weight in 1916 versus 1913, when taking into account the length of the body, which in this period has partly shifted in the opposite direction"*.

In summary, these studies were in line with common understanding: Undernutrition leads to weight loss and reduces growth velocity. But what happens when starving children are being refed?

Recovery from starvation is a different topic. Refeeding is usually characterised by marked catch-up in height, and in weight, both at the individual and at the population level. Schlesinger (39) summarised his observations on length and weight changes in school children after the war: *"The years 1921 and 1922 are marked by a significant improvement, an increase of average body height at almost all ages, especially in the elementary school in working class children; particularly in view of the shortest stature in 1919 and 1920, we may*

sometimes talk about saltatory height increments with average values surpassing those of previous years sometimes by 3 or 4, or even 5cm". He stated that: "*with improving nutritional conditions, especially in the sense of quality, with more abundant contents of fat, protein, and supplements, the improvement in longitudinal growth … is generally more pronounced than the elevation in body weight. The young organism uses the nutritional components now available … to first recover the growth deficit, and much later to fill up the fat deposits. The organism presses to recover the inhibition which is by no means irreparable; on the contrary, it is very accessible to reparation".*

It is important to emphasise that Schlesinger observed that first the deficit in height recovers, and second the deficit in weight. Immediate catch-up in height was pathognomonic for preceding growth impairments.

Goldstein (40) analysed case studies and general patterns of weight and height gain of severely undernourished Berlin school children during refeeding. Catch-up growth in height of on average 3cm within 6 weeks was reported (41) in children from Jena who were sent for refeeding to Switzerland. The historic sources outlined that catch-up growth during refeeding was characterised by a short period of excessive, sometimes saltatory growth of up to several centimetres within a few weeks. Catch-up in height usually terminated when the height deficit was corrected, with no further increments even when abundant feeding was continued, catch-up in weight may continue beyond the previous state. Goldstein demonstrated this with individual weight curves. He considered ~~It seems likely that~~ added fatness to be ~~was~~ the reason for the continuing weight increases.

~~We detected a final reference to the lack of association between weight and height in a German paper published by de Rudder in 1960 (42) referring to the well-fed short upper-class children of Munich at the beginning of the 20th century versus the malnourished but much taller children shortly after the monetary reform in 1948. After 1960, we detected no~~

~~more scientific work on the lack of association between food and growth. Instead, American publications started to focus on height deficit in the presence of malnutrition in Third World countries. We note especially the seminal articles by Seoane and Latham in 1971 (43) and by Waterlow (44). These articles provided a medical classification of malnutrition based on height for age. The diagnosis of "stunting" became a synonym for "chronic malnutrition". This purely anthropometric definition of nutritional status was discussed in detail in a World Health Organization 1971 report (45) and became quite broadly accepted after publication of a Nestlé nutrition workshop in 1988 (46). Evidence is mounting, however, that this late 20th century wisdom is not accurate. Dr Noel Solomons recently presented a review of contradictory research and concluded that any essential, "…nutrient deficiencies can cause growth impairment, but not all growth impairment in humans is attributable to a nutrient deficiency problem" (47).~~

Apart from the lack of evidence of associations between food and growth, we also detected interesting observations focused on the impact of chronic illness on child growth. School children who recovered from rickets, were not shorter than unaffected children. Measles, scarlet fever and pneumonia were listed among those illnesses that after recovery promoted, rather than impaired, overall growth, contrary to what the modern paediatrician would expect. These observations were not singular, we found multiple mentioning that particularly tuberculosis appears to stimulate growth. Schiötz (4~~2~~8) summarised much of this work and quantified the growth stimulation by tuberculosis mentioning an average height of 175cm for male Norwegian tubercular adults versus 170cm for healthy non-tubercular adults. Interestingly, Schiötz discussed the possibility of a higher susceptibility to tuberculosis of tall people and thus, introduced very modern aspects of life history theory treating this as trade-off between growth versus immune function.

