

ANTHROPOMETRIC HISTORY AND THE MEASUREMENT OF WELLBEING

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Abstract

It has often been recognised that the average height of a population is influenced by the economic and environmental conditions in which it finds itself, and this has inspired a generation of historians to use anthropometric data to investigate the health and wellbeing of past populations. This paper reviews some of the main developments in the field and assesses the extent to which height remains a viable measure of historical wellbeing. It explores a number of different issues, including the nature of human growth, the impact of variations in diet and exposure to disease, the role of ethnicity, the relationships between height, mortality and labour productivity, and the 'social value' of human stature. It concludes that, despite certain caveats, height has retained its capacity to act as a 'mirror' on the condition of past societies and the wellbeing of their members.

Keywords: Anthropometrics; height; health; wellbeing; standard of living.

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As Roderick Floud (1997, 1-2) once observed, economic historians have often seemed to place more emphasis on production than consumption. He argued that this emphasis was misplaced, since “the central purpose of economic life and economic growth [is] an improvement in the condition of the people”. However, although the reasons for focusing on the condition of the people may seem obvious (especially in a volume devoted to the ‘demographic aspects of human wellbeing’), the question of how this should be measured has proved much more controversial. This has been echoed in the efforts made by students of contemporary societies to examine the relationship between the ‘condition of the people’, the ‘standard of living’, and ‘wellbeing’. As Amartya Sen explained (1987, 1) explained:

Within the general notion of the living standard, divergent and rival views of the goodness of life coexist in an unsorted bundle. There are many fundamentally different ways of seeing the quality of living, and quite a few of them have some immediate plausibility. You could be *well off*, without being *well*. You could be *well*, without being able to lead the life you *wanted*. You could have got the life you *wanted*, without being *happy*. You could be *happy*, without having much *freedom*. You could have a good deal of *freedom*, without achieving much. We can go on.

Economic historians have sought to measure changes in the standard of living in a variety of ways, including the use of income-based measures, such as real wages or GDP per capita, as well as health-based measures (e.g. Feinstein, 1998; Clark, 2005; Allen, 2009), such as age-specific mortality and life expectancy (e.g. Szreter and Mooney, 1998). A number of writers have also sought to construct composite indices, such as measures based on the Human Development Index (Floud and Harris, 1997; Crafts, 1997; Prados de la Escosura 2019) or other combinations, including measures of income, health, time-use and inequality (Gallardo-Albarrán and De Jong, 2020; see also Jones and Klenow, 2016). However, a large number of writers have also attempted to investigate changes in living standards using a range of anthropometric measures (Steckel, 1995; 2009; Galofré-Vilà, 2018). The vast majority of

these studies have focused on the analysis of changes in average height, although some have also investigated changes in weight and BMI.¹

As Richard Steckel (1995) explained more than twenty years ago, the average height of a population offers a number of advantages as a measure of living standards and wellbeing. In the first place, it is itself a form of composite measure, since it reflects the net impact of the dietary resources consumed by human beings and the demands made on those resources by energy use and, especially, disease. Second, it also has functional consequences which individuals might themselves have “reason to value” (Sen 1999, 14), such as lower mortality, higher earning capacity, and even general happiness (see also Deaton and Arora 2009). Height data also have the advantage of being available for periods and places for which other data, such as wage or mortality data, may be lacking. This has become even more true in recent years, as new investigations have highlighted the availability of skeletal records which have been used to extend the anthropometric record back into the very distant past (Galofré-Vilà, Hinde and Guntupalli 2018; Steckel *et al.* 2019).

However, although the use of height data has become increasingly popular in recent years, it has also provoked criticism. Some authors have questioned the value of height data on the grounds that there is “no way of measuring the exchange rate of height for real income” (Crafts 1992, 428). Others have debated the conclusions drawn from specific studies, either because of disagreements over the use of particular statistical procedures (see e.g. Komlos 1993a) or because of doubts over the impact of possible selection biases (Bodenhorn, Guinnane and Mroz 2013; 2015; 2017). A third group has drawn attention to the issues raised by suggestions that height is particularly sensitive to certain foodstuffs (Mokyr and Ó Gráda 1996), and others have suggested that the value of international height

¹ The BMI, or body mass index, is equal to weight in kilogrammes divided by the square of height in metres.

comparisons may be vitiated by the impact of ethnicity (A'Hearn 2016). Some of the assumptions which underpinned the initial contributions have also been thrown into doubt by improvements in our understanding of the physiology of human growth (see e.g. Wells 2016), and the relationship between height and the economic and environmental factors which are associated with it may change over time (Alter 2004).

Given these developments, this paper asks whether the average heights of historical populations can continue to be regarded as a valuable measure of their wellbeing. It begins by looking at the background to the emergence of 'anthropometric history' before providing a brief summary of the sources which have been used to investigate average heights and the ways in which different factors are believed to have influenced them. It then discusses the literature on the question of 'critical periods' and the relationship between child and adult welfare. Section five reviews some of the technical debates which have either enlivened or bedevilled the field since the earliest publications and their relationship to other welfare indicators. Sections six and seven explore the relationship between height and diet and disease, and section seven discusses recent attempts to assess the relationship between height and ethnicity. The final sections look at the extent to which height helps to 'predict' aspects of wellbeing in later life and the 'social' value attached to height in areas such as the marriage market.

1. Background

Over the last forty years, economic, social, demographic and medical historians have explored the use of height data in historical studies in different ways. During the 1950s, 1960s and 1970s, Thomas McKeown and his collaborators had argued that the principal cause of the decline of mortality in Britain and other European countries was an improvement

in diet and the ‘standard of living’ (McKeown and Brown 1955; McKeown and Record 1962; McKeown, Brown and Record 1972; McKeown 1976) but this conclusion was (and has remained) highly contentious (for a recent summary, see Harris and Helgertz 2019). Fogel *et al.* (1978, 42) argued that one of the reasons for this was “the virtual absence of data bearing on the amount and nutritional adequacy of the food supply” and that height data might provide an indirect way of addressing this. However, it soon became apparent that this might be less straightforward than it initially appeared. This was because height was not simply a measure of dietary input, but also reflected the demands made by a wide range of external factors, including both workload and the disease environment (see e.g. Fogel 1986, 446-7).

Although the study of human height first attracted the attention of many historians in the context of debates about the decline of mortality, it also has profound implications for other debates in economic and social history. As Gallardo-Albarrán and De Jong (2020) have recently highlighted, there has been a (very) long-running debate over changes in the standard of living during the British industrial revolution, and this debate has often turned on the relative importance attached to real wages as opposed to a wider range of welfare indicators. Roderick Floud (1984, 14-15) argued that it was precisely because height reflected the impact of such a range that it had the power to contribute to this debate, as the following extract demonstrates:

To sum up this catalogue of problems, neither computations of the real wage nor those of national income per head seem easily to meet [Daniel] Usher’s (1980, 2) criterion that they should be more than “mere numbers with no apparent effect upon our lives and no status as indicators of progress towards goals than people might want the economy to achieve”. They give us only a most inadequate idea of the impact which the transformation of European society has had upon the lives of Europeans.

This is a dispiriting conclusion. But there has recently emerged an alternative source of information about the welfare of Europeans in the past which will at least supplement, and for some purposes replace, the traditional measures of welfare. This information lies in the millions of observations held in European archives of the physical height of people in the past. It has long been known – both from economic study and from common observation – that people have been growing taller, but it has only recently become clear that that fact carries with it much information about their welfare (Floud 1984a, 14-15).

This debate is directly related to the debates associated with the introduction of the concept of the “biological standard of living” by John Komlos. Komlos (1987, 921) argued that the average heights of successive birth cohorts of different sections of the United States population moved in different directions to conventional economic indicators during the years leading up to the outbreak of the US Civil War.² Although the average value of men’s heights was declining, the average value of real wages was increasing. Komlos argued that this indicated the need for a different conception of the standard of living:

The above argument suggests that the human biological system can experience periods of stress even as aggregate output per capita grows significantly. Thus anthropometric measurements do not appear to be perfect proxies to the material wellbeing of the population. Rather they might be considered a component of the biological standard of living, which under certain conditions might diverge in significant ways from such conventionally-defined standards as output per capita.

