**ANTHROPOMETRIC HISTORY AND THE MEASUREMENT OF WELLBEING**

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*Abstract*

Anthropometric history has been conceptualised as a way of measuring (net) nutritional status, the 'biological standard of living', and a composite index of human welfare combining the impact of dietary inputs with the external demands placed by work and the disease environment on the human body. However, there are also limitations. Variations in average height reflect the impact of diet and environmental conditions from conception to maturity, but reveal little about health in later life (though they may of course influence it). The available data continue to be dominated by males, raising questions about the relative invisibility of female wellbeing. Controversy continues to surround such issues as the ages when adult (mature) height is determined, selection biases and truncation issues. How do these issues affect height's capacity to act as a 'mirror of the condition of society'?

The last four decades have witnessed an enormous increase in the number of publications using anthropometric indicators (Steckel 1995; 2009; Galofré-Vilà 2018). This increase has been driven, in part, by a perceived need to compensate for the absence, in different periods and for different countries, of other kinds of data, such as real wages or mortality. However, the underlying justification for this work is the idea that measurements such as height and weight reveal something important about underlying economic and social conditions and that they are, ultimately, a significant measure of a population's 'wellbeing'.

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Although scholars have often argued that height is an index of 'welfare' (Inwood and Roberts 2011), 'wellbeing' (Koepke 2016; Steckel 2016) or 'the standard of living' (Steckel 2008), these terms are notoriously difficult to define. As Sen (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.

Many of these complexities have also been reflected in the ways in which economic historians have addressed these issues. During the 1920s, John Clapham (1926: vii) dismissed the 'legend that everything was getting worse for the working man, down to some unspecified date between the drafting of the People's Charter and the Great Exhibition' on the grounds that 'the purchasing power of wages … was definitely greater than it had been just before the Revolutionary and Napoleonic Wars'. However, the assumption that it was possible to reduce the study of living standards to the question of real wages was hotly contested. As J.L. Hammond (1930: 225) argued, 'there were thousands of men and women for whom life was easier and more comfortable because the Industrial Revolution had given them stockings and cotton clothes without making them pay the price that the mill worker paid … but the ugliness of the new life, with its growing slums, its lack of beautiful buildings, its destruction of nature and its disregard of man's [*sic.*] deeper needs, affected not this or that class of workers only, but the entire working-class population'.

One of the central claims made by supporters of anthropometric history is that it provides a way of reconciling these different perspectives. In other words, it reflects the impact of traditional economic indicators on people's capacity to purchase the items necessary for health whilst also reflecting the impact of environmental conditions, and other circumstances, on health. Although some writers have bemoaned the difficulties involved in tracing changes in height back to any single economic variable (see e.g. Crafts 1992), others might argue that it is precisely because height reflects the aggregated and cumulative impact of a variety of different factors that it is such a useful indicator of general 'wellbeing'.

This paper aims to review this idea in the light of the new research which has been undertaken in the field of anthropometric history over the last forty years. It begins with a brief account of the role played by anthropometric history in efforts to measure ‘wellbeing’ and the ‘standard of living’. It then discusses the literature on the question of ‘critical periods’ and their implications for the attempt to use heights to measure both current circumstances and the wellbeing of the population as a whole. Section three 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 four and five summarise the relationship between height and diet and disease, and section six explores recent attempts to assess the relationship between height and ethnicity. The final section looks at the extent to which height also helps to ‘predict’ aspects of wellbeing in later life.

## *1. Background*

Although social investigators have often argued that there is a link between height and social conditions, it is generally agreed that the first attempt to incorporate this into historical analysis originated with Le Roy Ladurie, Bernageau and Pasquet’s studies of the French Army conscripts of 1868. They noted that the conscripts’ heights appeared to vary systematically with their social backgrounds (Le Roy Ladurie, Bernageau and Pasquet 1969). Le Roy Ladurie and Bernageau (1971: 59-60) subsequently concluded that it was ‘the standard of living … rather than the way of life … which … produced … [this] contrast in physical anthropology’ (Le Roy, Bernageau and Pasquet 1969; Le Roy Ladurie and Bernageau 1971: 59-60). However, it was not until later in the decade that the full implications of this insight began to influence discussions more generally.