Irrespective of our focus on war and starvation, we also came upon several sources on birth measures and infant growth (table 1). Birth weight was close to that of modern Europeans,

but the subsequent length and weight increments of infants and children were less. The developmental tempo appeared slower than today, and puberty was late (43). The average child was short and stout. Figure 1 illustrates mean height and BMI z-scores of two growth references of, presumably, adequately-fed children and youth that were often cited in the late 19th and early 20th century: the Boston study published in 1877 by Bowditch (20), and the German data originally published by Camerer in 1893 (44) and reviewed by Pirquet in 1913 (45). Z-scores refer to the WHO Multicentre Growth Reference Study (16) and the WHO growth reference for school-aged children and adolescents (46). Even though historic data on height variance are missing, we may assume that height was normally distributed and roughly estimate that 15-20% of the healthy Boston children in 1877 and 25-30% of the healthy German children in 1893 were stunted at age six, according to the WHO references.

DISCUSSION

Science forgotten, science lost

During the three-day working visit to the Staatsbibliothek zu Berlin, we screened medical literature published at the end of the 19th and in the beginning of the 20th century that focused on the nutritional situation before, and during the period of starvation and subsequent refeeding after World War One. We detected comprehensive material on child growth and the nutritional situation during these decades. The abundance of food in the wealthy strata of Imperial Germany before World War One is well documented, so is the disastrous undernutrition of a large portion of the civilian population after 1916, and the slow recovery in the early 1920s, summarising in detail the clinical signs of child starvation and refeeding. Among thousands of paediatric publications, we identified 256 papers that appeared of interest for the modern reader. All the material reviewed is not electronically available, it is in the German language, and not cited in the current literature on child stunting.

At first view the historic observations seem to support the popular perception that starving negatively affects child growth, and refeeding results in catch-up. But the historic sources provide much more detail. The studies highlighted the temporariness of the effects of starving on growth, in particular, the suddenness and great magnitude of the almost saltatory catch-up following refeeding (41), and the absence of permanent effects on adult height. Shortly after World War One, Schlesinger (37) explicitly stated: *"The child's longitudinal growth is largely independent of the extent and nature of the diet*. This statement diametrically opposes modern statements such as Prendergast and Humphrey (497) who summarized in 2014: *"Linear growth failure is the most common form of undernutrition globally"*.

This contradiction is a dilemma and it is difficult to explain. On the one hand, one may consider undernourished historic European populations being inappropriate natural controls for comparison with modern stunted Third World populations. One the other hand, one may blame a lack of familiarity and understanding of the historic literature. The majority of the ample and well-documented historic material on European child growth is stored in libraries, but few researchers make physical visits to library shelves these days. The non-English historic studies may be difficult to access directly, but many early growth studies were summarised by James Tanner (4850) and Edith Boyd (4351) in their books covering the history of the study of human growth. More recent data on starvation studies reviewed by Keys et al in 1950 (4952) also questioned the association of food and growth in height. This material is rarely cited by those people designing and promoting the efficacy of modern food and nutrient interventions. The result is that most of lessons of the past appears lost, forgotten, and the non-English material is generally unavailable for the English-speaking researcher.

We detected a final reference to the lack of association between weight and height in a German paper published by de Rudder in 1960 (50) referring to the well-fed but short upper-class children of Munich at the beginning of the 20th century versus the malnourished children shortly after the monetary reform in 1948 that were much taller. After 1960, no more scientific work was found on the lack of association between food and growth. Instead, American publications now focused on height deficits in Third World countries and again started to link short stature to undernutrition. We note especially the seminal articles by Seoane and Latham in 1971 (51) and by Waterlow (52). These articles provided a medical classification of malnutrition based on height-for-age. The diagnosis of "stunting" became a synonym for "chronic malnutrition". This purely anthropometric definition of nutritional status was discussed in detail in a World Health Organization 1971 report (53) and became quite broadly accepted after publication of a Nestlé nutrition workshop in 1988 (54). Evidence is mounting, however, that this late-20th century wisdom is not accurate. Dr Noel Solomons recently presented a review of contradictory research and concluded that any essential, "…nutrient deficiencies can cause growth impairment, but not all growth impairment in humans is attributable to a nutrient deficiency problem" (55).