Although the concept of the ‘biological standard of living’ has gained widespread currency in the last thirty years, its value has not passed unchallenged. Although height might be regarded as a *biological measure* of the standard of living (see also Harris 2009, 60), it also needs to be set aside other biological measures, such as morbidity or mortality. The distinction between the ‘biological standard of living’ and ‘material wellbeing’ also implies that the concept of material wellbeing can itself be reduced to “such conventionally-defined standards as output per capita”. This runs directly counter to the claims made by those who believe that *any* meaningful concept of the standard of living must also include such factors as “health, longevity and the quality of life” (Floud *et al.* 2011, 14).

Although many economic historians have advocated the use of height data on the basis that they provide a “mirror of the condition of society” (Tanner 1987), some writers have also argued that height can be regarded as an important health indicator in its own right. Derek Oddy (1982, 121-5) argued that height data enabled medical historians to measure the health

² This interpretation has been challenged by Bodenhorn *et al.* (2017); for Komlos’s response, see Komlos and A’Hearn 2016; 2019; Komlos 2019 and section 5 below.

of past generations directly, rather than relying on the inversion of measures such as mortality which, as he pointed out, measured the absence of health rather than its presence. Costa and Steckel (1997, 71-2) also advocated the use of height as a health indicator in their attempts to develop a historical version of the Human Development Index. As they pointed out, contemporary efforts to measure human development are based on a composite index incorporating measures of GDP per capita, life expectancy and literacy. Although they recognised that height and life expectancy are not precisely analogous, they argued that it was possible to apply this measure to populations for which mortality data were lacking by substituting height for life expectancy.

Although Costa and Steckel's paper played an important role in demonstrating the value of height data in a wider context, it also highlighted a potential source of tension between approaches which sought to incorporate height within other welfare indexes and approaches which treated height as a (relatively) comprehensive indicator in its own right. In a previous paper, Steckel (1992, 284) had argued that one of the attractions of height data was the extent to which they captured the influence of a wide range of factors associated with Sen's efforts to measure wellbeing. This reflects a longstanding debate between those who regard height as a supplement to conventional measures of wellbeing and those who believe it offers an alternative to them (see also section 6 below):

Average height is particularly adept at assessing degrees of deprivation, a feature that places the measure nicely within the basic-needs approach to living standards. While the basic needs approach has been criticised for the conceptual problems associated with ascertaining what is basic, in many ways average height finesses this problem because it is a measure of net nutrition. Average height incorporates the extent to which individuals have greater needs created by factors such as a harsher disease environment or greater workloads. In this vein, average height is also conceptually consistent with [Amartya] Sen's framework of functionings and capabilities, though, of course, height registers primarily conditions of health during the growing years as opposed to one's status with respect to commodities more generally.

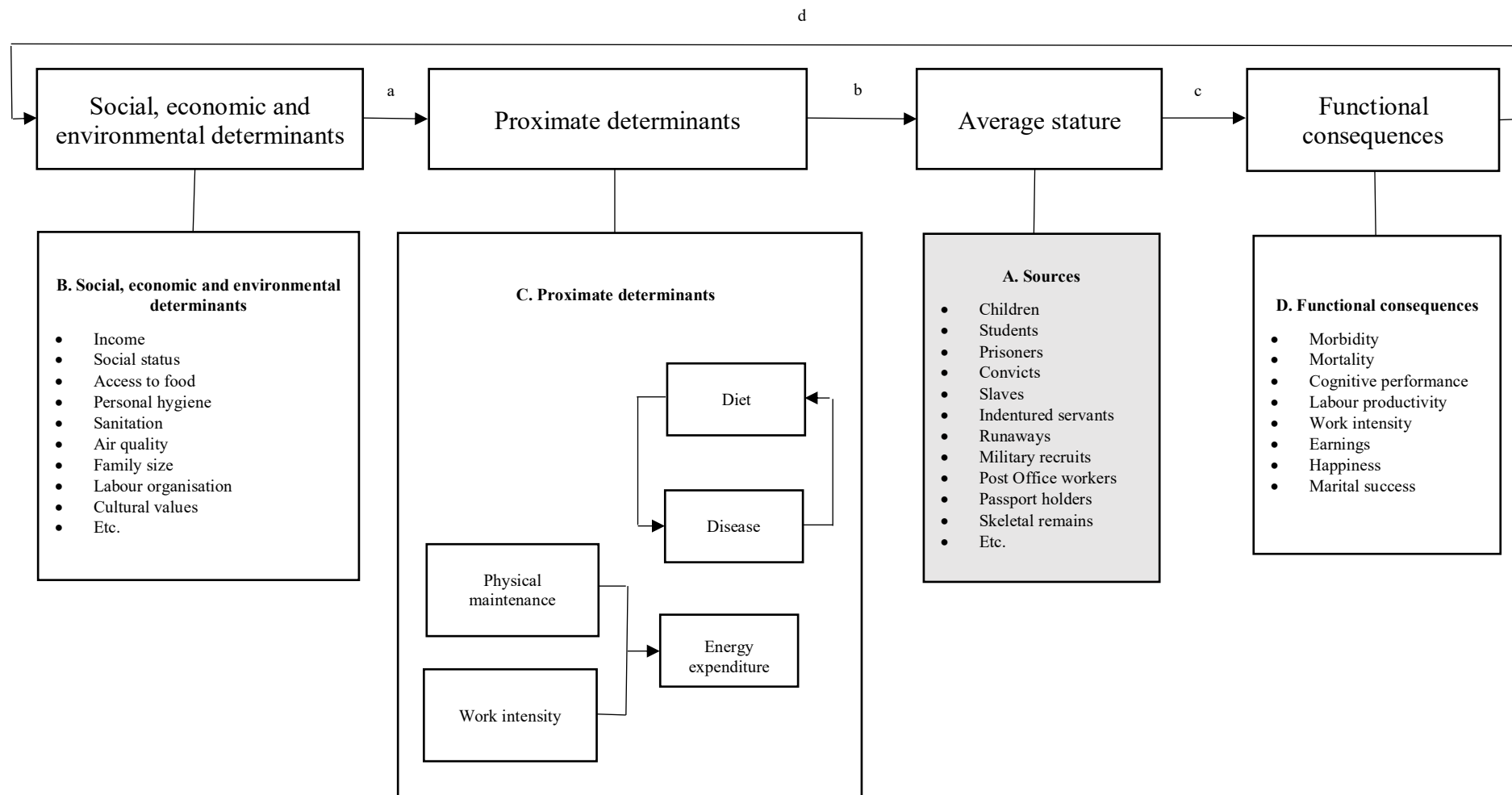
This section has focused on the use of height as a proxy for variables associated with the determination of mortality trends, a 'mirror of the condition of society' and a health indicator

in its own right. However, in order for height to function as a measure of wellbeing, one might argue that it also needs to be correlated with other aspects of people's lives which, in Sen's words, they might have "reason to value" (Sen 1999, 14). Anthropometric historians have sought to explore these dimensions by examining the relationship between height, as a summary measure of living conditions which people experience in childhood, and different aspects of their adult experience. As Floud *et al.* (2011, 20-5) have argued, height 'matters', not only because of what it reveals about the impact of childhood conditions on growth, but also because of the extent to which increases in average height have been associated with improvements in cognitive performance, labour productivity, and life expectancy.

2. Height as a measure of wellbeing

As *Panel A* of Figure 1 indicates, anthropometric historians have obtained data from a wide range of sources, but the majority of the available data refer to males and have been derived from populations which are subject to some form of surveillance or control, such as schoolchildren, prisoners and convicts, military recruits, indentured servants and slaves. Other information has been obtained from skeletal remains, passport holders and selected groups of workers, such as postal workers. This has prompted a number of questions about selection biases and representativeness. These issues will be discussed in more detail in sections 3-5 below.

