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LIVING STANDARDS AND INEQUALITY IN THE INDUSTRIAL REVOLUTION: EVIDENCE FROM THE HEIGHT OF UNIVERSITY OF EDINBURGH STUDENTS IN THE 1830S

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Living standards and inequality in the Industrial Revolution: Evidence from the height of University of Edinburgh students in the 1830s

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Abstract

Trends in living standards during the Industrial Revolution is a core debate in economic history. Studies using anthropometric records from institutional sources have found downward trends in living standards during the first half of the nineteenth century. This paper contributes to this literature by utilising an overlooked source of middle and upper class anthropometric data: the height and weight of university students. Combined with more traditional anthropometric sources these data give us a snapshot into the range of living standards experienced by different sections of society in the United Kingdom. Our findings suggest that inequality was most pronounced in Ireland, followed by England. Height inequality in Scotland was still substantial, but somewhat lower in comparison.

JEL codes: D63, I14, N13.

Keywords: height; anthropometrics; Industrial Revolution; economic history; United Kingdom.

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Introduction

The impact of economic development on living standards during early industrialisation continues to be a central debate in economic history.[1] There is a vast literature debating whether an 'optimistic view' (i.e. living standards improved) is appropriate or whether indeed there is reason to be pessimistic in this regard. The development of real wages suggests improving living standards, although there are varying estimates that leave doubt regarding the magnitude of this effect (Clark 2001; Feinstein 1998; Lindert and Williamson 1983).

Anthropometric studies predominantly find that health and nutritional standards, proxied by average height, deteriorated during industrialisation.[2] Essentially, urbanisation, absence of modern sanitation, lack of hygiene, inferior housing and heavy workload put pressure on physical development that in many cases resulted in stunted growth (Floud et al. 2011).[3] Moreover, distance to food production and high transaction costs resulted in relatively high food prices in urban areas and inferior nutrition of urban dwellers (Komlos 1998). Another striking aspect of the early Industrial Revolution was its use of child labour; Horrell and Humphries (1995) show how children were active participants in labour markets in early industrial Britain. Horrell and Oxley (2016) find clear evidence of stunting of children born in the 1830s compared to modern WHO (2007) growth standards. These reports are generally in line with Mokyr (1988) and Clark et al. (1995) who find that increases in income in Britain during 1770-1850 did not coincide with higher food consumption.[4]

Yet, given this debate, surprisingly little is known about trends in inequality in living standards during this period (Allen 2019), although rapid industrialisation and structural change cannot have left societies and their level of inequality unaffected. Monetary indicators suggest that in the UK gaps in wealth and earnings widened during early stages of the Industrial Revolution (Lindert 2000). In complementary studies, Allen (2009, 2019) looks at functional and the size distribution of income over the 1700 and 1800s. In terms of the functional

[1] e.g. see Potter (1962)'s survey of the early debate

[2] A series of studies confirm this pessimistic view for the other regions too. Evidence supports the pessimistic view for the Habsburg Monarchy, UK, Alsace, Belgium, Catalonia, France, Italy, Quebec, Sweden, Saxony, the Netherlands, and the US (Komlos 1989, Komlos 1993, Cinnirella 2008, Heyberger 2005, Alter et al. 2004, Ramon-Muñoz and Ramon-Muñoz 2016 Komlos 2003, A'Hearn 2003, Morin et al. 2017, Sandberg and Steckel 1987, Cinnirella 2008, Drukker and Tassenaar 1997, Komlos and A'Hearn 2016). Although, see Floud, Wachter and Gregory (1990) for a more positive evaluation.