History of science and medicine is too often considered a field separate from the current practice of epidemiology and public health. Some public health and medical researchers may consider 'history books' irrelevant to their research. A more realistic appreciation of that literature would correct this artificial and inappropriate distinction and show that in many ways 19th and early 20th century Europe and the United States were developing nations. There was poor sanitation, unreliable food supply and food storage to be sure, but there was also great economic inequality, undemocratic politics, lack of education for the poor, and exposure to much violence for poor and rich. Similar in many essential ways to least developed nations today. All of these physical, social and political factors are associated with shorter height for the people who most suffer, and shorter average height for the population as a whole (5~~3~~6). We return to this point later in this Discussion.

~~Our review of the historic sources finds that birth weight was close to that of modern Europeans, but the subsequent length increments of infants and children were less, and puberty was late (51). The average child was short and stout. Figure 1 illustrates mean height and BMI z scores of two growth references of, presumably, adequately fed children and youth that were often cited in the late 19th and early 20th century: the Boston study published in 1877 by Bowditch (20), and the German data originally published by Camerer in 1893 (54) and reviewed by Pirquet in 1913 (55). Z scores refer to the WHO Multicentre Growth Reference Study (16) and the WHO growth reference for school aged children and adolescents (56). Even though historic data on height variance are missing, we may assume that height was normally distributed and roughly estimate that 15-20% of the healthy Boston children in 1877 and 25-30% of the healthy German children in 1893 were stunted at age six, according to the WHO references.~~

Not only the~~se~~ classic studies of the late 19th century, but also the later studies on height and weight patterns during war and other times of food constraints in affluent Western societies are barely cited. The common knowledge of European paediatricians at the beginning of the 20th century, that body height is an invalid measure of nutritional status and that severe long-term nutrition constraints lack effects on adult height, was simply lost after World War Two. Quite in contrast to~~-~~ current-day perception, height is in fact remarkably resilient. German and Japanese conscripts (57-59) may serve as excellent examples: even those cohorts who experienced exceptionally severe and long-lasting undernutrition during and particularly after World War Two, lacked evidence of persistent height impairments. The secular trend for the height of 20-year-old Japanese men and women shows the steepest upward slope for birth cohorts between 1940 and 1950 (59).

Discussing the truth content of scientific data is difficult. Recently we debated the problem of perception (60). The current understanding of the impact of starvation, stunting and refeeding on growth was largely developed by scientists who never personally experienced war and severe nutritional deprivation in their home country. In other words, this understanding~~, and~~ is ~~based on~~limited to observations that were done in Third World low-income and middle-income countries by people who were raised under wealthy conditions in the First World. ~~These scientists never made first hand observations similar to those published in Germany during and after the two great wars.~~ The confinement of personal perception of ~~these~~ scientists who never made first-hand observations at home among friends and family members similar to those published in Germany during and after the two great wars, seems important to us.

Let us talk about knowledge. Young children take up much of their parents' concepts of life. Common parental concepts are based on traditional perception and popular knowledge. They match most other people's concepts and do not reflect scientific evidence. Children eat and children grow. This is trivial popular wisdom. Also the opposite linking lack of food and lack of growth, is trivial. Remember when you did not clean your plate, our mothers said: "Eat", otherwise "you will not grow". But what about the inversion of this link? When you finally grew up and travel through the world, and ~~our mother's statement persists.~~ ~~W~~when~~ever~~ you see a Third World child who looks a little short, can you truly know: "this child did not eat well"?~~ It all seems to make sense. Children eat and children grow. Undernutrition leads to weight loss, reduces growth velocity and if food shortage last for longer periods, result in loss of height. This popular wisdom linking lack of food and lack of growth is trivial. Less trivial however, is the question whether the inversion of this link i~~s it also legitimate to state that : *is short stature is due to food constraint?*