Figure 1. Stature as a measure of the standard of living



Sources: Steckel 1995, 1908, and text.

Figure 1 also aims to summarise the different factors which are associated with variations in average stature. Although most of the individual variation in stature can be attributed to genetics, some of the earliest investigations highlighted the existence of systematic differences between the heights of different social groups (Villermé 1829, 384-5). These systematic differences are related to a large number of factors including income, social status, access to food, personal hygiene, sanitation, air quality, family size, labour organisation and cultural values which reflect the ways in which economic, social and environmental conditions may prevent a person from achieving their genetic height potential (*Panel B*).

Panel C illustrates the proximate determinants through which these factors exercise their effects. The key proximate determinants are diet, disease, and the energy required for physical maintenance and activity. The panel also illustrates the different ways in which these factors interact with each other. As Fogel and others have argued, height is a measure of *net* nutrition. It reflects the balance between the nutrients which a person consumes and the demands made by such factors as the “level of physical activity ... climate ... and ... exposure to various diseases” (Fogel 1986, 446-7). The relationship between diet and disease is particularly important. As Eveleth and Tanner (1990, 191-2) explained, exposure to disease can lead to a loss of appetite whilst also increasing the body’s need for extra nutrition, and diarrhoeal infections prevent the body from retaining the nutrients which are consumed.

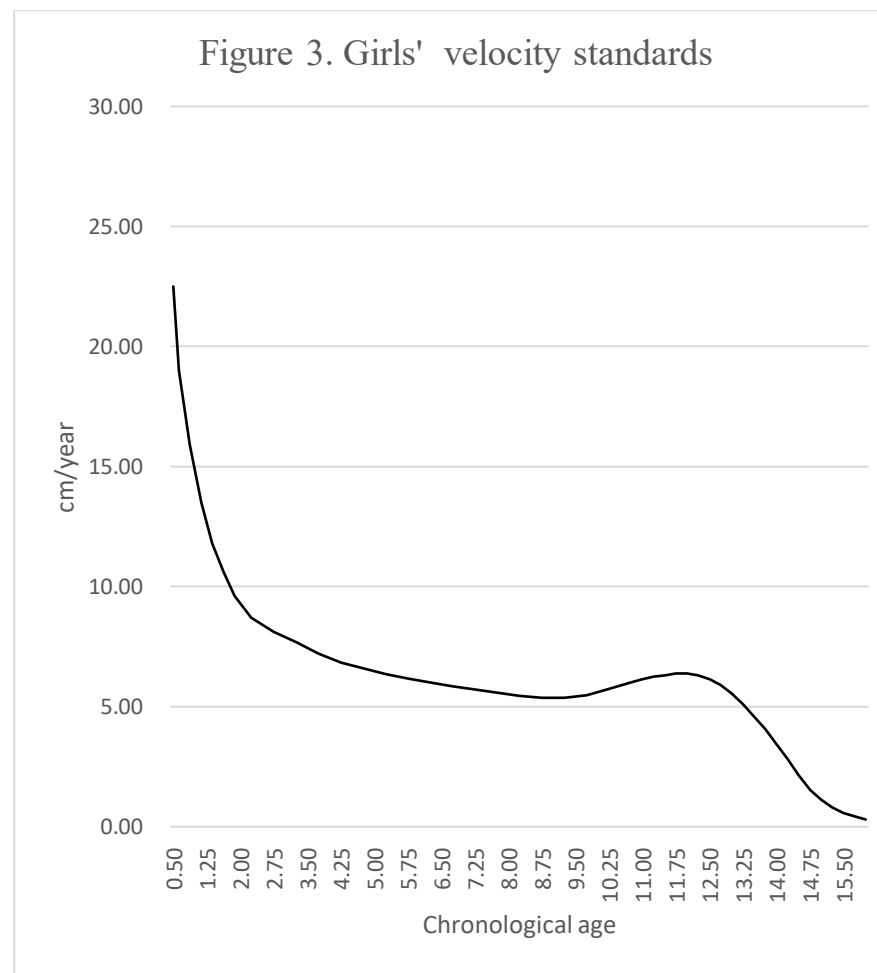
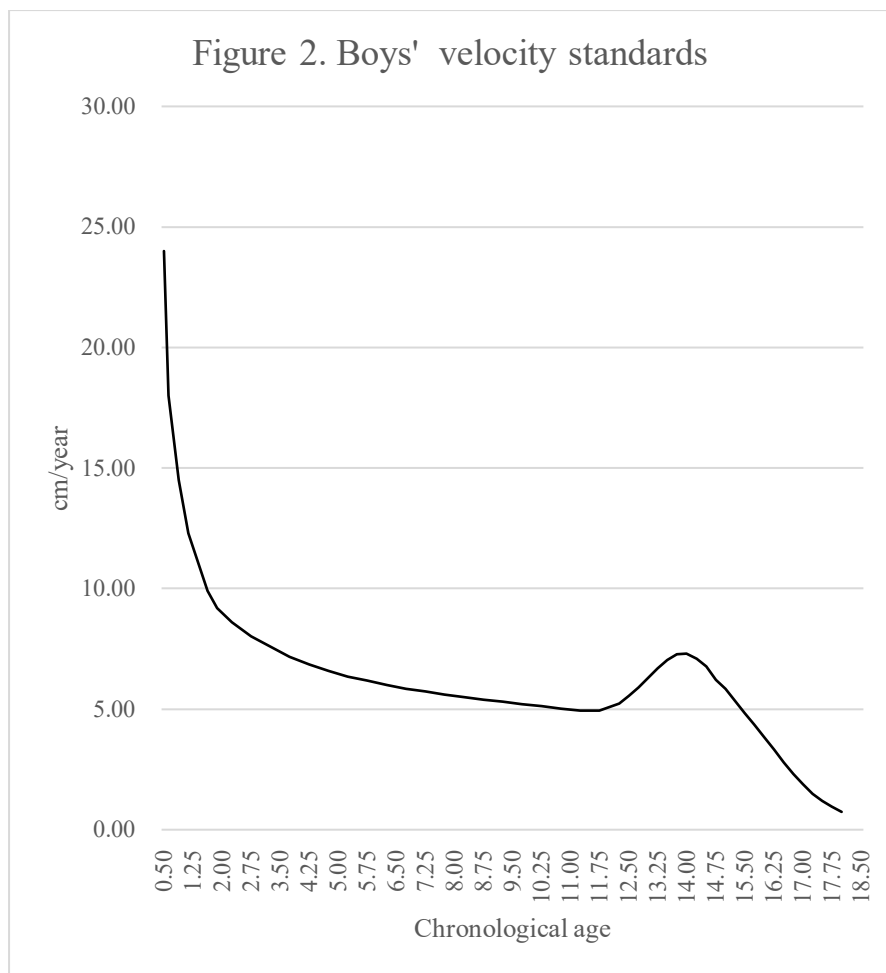
The fourth panel (*Panel D*) highlights some of the functional consequences associated with improvements in stature. These include lower morbidity and mortality, improved cognitive performance and greater work capacity, as well as the prospect of greater happiness and social mobility. These relationships have underpinned the theory of ‘technophysio evolution’, whereby improvements in the height and wellbeing of one generation pay the way for subsequent improvements in the height and wellbeing of its successors (Floud *et al.* 2011, 1-40).

The theory of technophysio evolution is also illustrated by the arrows linking the panels at the top of the Figure. As we have already noted, variations in the average heights of different sections of a population can be linked to systematic differences in a range of social, economic and environmental determinants (*Relationship a*). These influence height through their impact on the proximate determinants of diet, disease and energy requirements (*Relationship b*). Differences in height can also be associated with a range of functional consequences (*Relationship c*). These functional consequences then exert their own influence on the social, economic and environmental factors which shape the height of the following generation (*Relationship d*).