It is common to trace the origins of anthropometric history as a distinct approach within the broader fields of economic, social and demographic history to the work of Robert Fogel, Stanley Engerman and their associates in the 1970s. Their initial focus was on the value of anthropometric data as indices of nutrition, and their aim was to use these data to shed new light on the role played by diet in the decline of mortality (Fogel *et al.* 1978: 42). However, it soon became apparent that this was less straightforward than it might initially have appeared. This was because height was not simply a measure of dietary input, but was in fact a measure of *net* nutrition, incorporating not only inputs, but also the demands made on these by external factors, such as work and the disease environment (see e.g. Fogel 1986: 446-7).

Although the introduction of the concept of net nutrition may appear to have clouded the debate in one way, it also opened up other possibilities. In 1984, Roderick Floud linked the value of anthropometric history directly to debates over the standard of living in Britain during the industrial revolution. He argued that it was precisely because of the multidimensional nature of anthropometric data that they had the potential 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 1984: 14-15).

This insight has also been reflected in the work of Richard Steckel and John Komlos. Steckel (1992: 284) argued that:

> 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.

John Komlos' concept of the 'biological standard of living' has something in common with these approaches, though there are also differences. Komlos (1987; 1993a) argued that a new concept was necessary because of divergences between anthropometric indicators and more conventional welfare measures. However, other commentators have questioned whether it is necessary to introduce a new concept for this particular purpose. Floud *et al.* (2011: 14) argued that the concept of the 'biological standard of living' was 'a distinction without a difference …. The problem arises not from the inappropriateness of the term "nutritional status" but from the restricted definition of "standard of living" adopted by economists … it is simply foolish to exclude from consideration matters which clearly contribute to welfare, such as health, longevity, and quality of life'.