Instead of a commodity which is transported from one mind into another, knowledge, that is "truth" in the sense of a true picture of a reality that exists independent of us, can be viewed as a property of an individual. The individual links up specific interpretations of experiences and ideas with his own reference of what is possible and viable. ~~Ernst von Glasersfeld was a prominent proponent of radical constructivism (61).~~ Radical constructivism as defined by Glasersfeld (61) replaces the term "truth" by "viability" within the world of personal experience -- one's own experience made by one's own sensory perception. Individuals can never exceed the limits of personal experience. The process of constructing knowledge, of understanding, thus depends on the individual's subjective interpretation, not only on what "actually" occurs. Understanding and acting are circularly conjoined. Even if people use the same scientific knowledge successfully for themselves, it does not make it objectively true.

We realised that at least since the Nestlé nutrition workshop in 1988, where the terms "wasted, stunted, or wasted and stunted" ~~(defining wasted as <80% of reference median; and stunted as <90% of reference median)~~ were established as criteria of malnutrition (52~~44~~), the modern literature has started to use the terms "stunting" and "undernutrition" synonymously ~~in spite of the limited evidence for the association between total food intake and growth (4-8)~~. Modern concepts of the "double-burden of malnutrition", that is short stature plus obesity within the same community highlight~~s~~ that more food does not prevent from stunting. We are afraid that ignoring the absent associations between food and stature in modern nutrition science, may be a convenient denial of the more direct causes of stunting.

There are some limitations to our considerations. Historic literature significantly differs from modern literature. Not before the mid-20th century, articles lacked the usual structure, but were written more or less in the form of a novel. Some monographs comprised more than 100 pages, others were just short comments without mentioning an author. Data collection methodologies and sampling protocols were not always appropriate. Even so, the sheer numbers of school children these observations were based upon – Schlesinger reported on

more than 10,000 male children and adolescents from Strasbourg/Alsace – provides strong observational evidence ~~of a lack of association between food and growth.~~ Ronald Fisher published his work on statistical hypotheses and testing in 1925 (62). Consequently, the older literature does not make use of modern statistics, and the comparability of modern studies and historic studies may be problematic for technical reasons. As it was not the intent of this study to write on medical history, we deliberately refrained from providing lists on study design, exposure, and outcomes, and except for providing table 1, decided not to present this review in the usual form of a meta-analysis. In addition, modern nutrition interventions in stunted populations have mostly been performed in the rural areas of low- and middle-income countries, whereas the historic studies usually report from urban regions. ~~Even so, the sheer numbers of school children these observations were based upon – Schlesinger reported on more than 10,000 male children and adolescents from Strasbourg/Alsace – provides strong observational evidence of a lack of association between food and growth.~~

In support of the older literature, it needs to be considered that US studies, published in the late-19th and early and mid-20th century, often focused on low-income people and on recent immigrants, even within their countries of birth, such as rural-to-urban immigrants. Poor housing conditions, poor water and sanitation, lack of food safety and of medical care were certainly problems. Living conditions for these low-income people were similar to Third World countries today~~. . Poor housing conditions, poor water and sanitation, lack of food safety and of medical care were certainly problems~~. With these similarities, the interpretation differences between the older and the modern intervention studies are surprising. The historic studies concluded that more food would only allow for catch-up growth, but not more. The modern studies interpret the, often, negligible effects of food supplementation as either a small success or as a failure of the intervention, and not as the normal biology of human growth. If scientists, clinicians, policy makers, and politicians understood better the normal biology, as revealed from the old literature, there would need to be a major change in the approach to

the causes of growth stunting. We expect that this shift of theory and application would be along the lines proposed by Subramanian et al (63), who recommend that we look to the upstream, structural factors of the social-economic-political systems that systematically deprive lower class families of hope, dignity, and a belief that they can better themselves economically and socially. Subramanian and colleagues propose that we move away from growth-mediated strategies to prevent stunting and move toward support-led strategies that offer integrated policies to reduce risks for stunting. To do this requires changing the upstream factors to create, *"… equitable public policies and provisions that matter…"* to improve sanitation, health care, food quality and distribution, and, especially, education and economic opportunities. This is what happened in Europe and the USA where environmentally induced stunting is virtually non-existent.