3. *Critical periods*

Although the study of anthropometric history is ultimately concerned with groups, the field is based on an understanding of the basic pattern of individual growth. As Figures 2 and 3 demonstrate, individuals grow rapidly during infancy and early-childhood, and more slowly between early-childhood and adolescence. The rate of growth accelerates at adolescence before slowing. In countries such as modern Britain, the majority of individuals achieve their mature height between the ages of sixteen (in the case of girls) and eighteen (boys). However, in the past, it seems likely that the onset of adolescence was delayed and that individuals continued to grow for longer (see e.g. Tanner 1990, 157-62; Beekink and Kok 2017).³

³ Although most anthropometric historians have tended to assume that the onset of the adolescent growth spurt was delayed for historical populations, Gao and Schneider (2020) have recently suggested that it may not have occurred at all. If confirmed, this conclusion could have major implications for our understanding of the pattern of human growth in the past and among deprived populations today.



Source: Tanner, Whitehouse and Takaishi 1966, 630-1.

Height and weight have often been used to monitor the health of both individuals and populations. At the individual level, auxologists use height data to identify children who are pathologically short, and they use growth curves to establish whether children are failing to grow at the rates which might be expected of them (see e.g. Tanner 1990, 178-9). However, differences in the average heights of different groups of people can also provide an essential guide to differences in their conditions of nurture. As Eveleth and Tanner (1976, 1; 1990, 1) explained:

A child's growth rate reflects, perhaps better than any other single index, his [*sic.*] state of health and nutrition, and often indeed his [*sic.*] psychological situation also. Similarly, the average values of children's heights and weights reflect accurately the state of a nation's public health and the average nutritional status of its citizens, when appropriate allowance is made for differences, if any, in genetic potential.... Thus a well-designed growth study is a powerful tool with which to monitor the health of a population, or to identify sub-groups ... whose share in economic and social benefits is less than it might be.

It has often been argued that children's heights are most susceptible to the influence of adverse conditions during the years in which they should be growing most rapidly. Tanner (1990, 131) argued that "in many populations, the period when the child is most at risk from malnutrition, often combined with infection, is six months to three years", whilst Eveleth and Tanner (1990, 194) identified the period from birth to five years as most critical. They also argued that "a second period when the child may be especially sensitive to the influence of undernutrition is adolescence" (*ibid.*, p. 196). This conclusion has recently been echoed by Depauw and Oxley (2019, 925) in their analysis of changes in the heights of Belgian prisoners during the nineteenth century. Although they acknowledged that "it is frequently assumed that conditions at birth" had the greatest effect on adult stature, they argued that it was the years between the ages of eleven and eighteen which mattered most.

These arguments have important implications for the way in which we use height and other anthropometric data to measure the health and wellbeing of past societies. If the factors which influence growth only exert a substantial effect during 'critical periods', this might

limit the extent to which we can use such data to represent social conditions more generally. However, such a conclusion may be premature. For anthropometric historians, two important questions arise: first, to what extent are rates of growth influenced by environmental and nutritional conditions throughout a person's growing years; and, second, what is the relationship between specific periods of infection or nutrition and final (or mature) adult stature?

Unfortunately, we possess relatively few data showing concurrent changes in the heights of children at different ages. Harris (1994, 364) examined changes in the heights of children in different parts of the UK during and after the First World War and concluded that “the differences between the heights of children who were born in 1914 and the heights of children born in 1918 may have owed at least as much to conditions around the time of measurement as ... to conditions at the time of birth”, although he also acknowledged that “it is difficult to reach any firm conclusions on the basis of the evidence ... currently available”. However, the most famous demonstration of this effect was provided by Howe and Schiller (1952) and Tanner (1962, 121-3; 1990, 129-30) in their accounts of changes in the heights of children attending schools in Stuttgart between 1911 and 1953. Tanner found that “there was a uniform increase at all ages from 1920 to 1940, but in both world wars the height dropped as ... food intakes ... became restricted” (Tanner 1990, 129-30).⁴

The second key question concerns the relationship between childhood experiences and adult stature. Eveleth and Tanner (1990, 195) argued that “the question of whether undernutrition in the first one or two years of life necessarily leads to an adult deficit in body size has been discussed frequently and inconclusively”, but their overall conclusion was that

⁴ Schneider and Ogasawara (2018) have recently studied the impact of the disease environment on the growth of children in Japan between 1917 and 1939. Their conclusion is that “the secular increase in height in interwar Japan was more strongly influenced by cumulative responses to the health environment at all ages across development rather than being simply the outcome of improving health conditions in early life” (p. 65).

“much depends on the circumstances obtaining when the severe episode of undernutrition is over” (see also Tanner 1990, 135). In a very influential historical study, Steckel (1986, 724-5) found that the relative values of the heights of slave children increased very rapidly from the age of ten onwards. Prentice *et al.* (2013, 911) have recently argued that “substantial height catch-up occurs between 24 mo[nths] and midchildhood and again between midchildhood and adulthood, even in the absence of any interventions”. They also cited evidence from their own study of growth patterns in rural Gambia, showing that “an extended pubertal growth phase allows very considerable height recovery, especially in girls during adolescence” (see also Wells 2016, 373; NCD Risk Factor Collaboration 2020).

One of the main issues raised by this literature is the importance of catch-up growth. If children are exposed to short periods of malnutrition or disease, they may experience a cessation in growth, but they are likely to return to what Tanner (1990, 165) described as a “predetermined growth curve” if conditions improve. This suggests that short-term periods of illness or malnutrition are unlikely to have an effect on adult or mature height and that adult height will only be affected if adverse conditions are maintained. However, catch-up growth may not necessarily be “cost-neutral” (Wells 2016, 224). As Singhal (2017, 236-7) has suggested, “there is now compelling evidence that ‘accelerated’ or too fast growth during critical or sensitive windows in early life has detrimental effects on long-term health, and particularly the risk of obesity and cardiovascular disease”(see also Leon *et al.* 1996).

These findings have different – and possibly conflicting – implications for our understanding of the relationship between height and wellbeing. If children experience short-term periods of illness or malnutrition, this may lead to a temporary reduction in their rate of growth, but they are also likely to regain their predetermined growth curves if conditions improve. However, even if catch-up does occur, this may nevertheless be associated with longer-term health deficits. On the other hand, if adverse conditions are maintained, adult

height is likely to be shorter. This suggests that adult height can be a sensitive barometer of the cumulative impact of adverse circumstances throughout the growing years, even if the impact of short-term fluctuations can sometimes be masked (see also Harris 2008a).

4. *Children and adults*

A second problem is presented by the question already highlighted by Richard Steckel (1992, 284) – namely, that average heights reflect the impact of living standards on health during the period from conception to maturity “as opposed to one’s status with respect to commodities more generally”. There are a number of possible responses to this issue. One argument is that heights might capture the impact of some aspects of adult health insofar as the height of one generation may be determined, in part, by previous standards of maternal nutrition. In other words, insofar as child and adult heights reflect the impact of the maternal environment, so they capture some aspect of the welfare of adult women during pregnancy. However, this would probably be insufficient to counter the view that heights still only capture aspects of human welfare during particular periods of life.

Steckel’s observation also raises an important question about the particular demands placed on people during childhood and the allocation of resources between adults and children. If there is an increase, for example, in the demand for child labour, this might exacerbate the burdens placed on children but also enhance their claims to a larger share of household resources (see e.g. Floud *et al.* 2011, 138). Equally, if parents decide to devote more resources to their children, this may enhance the standard of child welfare without necessarily reflecting a change in the welfare of society as a whole.