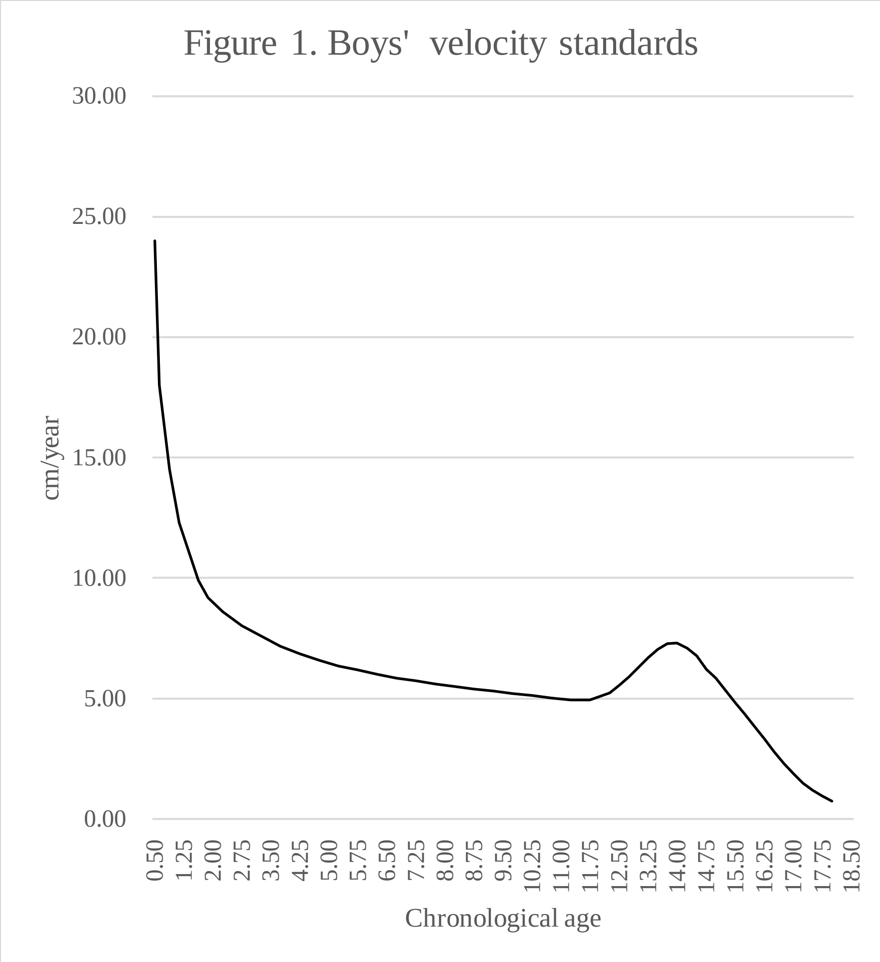
## *2. Whose wellbeing?*

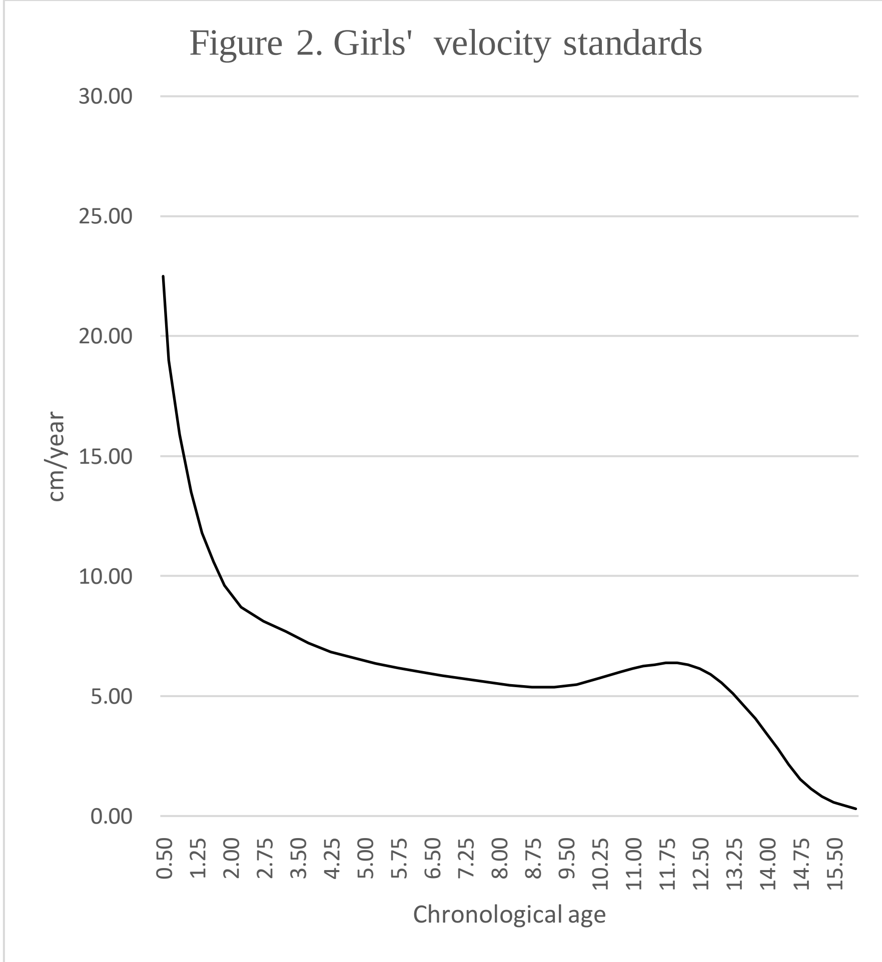
Although the study of anthropometric history is ultimately concerned with groups, the field is based on an understanding of the basic pattern of individual growth. As Figures 1 and 2 demonstrate, individuals grow rapidly during infancy and early-childhood, and more slowly between early-childhood and adolescence. The rate of growth accelerates at adolescence before slowing. In 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).[1]

In contemporary societies, height and weight are 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.

[1] Although most anthropometric historians have tended to assume that the onset of the adolescent growth spurt was delayed for historical populations, Gao and Schneider (2019) 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.

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's 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 concluded that it was the years between the ages of eleven and eighteen which mattered most (Depauw and Oxley 2018: 1).

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 question 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).[2]

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 ‘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’.

One of the main issues raised by this literature is the importance of catch-up growth. Tanner (1990: 165) argued that ‘the power to stabilise and return to a predetermined growth curve after being pushed … off trajectory persists throughout the whole period of growth and is seen in the response of young animals to illness or starvation’. The clear implication is that adult height is most likely to be affected under circumstances of chronic malnutrition or disease exposure. This can sometimes be challenging for historians who wish to associate changes in adult height with short-term fluctuations in economic or social conditions spanning one or two years (see Harris 2008a). However, it also suggests that adult stature can provide a more general indication of a society’s wellbeing, insofar as it reflects the cumulative impact of economic and social conditions on the health and welfare of the child population over a sustained period of time.

2 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).

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.