Considering cost-effectiveness of the time we spent in the library, and the scientific outcome, it appears prudent to substantially stimulate similar activities in other large non-Anglo-American libraries, and to rigorously translate historic articles, and to post them unabridged to the World Wide Web.

CONCLUSION

In the late 19th and early 20th century, ~~g~~infant ~~g~~rowth of ~~the wealthy~~ European infants ~~populations~~ was remarkably poor. Even breastfed infants of the upper social class usually grew below modern World Health Organisation (WHO) standards.

The historic literature lacks evidence of a strong association between food, child growth and adult height. Even in view of mass starvation during and shortly after World War One, German paediatricians concluded that the shorter stature of those children affected was an inhibition, that is a delay in growth tempo. It was explicitly stated~~; and~~ that *"the child's longitudinal growth is largely independent of the extent and nature of the diet ...*" (37). ~~The~~

~~older studies reported that e~~Even prolonged starvation during childhood did not affect adult height.

With on average 3cm within 6 weeks, c~~Historic c~~atch-up growth in height of severely undernourished school children during refeeding, ~~with on average 3cm within 6 weeks,~~ wa~~i~~s~~s~~ significantly greater than any catch-up reported in modern nutrition intervention studies.

A sharper research focus on appropriateness and effect size of modern nutrition interventions is needed. Historical studies are indispensable to understand why modern diet interventions often fail to prevent stunting. It appears prudent to substantially stimulate activities in the large non-Anglo-American libraries to rigorously identify and translate important historic articles, and to post them unabridged to the World Wide Web.

Abbreviations used:

WHO	World Health Organisation
UNICEF	United Nations International Children's Emergency Fund
BMI	Body Mass Index

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Table 1:

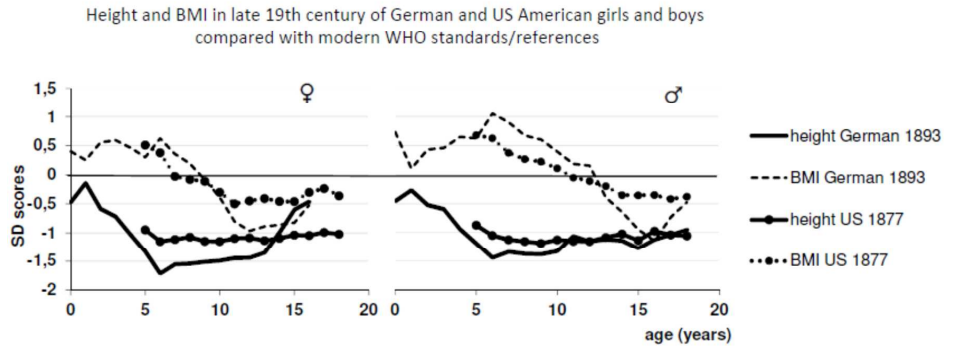
Basic information including short comments of those publications that were primarily selected and photographed.

[please see additional file]

Figure 1:

Mean height and BMI of adequately-fed Boston and German children, published in 1877 by Bowditch (20), and by Camerer in 1893 (~~45~~4,~~54~~5), given as z-scores referred on the WHO Multicentre Growth Reference Study (16) and the WHO growth reference for school-aged children and adolescents (~~54~~6). Assuming a normal distribution for height, some 15-20% of the Boston and some 25-30% of the apparently healthy German children were stunted at age six.

[please see additional file]



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