Although the majority of anthropometric historians have tended to assume that average heights reflect the experience of current generations, others have argued that the secular

increase in height is an “intergenerational phenomenon, with the offspring of each generation becoming taller than the previous generation, but with the increase in height per generation being tightly controlled” (Cole 2003, 166). However, other evidence suggests that average heights can increase very rapidly indeed when living conditions improve. Gruenwald *et al.* (1964, 1028) estimated that the average height of six-year old children in Japan increased by between 3.2 and 3.7 cm between 1945/6 and 1957/8 and Tanner *et al.* (1982) argued that the average heights of Japanese adolescents increased by between 7.9 and 9.7 cm between 1957 and 1977. Ling and King (1987, 187) observed an increase of between 4.2 cm and 6.7 cm in the average heights of Chinese adolescents in Hong Kong between the early-1960s and early-1980s (see also Harris 2001, 1432).

Although these studies suggest that average heights can increase very rapidly when circumstances change, this does not mean that the problem of intergenerational effects can be discounted entirely. As Wells (2016, 104) has explained, several studies have shown that the children and grandchildren of mothers who were exposed to undernutrition in their own lifetimes seem to face a higher risk of obesity. This suggests that, even if these children grow to be taller than their forebears, they may still be exposed to medical risks which originated in the experience of earlier generations (see also *ibid.*, 313).

The use of height as a measure of wellbeing may also be complicated by the relationship between height and mortality. As we shall see, it has often been argued that shorter people are more likely to die at any given age than taller people, and this has led some observers to argue that this will necessarily inflate the average height of survivors (Alter 2004, 545). Gerald Friedman (1982, 502) argued that “the mean height of adult males in Trinidad (aged 26-45) who died [during the early-nineteenth century] ... was 0.61 inches [1.5 cm] less than for those who survived” with the result that the “mean height of the survivors was 0.03 inches [0.01 cm] taller than that of the initial population”. However, these results referred to the

impact of deaths which occurred after mature height had been achieved. If mortality occurs at ages when children are still growing, any selection effect is likely to be outweighed by the impact of adverse conditions on the growth of those who survive (Hatton 2010; 2014; see also Prentice *et al.* 2013, 914).

Regardless of one's views on these questions, there are clearly limits to the extent to which heights provide direct evidence of standards of living after mature height has been attained. Some historians have attempted to compensate for this by using evidence of adult weights. Weight is a useful indicator, in this context, because it continues to change after mature height has been achieved (Horrell, Meredith and Oxley 2009, 96). However, it is also more ambiguous, partly because of its subjective element, and partly because being underweight and being overweight can both be indicators of ill-being (Harris 2014, 128).

It is also essential to consider the question of gender. As Osmani and Sen (2003) explained, the study of female heights is important not only in its own right (as an indicator of female wellbeing) but also because of the potential impact of women's nutritional status on the health of their offspring. However, there are relatively few studies of changes in female stature and many of the studies which do exist have focused on the heights of convicts and prisoners. Whilst these sources have also been used to examine changes in male height, the heights of male and female convicts may not be entirely comparable because of differences in patterns of male and female criminality as well as policing and sentencing procedures (Harris 2008b, 165).

Although researchers are beginning to examine a wide range of sources, it is arguable that no consistent picture has yet emerged. Koepke *et al.* (2018) have recently compared changes in the heights of men and women in Switzerland using data obtained from passport applicants, convicts, female auxiliaries and mothers attending the Basel maternity hospital. They argued that a secular increase in female heights began a generation earlier than the

onset of a similar increase in male heights. However, the evidence from other studies is more mixed. Ezzati *et al.* (2016, 7) argued that “at the turn of the twentieth century, men seem to have had a relative advantage over women in under-nourished compared to better-nourished societies”, whereas Perkins *et al.* (2016, 152) concluded that “sexual dimorphism in stature is more pronounced when undernutrition and childhood disease are mitigated”.

One of the main challenges involved in comparing male and female heights is the need to take account of both social and economic factors, on the one hand, and physiological differences on the other. Tanner (1962, 127-8) argued that girls were more resistant to the effect of adverse circumstances because they showed greater powers of canalisation, or homeorrhexis. Although the concept of canalisation has been questioned, this might help to explain why other studies have also found that the heights of past generations of girls appeared to compare more favourably with the heights of current generations than was the case for their male counterparts (see also Harris 2009).⁵

5. Truncated samples and selected populations

Although many authors would agree that, in principle, height data provide an important index of wellbeing, there have been a number of significant disagreements over the main trends in height in particular contexts. There is a longstanding argument over the correct representation of the main trends in height in Britain during the late-eighteenth and early-nineteenth centuries, and there have also been important debates over the representativeness of the

⁵ The concept of canalisation was introduced by the geneticist and developmental biologist, C.H. Waddington, who argued that “developmental reactions, *as they occur in organisms submitted to natural selection*, are in general canalized. That is to say, they are adjusted so as to bring about one definite end-result regardless of minor variations in conditions during the course of the reaction” (Waddington 1942, 563). It implies that children should grow at the same rate, relative to the rest of the population, throughout their growing years. Although it is widely used, it has not been accepted uncritically (see e.g. Hermanussen, Largo and Molina 2001). These authors also found, *contra* Tanner, that “growth in boys appeared slightly more canalised than in girls” (pp. 163, 166).

height data used to measure changes in wellbeing in both Britain and the United States during the second and third quarters of the nineteenth century.

In their original study, Floud, Wachter and Gregory (1990) argued that there was a slow and irregular improvement in the average heights of successive birth cohorts of British males between the mid-eighteenth century and the end of the first quarter of the nineteenth century, but this interpretation has been challenged by Komlos (1993a; 1993b) and other authors (see e.g. Cinnirella 2008; Komlos and Küchenhoff 2012; Meredith and Oxley 2014).⁶ Although some of the debate has focused on Floud *et al.*'s analysis of the heights of children who joined the Marine Society between *circa* 1770 and 1859, most of the controversy has revolved around their analysis of the heights of military recruits. Critics have challenged Floud *et al.*'s decision to pool data from different military sources and they have also criticised the estimation procedures used to extrapolate from the heights of military recruits to the (male) population as a whole.⁷

In addition to these statistical questions, different authors have attempted to support their interpretations of the data by comparing them with indicators which can either be regarded as proximate determinants of welfare, such as real wages or food availability, or with other indicators, such as mortality, which could be regarded both as alternatives to stature or as an indirect determinant of it. Komlos (1993b, 365) sought to reinforce his initial critique of Floud *et al.* by highlighting evidence which suggested that average food supplies had also

⁶ Galofré-Vilà, Hinde and Guntupalli (2018, 87-8) have also found evidence of a small decline in average heights during the course of the eighteenth century in their study of skeletal remains. However, they are careful to point out that their conclusions are based on very small sample sizes and may be distorted by changes in the composition of the population from which their samples are drawn.

⁷ As Floud, Wachter and Gregory (1990, 118) explained, the British Army imposed a number of different minimum height standards to control the flow of volunteers at different times. They advocated the use of Reduced Sample Maximum Likelihood Estimation to compensate for the effects of this when estimating the average height of the underlying population. Komlos (1993a; 1993b) claimed that this procedure was flawed and led to erroneous inferences. He provided a fuller discussion of the use of different methods for correcting for the effects in truncation in 2004 (Komlos 2004). For a further response, see Floud *et al.* 2011, 66-7, 136-8.

deteriorated. However, this argument has also been challenged and, in their latest contribution, Harris, Floud and Hong (2015) argued that average food supplies rose, overall, between 1750 and 1850 (see also Harris 2016).

The point of rehearsing these issues is not to revisit the technical aspects for their own sake but to highlight their broader implications for the study of anthropometric history. If one regards stature as an entirely separate measure of the standard of living – which may or may not be implied by the use of such terms as the ‘biological standard of living’ – then there is perhaps less need for it to be correlated with other indicators. However, if we regard it as an alternative measure of ‘the’ standard of living, then it is more important to show how trends in height may or may not be related to more conventional indicators, where evidence for such indicators exists.