Floud *et al.* (2011: 3-6) suggested that the history of human height formed part of an integrated schema of 'technophysio evolution'. They argued that improvements in the standard of living of one generation might increase its capacity to invest in the next, creating a virtuous circle of intergenerational improvement. However, some auxologists have proposed a different kind of intergenerational relationship which also has implications for the ways in which we might interpret children's heights. Tim Cole (2003: 166) has 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'. However, other evidence suggests that average heights can increase very rapidly indeed when living conditions improve. Tanner *et al.* (1982) found that the average heights of Japanese adolescents increased by between 7.9 and 9.7 cm between 1957 and 1977, and 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).

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 less than for those who survived' with the result that the 'mean height of the survivors was 0.03 inches 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 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. 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 has often been noted, the most prolific sources of data on the heights of past generations have been derived from military sources which, until relatively recently, have been overwhelmingly male in their nature. This raises a critical question regarding the extent to which we can be confident that the conditions experienced by boys and girls during their growing periods did not differ significantly from each other in ways which might influence their final stature. This is a very fraught issue and there is no reason to assume that the same answer should apply either to all periods or to all societies. It is also complicated by the question of whether males and females respond equally to the same environmental or nutritional stresses. The authors of one recent study of global height trends have concluded 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' (Ezzati *et al.* 2016: 7). However, it is not clear whether this conclusion takes account of long-established arguments about greater female resilience (Harris 2009).

### *3. 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 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 a number of subsequent authors (see e.g. Cinnirella 2008; Komlos and Küchenhoff 2012; Meredith and Oxley 2014).[3] 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.[4]

[3] 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.

[4] 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

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. After Komlos published his initial critique of Floud *et al.*, he argued that his interpretation was rendered more plausible by changes in food supply (Komlos 1993b: 365). 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. However, 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.

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 influences. 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.

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.[5]

Although Bodenhorn *et al.* were undoubtedly correct to highlight the importance of selection bias, it also important to note at least two caveats. In the first place, it is necessary to acknowledge that their reworking of both the UK data and the US data has itself 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. In the conclusion to their 2017 paper, they acknowledge 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 also legitimate to ask why they believe that these factors should not have also been reflected in the anthropometric record.

## *4. 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.

[5] It may be worth noting that these 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.

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.[6]

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.

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

6 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"'.

and Baten 2005; 2008). 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.

### *5. 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 1984).

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, 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 (p. 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).

### *6. 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 (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 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’.[7]

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;

[7] This paper was originally published by the National Bureau of Economic Research in 1984. See R. Floud, ‘The heights of Europeans since 1750: a new source for European economic history’, *NBER Working Papers*, no. 1318.

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.[8]

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 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

8 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'.

intolerance and food preferences', they concluded that 'the height impact of "race" seems rather small' (p. S69).

### *7. 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 traditionally been associated 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. He showed that slaves who survived in the initial registration period were 0.61 inches (1.5 cm) taller than non-survivors, and that male 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, 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 an optimistic 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 which show an opposite relationship (i.e. height and mortality are correlated positively) (Floud, Harris and Hong 2014: xxxiii). As the cause-structure of mortality changes, one may therefore expect to see further changes in the relationship between height and mortality.

## *8. 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 demonstrating the link between Tanner’s original insight and the efforts made by various anthropometric historians to use heights and other anthropometric indicators to examine different aspects of the ‘standard of living’. It then explored some of the issues associated with the identification of ‘critical periods’ and efforts to extrapolate from the analysis of male height heights to the understanding of differences in welfare between different genders and different age-groups. It also provided a brief account of the impact of 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.

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. As we have seen, it has sometimes been suggested that the growth of any particular cohort is especially sensitive to conditions operating during particular ‘critical periods’, such as infancy or adolescence. However, it also seems likely that these conditions will only have lasting effects on final stature if conditions continue to be poor throughout the growing period. This suggests that height retains its value as a cumulative measure of the impact of external conditions throughout the period from conception to maturity.

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.

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 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). As a result, a number of authors have also argued 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 proxy for '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, Eltis (1982: 474-5) argued that many populations may – no doubt unintentionally – have reduced their children's growth by prioritising leisure over work. He described this process as one of 'nutritional satisficing' or 'aim[ing] for a nutritional target lower than maximum'. Although he did not discuss this issue at great length, he also speculated that this practice only ceased under conditions of either partial or complete coercion.

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 codicil to the long-term history of anthropometric change.

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