The interpretation of the height data drawn from volunteer samples, including both military recruits and prisoners, has also been called into question by Howard Bodenhorn and his coauthors (Bodenhorn, Guinnane and Mroz 2013; 2017). Anthropometric historians have tended to organise the heights of mature adults by birth cohorts, either because they believe that the factors which influence height exert their strongest influence during infancy and early childhood, or because they believe that the factors which shape average heights operate from conception to maturity. Bodenhorn *et al.* argued that we also need to consider the ways in which economic fluctuations might influence the propensity of men and women of different heights either to volunteer for the army or commit crimes. This led them to conclude that the declines in average height observed by students of both antebellum America and mid-nineteenth century Britain were both artefacts of selection bias.

Although Bodenhorn *et al.* were undoubtedly correct to highlight the importance of selection bias, it is also important to note at least two caveats. In the first place, it is necessary to acknowledge that their concerns were not new – Floud, Wachter and Gregory (1990, 115-

8) discussed the impact of labour market fluctuations on the pool of army volunteers at some length – and their efforts to rework both the UK data and the US data have themselves been challenged (Zimran 2019; Komlos 2019; Komlos and A’Hearn 2016; 2019). Second, Bodenhorn *et al.*’s conclusions also raise questions about how they see the relationship between height and other welfare indicators. Their work appeared to pose a direct challenge to the role played by anthropometric studies in supporting ‘pessimistic’ accounts of the impact of industrialisation on the standard of living (see e.g. Bodenhorn, Mroz and Guinnane 2013, 6-8; *ibid.* 2015, 8-10; *ibid.* 2017, 174-5). However, in the conclusion to their 2017 paper, they acknowledged that “mortality rates remained stubbornly high through the early decades of industrialisation ... and in some cases actually increased, as cities became larger and less healthy.... Real wages rarely fell, but there is reason to doubt that feeble nominal wage growth protected the lowest strata from the consequences of food-price shocks” (Bodenhorn, Guinnane and Mroz 2017, 202). If this is correct, it is legitimate to ask why they believe that these factors should not have also been reflected in the anthropometric record.

6. Dietary influences on stature

As the anatomist, David Sinclair (1978, 140) once explained, “the best way of growing tall and heavy is to have tall and heavy parents”. This insight has been reinforced by more recent studies which have suggested that approximately eighty per cent of the variation in height between individuals of European descent (Visscher 2008) or living in modern western societies (Silventoinen 2003) is genetic in origin, with the remainder being attributed to environmental conditions, of which the most important are nutrition and infection. As Eveleth and Tanner (1976, 246) explained:

An ill child is a poorly-nourished child, although the extent of slowing down depends on a number of factors. Poorly-nourished children are more susceptible to and more

severely-affected by infection than well-nourished children.... Infection in turn lowers the nutritional intake of the child and the vicious spiral continues.

Anthropometric historians have often considered the question of whether some foods may be more nutritious, and therefore growth-promoting, than others. As Floud, Wachter and Gregory (1990, 298) acknowledged, it has often been assumed that the Scots and Irish were poorer, at the end of the eighteenth century, than the English or Welsh, and yet their children also grew to be taller. They speculated that this may have reflected the extent to which “potatoes and milk, and perhaps also the oatmeal of the Scots, seem to have provided a healthy and balanced diet for those who did not have to fight off urban disease”.

The question of whether either the Scots or the Irish owed their relative tallness to the particular characteristics of their staple diets has also been examined by Mokyr and Ó Gráda (1996, 163-4). They suggested that the specific claims made on behalf of the nutritional value of particular foods meant that anthropometric historians needed to ‘tone down’ claims that height provided an alternative, or even superior, guide to the ‘standard of living’. However, they also argued that some of the height advantage enjoyed by Irish recruits may have been caused by selection effects, clouding the issue further.⁸

The importance of different kinds of foodstuffs has also been discussed elsewhere. Floud *et al.* (2011, 162) noted that people who were over-dependent on cereal-based diets needed to consume more food in order to obtain the same nutritional benefit. Dasgupta and Ray (1990, 215-6) argued that individuals who consumed high-fibre diets under pre-industrial conditions needed to increase their total consumption by around 35 per cent in order to derive the same nutritional benefit from their diets as people living under more favourable circumstances.

⁸ Grasgruber *et al.* (2016, 164-5) have recently examined the relationship between a wide range of variables and differences in height in 105 countries. They found that potato consumption was correlated positively with height ($r = 0.68$; $p < 0.001$) but were unable to explain why. They noted “the significance of potatoes ... is unexpected because of the poor quality of potato proteins, their low consumption rate and a very low ‘nutrient density’”.

Other authors have also highlighted the possible importance of meat and, especially, dairy products. Jörg Baten and his coauthors have argued that variations in milk consumption help to explain regional variations in stature in nineteenth-century Bavaria, Prussia and France (Baten 2009; Baten and Murray 2000), and in other parts of Europe during the time of the Roman Empire (Koepke and Baten 2005; 2008). These findings have been reinforced by contemporary surveys which have also highlighted a positive association between height and milk consumption (Perkins *et al.* 2016, 153-4; Wells 2016, 302, 362). However, Baten has also suggested that the impact of milk consumption on variations in stature in the latter case may have been mediated by the specific economic situation of the Roman Empire and high population densities (Meinzer *et al.* 2019, 238-9).

Although the significance of this issue should not be exaggerated, it does pose a challenge to the idea that height provides a *general* guide to the ‘standard of living’. As Mokyr and Ó Gráda (1996, 163-4) suggested, if one population was shorter than another because its staple diet was based on wheat rather than potatoes, one would not automatically conclude that its standard of living was poorer. It is perhaps for this reason that both Mokyr and Ó Gráda (1996, 163-4) and Baten and Blum (2014, 568) argue that height data should be used to complement conventional welfare indicators, rather than being cited as replacements for them.

7. *Height and disease*

As we have already seen, one of the key arguments in favour of anthropometric approaches is the claim that height is a measure of *net* nutrition – i.e. that, in addition to capturing the effect of dietary inputs, it also reflects the impact of the external demands placed on the body by the environment in which it is placed. These might include not only the demands created by the

need for calories for work and physical maintenance, but also the effects of disease. This argument is particularly important in the context of debates about the impact of industrialisation on the standard of living. Proponents of the anthropometric approach argued that height was able to capture not only the effect of changes in real wages, but also the impact of urbanisation on the disease environment (Floud 1984a).

Auxologists and anthropometric historians have identified a number of different ways in which stature may be affected by disease. In the first place, illness can suppress appetite and also increase the number of calories required to ward off infection. It can also interfere with the absorption of essential nutrients. Children who are subjected to repeated bouts of diarrhoea are likely to grow more slowly if they lack access to nutritional supplementation. As Floud, Wachter and Gregory (1990, 245) explained:

Infection affects nutritional status by a number of different mechanisms. These include loss of appetite, energy lost as heat during fever and loss of other nutrients in sweat, vomiting, decreased absorption of nutrients, protein catabolism, and reduced food intake resulting from cultural factors. Malabsorption can also result from infestation with intestinal parasites, but the most common and severe cause is diarrhoea, which causes food to pass through the intestine too quickly to be absorbed.

Other historians have also highlighted the impact on stature of malaria (Hong 2007) and hookworm infestation (Coelho and McGuire 1999), and others have begun to direct attention to the impact on atmospheric pollution. Sharpe (2012) identified a number of different diseases causing stunting, including measles, whooping cough, bronchopneumonia, diarrhoea and rickets. The last of these was associated not only with poor diet but also reduced exposure to sunlight in the dense fog enveloping Britain's cities. Bailey *et al.* (2018) have recently built on this foundation in their study of the impact of air pollution on the heights of men who completed their army service in Britain between 1914 and the early-1920s. They concluded that coal smoke reduced adult height by almost half an inch (1.2 cm), and that efforts to clean up Britain's air accounted for approximately 25 per cent of the gain in average male stature between the birth cohorts of the 1890s and 1980s (*ibid.*, 33).

Although most anthropometric historians would accept that height reflects the impact of a wide range of influences, some observers have suggested that this is less of a strength than a weakness. Crafts (1992, 428) complained that it was “unclear how to incorporate height in a welfare index” because “no way of measuring the exchange rate of height for real income has yet been devised” but one might argue that, in some ways at least, this misses the point. It is precisely because height captures a wider range of influences, in addition to real income, that its proponents regard it as a superior measure, even if this also means that it is more difficult to relate changes or variations in height to any single cause (see also Floud *et al.* 2011, 12-13; Steckel 2008, 136; 2016, 38).

8. Height and ethnicity

As we have already seen, anthropometric historians have devoted a great deal of effort to the challenge of identifying trends in average height within individual countries. However, some of the earliest (and most foundational) papers also sought to draw comparisons between countries. After comparing data from twenty countries in different parts of the world, Steckel (1983) concluded that international differences in mean stature were particularly sensitive to variations in per capita income and the degree of income inequality. Floud (1984b, 23; see also *ibid.* 1994, 23) examined trends in the average heights of men in eleven European countries between the mid-nineteenth and late-twentieth centuries, and concluded that “western European heights have responded entirely systematically, over the past hundred years, to changes in income and disease, just as heights in the modern world respond to similar differences between countries”.

In recent years, it has become possible to study the impact of environmental and genetic factors on height in much more detail, and this has led some authors to suggest that genetic

factors may play a larger role in influencing cross-national variations in adult stature. Brian A'Hearn (2016) has recently argued that the distribution of heights in southern Europe correlates quite closely with variations in real wages before 1850 but less so thereafter. He suggests that this can be explained partly by changes in work intensity (i.e. workers compensated for reductions in hourly wages by working longer) and partly by changes in the disease environment (including the eradication of malaria). However, when looking at variations in the heights of adult males born during the 1980s, he argued that genetic differences also played an important role.

As A'Hearn acknowledged, this analysis was subject to a number of limitations. In order to measure the impact of variations in the disease environment, he examined differences in life expectancy, but much of the variation in life expectancy is also likely to reflect the impact of cross-national differences in mortality from non-communicable diseases at higher ages. Other writers have preferred to study the correlation between height and child mortality rates (see e.g. Grasgruber 2014; 2016). These measures also have their limitations, but the correlation between child mortality rates and height in A'Hearn's sample was greater than the correlation between height and life expectancy.⁹

However, despite this, other writers have also concluded that genetic factors have played an increasingly important part in explaining contemporary height variations. Grasgruber *et al.* (2014) explored the impact of a range of factors in variations in adult male stature in 45 European territories and their 'offshoots' in Australia, New Zealand and the United States. Although they concluded that height was quite closely correlated with a number of economic

⁹ We possess data on adult male stature, life expectancy at birth and children's mortality rates for 27 of the countries which A'Hearn examined. The correlation between height and life expectancy was 0.487 ($p = 0.01$) and the correlation between height and child mortality was -0.569 ($p = 0.002$). For data on height and life expectancy, see A'Hearn 2016, 769-70; for data on child mortality rates, see <https://datacatalog.worldbank.org/dataset/world-development-indicators>. The child mortality rate is the average for the period 1980-85, with the exceptions of Czech Republic (1981-5), Serbia (1984-5) and Slovenia (1981-5). A'Hearn's original study also included results for 'Med-Yugoslavia'.

and socio-economic factors, including nutritional quality, GDP per capita, health expenditure, child mortality and income inequality, they also discovered relationships with a number of genetic variables, including the distribution of Y-haplogroup I-M170, combined frequencies of Y-haplogroup I-M170 and R1B-U106, and the phenotypic distributions of lactose tolerance. They also reported similar, though not identical, conclusions after extending their analysis to include countries in Africa, Asia and Oceania (Grasgruber *et al.* 2016).

These findings suggest that genetic factors may play a larger role in determining international variations in stature than previously supposed but economic, environmental and nutritional factors are also important. Even if the impact of these factors has declined over time, they have not been eliminated altogether. As Grasgruber *et al.* (2016, 194) have argued, “the factors leading to the increase in the average height intertwine with public policies that improve the overall quality of life”. Even if genetic factors have become more important, the evidence suggests that height continues to be an important tool for monitoring the extent to which these policies have succeeded. Baten and Blum (2012) reviewed the historical evidence on changes in average male stature in 156 countries between *circa* 1810 and 1989. After “taking into account ... protein availability, disease environment, lactose intolerance and food preferences”, they concluded that “the height impact of ‘race’ seems rather small” (p. S69; see also NCD Risk Factor Collaboration 2020, 1520).

9. Height, wages and mortality

The majority of this paper has been concerned with the use of height data as summary reflections of the aggregated impact of factors such as real income, food consumption and disease, all of which have been associated traditionally with the ‘standard of living’.

However, an important part of the argument in favour of using height data as indicators of

wellbeing is that they also capture aspects of human development which have functional consequences for other welfare measures, including both labour productivity and longevity.

An early illustration of the relationship between height and both longevity and productivity was provided by Friedman's study of the heights of Trinidadian slaves. As we have already seen, he showed that slaves who survived in the initial registration period were 0.61 inches (1.5 cm) taller than non-survivors, and that craftsmen were 0.5 inches (1.25 cm) taller than fieldhands (Friedman 1982, 488-9). Similar results were also reported by Margo and Steckel (1982) and Costa (1993). These findings have also been echoed in studies of more recent societies. Waaler (1984) showed that shorter people were more likely to die at younger ages and Schultz (2002) demonstrated that taller people enjoyed higher wages. Deaton and Arora (2009) concluded that height was positively correlated with both income and education, as well as with happiness and wellbeing.

As we have already seen, height is an important marker for the effects of environmental and nutritional conditions on childhood growth. However, in modern western societies, approximately eighty per cent of the individual variation in heights is likely to be due to genetic effects. It is therefore important to ask what dimensions of stature are being captured by the association between height and other indicators. This question is particularly important when considering historical data. It seems reasonable to assume that environmental factors accounted for more of the variation in individual stature in the past, when a greater proportion of the population was subjected to conditions which were likely to restrict their growth. If this is the case, we might therefore expect the association between height and other measures to have been stronger, if this association was caused by the impact of early-life conditions on adult stature.

One way of approaching this issue to compare the association between height and mortality in historical and contemporary populations. Both Costa (1993) and Alter (2004)

have compared the association between height and mortality within historical populations with Waaler's (1984) analysis of the relationship between height and mortality in mid-twentieth century Norway. In all three cases, mortality declined as height increased, up to a height of approximately 73 inches (183 cm), at which point the relationship was reversed. If the association between height and mortality was caused primarily by genetic factors, one might have expected the curve to shift to the right as average heights increased. The fact that it appears to have remained constant suggests that environmental factors also played a role (see also Harris 1997).

This is a reassuring conclusion for those who believe that improvements in the environmental and nutritional conditions which are associated with adult stature will also lead to reductions in mortality. However, it is important to recognise that the association between height and mortality is also linked to specific causes of death, such as cancer, coronary heart disease and chronic obstructive pulmonary disease, and there are other causes of death for which height and mortality are correlated positively (Floud, Harris and Hong 2014, xxxiii; Perkins *et al.* 2016, 155-7). As the cause-structure of mortality changes, one may therefore expect to see further changes in the relationship between height and mortality.

10. The social value of height

The preceding sections have focused on the extent to which height can be correlated with other factors associated with the measurement of wellbeing. This has involved an examination of factors which influence height and rates of growth as well as other indicators which may be affected by them. However, it is worth asking whether height also possesses a more 'subjective' value as either an index or dimension of wellbeing. If height is correlated

with measures of happiness or ‘subjective wellbeing’, is this because it is also associated with other correlates or because it is valued in its own right?

In an intriguing paper, Deaton and Arora (2009) compared the height and weights of more than 450,000 men and women with their position on a “self-anchoring sliding scale”. This scale asked respondents to rate their quality of life on a sliding scale of 1-10, where ‘1’ represented “the worst possible life” and ‘10’ the highest. They found that “men who are above average height ... report that they are a little more than one-seventh of a step ... above men who are below average height” and that women who were above average height were a little less than one-tenth of a step higher than women whose height was below the average. However, they also found that almost all of the difference disappeared after making allowances for the effects of income and education. In other words, if taller people were happier, it was not because they were taller but because they were wealthier and better-educated.

However, despite this, there are some indications that height may also possess a value of its own. As Floud *et al.* (2011, 13) observed, there is some evidence for this in the “immense effort and expenditure undertaken by some parents of particularly short children to lengthen their children by persuading surgeons to break their leg bones and then ... stretch their legs as they heal”. There is also evidence to suggest that height is often a quality we value in others. Several studies have shown that taller men are more likely to marry at younger ages and more likely to ever marry, although the reasons for this remain unclear. Murray (2000, 518) argued that, whilst women may have preferred taller men on cultural or aesthetic grounds, they may also have recognised that such men were likely to be healthier or have better earnings prospects (see also Weitzman and Conley 2014; Yamamura and Tsutsui 2017). Sohn (2015, 111) examined the ‘trade-off’ between height and income in Indonesia and found that, whilst much of the association between male height and marriage was related to income, “there are

still other attributes that women look for in male height, and this indicates that there are marriage market penalties for short men”.

Although much of the available evidence suggests that height does possess a social value, it does not necessarily follow that societies will always behave in ways which seek to maximise stature. As we have already suggested, height is a measure of net nutritional status ‘from conception to maturity’ and may therefore reflect, in part, the extent to which parents are either able or willing to behave in ways which maximise children’s nutritional status. Variations in stature may also reflect the extent to which societies ‘trade off’ some aspects of wellbeing against others. Eltis (1982, 474-5) argued that many historical populations may have engaged in “nutritional satisficing” or “aim[ing] for a nutritional target lower than maximum”. He argued that this was because they valued “self-employment” over the achievement of more material goals. He also suggested that, in many cases, improvements in average stature only occurred when labour was either partially or entirely coerced.

11. Conclusions

Eveleth and Tanner (1976, 1; see also *ibid.* 1990, 1), argued that “a well-designed growth study” was not only “a powerful tool with which to monitor the health of a population” but also “to pinpoint sub-groups ... whose share in economic and social benefits is less than it might be”. The link between height, health and ‘economic and social benefits’ was the basis for Tanner’s subsequent description of height as a “mirror of the condition of society” (Tanner 1987). To what extent does this claim continue to apply to the study of historical populations?

This paper began by examining the background to the development of anthropometric history and the impact of economic, social and environmental factors on variations in human

stature. It then explored some of the issues associated with the identification of ‘critical periods’ and efforts to extrapolate from the analysis of male heights to the understanding of differences in welfare between different genders and age-groups. It also provided a brief account of the impact on height of both diet and disease before looking at some recent debates over the impact of ‘race’ and ethnicity. It concluded by examining the relationship between height, wages and mortality, and between height and ‘subjective wellbeing’.

In general, this brief survey suggests that height has retained its capacity to shed light on the welfare of past populations, with some possible caveats. One problem concerns the question of ‘catch-up’ growth. There is increasing evidence – especially at the youngest ages – to suggest that even though children are able to ‘catch up’ if their environmental or nutritional circumstances improve, this may still come at the cost of future health problems. If this is the case, then their ability to return to their ‘predetermined growth curves’ may still mask significant health deficits. On the other hand, if their circumstances do not improve, their final, or mature, height is likely to be lower, and this will reflect the cumulative impact of adverse circumstances throughout their growing years.

The value of height as a measure of welfare is also affected by the role played by particular foodstuffs. Various authors have argued that height is especially sensitive to the consumption of oats, potatoes, milk or other sources of animal protein. Some of these findings may, of course, have been affected by selection issues. However, insofar as growth is affected by particular foodstuffs, it is also important to consider the extent to which access to the most nutritious – and growth-promoting – foods is itself related to broader conditions.

Another controversial issue concerns the relationship between height and ethnicity. It has recently been suggested that ethnicity may play an increasingly important role in determining international variations in stature, although this may depend, in part, on the particular nature of the variables which have been used as proxies for economic and health conditions.

However, it still seems likely that international variations in stature would have been more closely associated with variations in economic and environmental circumstances in the past, when the impact of these factors on individual height differences may also have been greater.

The use of height as a measure of wellbeing depends partly on the argument that it can be correlated with a range of causal factors which are broadly associated with the ‘standard of living’, and partly on the claim that it is also correlated with other dimensions of wellbeing which individuals might have “reason to value” (Sen 1999, 14). Two issues which have received particular attention in this context are wages and mortality. However, it is important to remember that the correlations between height and both of these indicators may change over time. Costa (2015, 551) has argued that “returns to height in the United States *circa* the mid-nineteenth century were very low” because they were generally associated with low-status occupations, but they have increased over time because of the correlation between height and cognitive performance and the transition “from a brawn- to a brain-based economy”.

The relationship between height and mortality is also, in some senses, time-contingent. As we have seen, it seems reasonable to suppose that environmental factors had a greater influence on variations in stature in the past than they do today. If the relationship between stature and mortality reflected the relationship between stature and living conditions, one might therefore expect the relationship between stature and mortality to weaken over time. This effect is compounded by changes in the cause-structure of mortality. If height is negatively correlated with diseases whose impact on mortality is declining, one would then expect the relationship between height and overall mortality to change accordingly.

Although increases in height have generally reflected improvements in living standards, this may also be complicated in other ways. As we have already seen, height is a cumulative measure of the conditions experienced by children from conception to maturity. As a result,

in addition to a household's general living conditions, it may also reflect the way in which resources are distributed within the household. In many contemporary societies, it is still the case that girls often receive a smaller share of the available resources than their brothers but historians have continued to disagree over the extent to which this may also have been true in the past (see e.g. Harris 2008b). This is one reason why the relative paucity of data on female heights remains a significant challenge for anthropometric historians.

The long-term history of anthropometric change may also be affected by changes in household size and structure. Previous studies have shown that height can vary with birth order and that children who grow up in (numerically) large families have often been shorter than children who grow up in smaller families (Öberg 2017). This has led a number of authors to conclude that one of the major causes of the improvement in heights during the twentieth century was the decline of fertility, even though not everyone might see the decision to have fewer children as a form of 'wellbeing' (Hatton and Martin 2010; see also Hatton and Bray 2010).

This issue also highlights the potential significance of parental choice in determining children's growth. Although parents may not necessarily 'purchase' height (Floud *et al.* 2011, 13), it is generally assumed that they will seek to obtain the living conditions with which height is often correlated. However, as Eltis (1982, 474-5) argued, many adult populations may – no doubt unintentionally – have reduced their children's growth by prioritising leisure over work. Although he did not discuss this issue at great length, he also speculated that this practice only ceased under conditions in which labour was either partially or entirely coerced.

This is not the only perplexing conclusion which the history of human height has sometimes evoked. In general, as material conditions have improved, children have grown taller and heights have increased. However, a number of scholars have also suggested that some of the largest improvements in stature in earlier periods were preceded by significant

disasters. Clark (2007, 101) argued that the Black Death of 1347-51 “raised living standards all across Europe” in the following years. In a similar vein, some anthropometric historians have argued that “the tremendous reduction of the population during the Justinian Plague and the end of the West Roman Empire had a strong impact on health, because the much smaller population [in number] was likely better nourished” (Baten *et al.* 2019, 394). Although this interpretation has not gone unchallenged (see Galofré-Vilà, Hinde and Guntupalli 2018, 81-2), it nevertheless provides a rather sobering coda to the long-term history of anthropometric change.

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