[3] Anthropometric indicators are outcome variables, the other approach is calorie accounting to assess the amount of food available during the industrial revolution (e.g. see Kelly and Ó Gráda 2013 & Meredith and Oxley 2014)

[4] However, a recent study by Bodenhorn et al. (2017) argue that these results suffer from selection issues at the individual level that cannot be observed.

distribution of income, Allen (2009) highlights the fact that real wages were constant and productivity growing to illustrate high levels of inequality in the early industrialisation of England. Allen's (2019, p 110) recent study of the size distribution of inequality in England uses distribution of income in social tables and finds a higher share of income going to the top decile and increases in the gini coefficient from 0.54/0.54 in 1668/1759 to 0.60 by 1798. The implications of Allen's studies were that early industrialisation disproportionately benefitted capital more than other factors of production. As it is well-known that wealth inequality is greater than income inequality (Piketty 2014), Allen's findings are amplified in Lindert's (1986) study of wealth inequality in England, where, using probate records, he finds increases in wealth inequality during the Industrial Revolution. Elsewhere, Hoffmann et al.'s (2002) attempt to explain inequality points towards a long-term evolution of incomes and inflation between the sixteenth and the early nineteenth centuries. During this period, nominal incomes in the UK increased, but an unfavourable development in consumer prices shrank the incomes of the working class further while the upper class enjoyed a fall in prices of luxury goods.

In a similar vein, studies have used heights of different socio-economic groups, particularly elite students versus working poor, to assess inequality in the nineteenth century. [5] Examples of this approach include, Floud and Harris (1997) and Komlos (2008), who compare the heights of Sandhurst Academy recruits, a proxy for the height of the gentry, with the height of boys in the Marine Society, a proxy for the ultra poor and find high levels of inequality.[6] Similarly, Koepke et al. (2018) find height differences between socio-economic groups in the case of Switzerland, with the higher socio-economic groups having a height advantage over lower groups.[7] Moreover, Floud et al. (2011, p.349) note that inequalities in economic status led to lower socioeconomic groups being more exposed to infectious environments and having less means to access better diets.

This study contributes to this literature by exploring a snapshot of middle class anthropometrics in the early nineteenth century. Our results indicate that inequality in the UK was more pronounced than conventional indicators suggest – in line with Allen (2019)'s finding of high levels of inequality in England. Our results are based on the outcome of an experiment conducted on University of Edinburgh (U*of*E) students in the 1830s by James

[5] In terms of the US, Komlos (1987) analyses recruits entering West Point Military Academy between 1843 to 1894, Murray (1997) focuses on Amherst students born in the 1830s to 1870s, sampled from 1860-1900. Both use their data to infer levels of inequality in the US.

[6] However, in both cases there were height requirements (minimums for the marine society varied over time (Floud and Wachter 1982, p. 430)).

[7] Koepke et al. (2018) use different sources of data, passports, prisoners, maternity hospitals and WWII auxiliary service, to study long-run height trends in Switzlerland.

David Forbes, a famed natural philosopher.[8] Our contribution is to utilise this middle and upper class snapshot in combination with other sources that allow to proxy living standards of the working class. This study complements the findings of Komlos (2007) whilst also providing an insight into developments across the British Isles. We analyse height inequality between English, Irish and Scottish students enrolled in the U*of*E in the 1830s, and corresponding working class populations. Crucially, there are no time specific unobserved effects in this short window of time enabling us to clearly identify height inequality (as opposed to Bodenhorn et al. 2017 critique).[9]

Studies have shown variation within working class and between working classes and upper classes (Floud et al. 2011, p. 231).[10] Notably, Komlos (2007) uses height inequality to assess the height gap between the lower and upper classes in England, finding this height gap to be at its maximum of 22cm at age 16. While the English poor suffered from unhealthy environments and malnutrition the English rich were relatively tall, even in international comparison. Elsewhere, Cinnirella's (2008) analysis of conscripts' heights suggest that there are small height differences within the working class that can be explained with information about occupation and place of origin. Generally, Scots were taller than English and a height premium was observed for some occupational groups. This finding in itself is no surprise given the pressure on biological living standards in England and the allegedly superior Scottish nutrition which benefitted from oatmeal and milk availability (Devine 2004). Our findings contribute to this body of literature; this evidence suggests that inequality was most pronounced in Ireland, followed by England. Height inequality in Scotland was still substantial, but somewhat lower in comparison.

Data and methodology

Average height is an output-oriented metric, reflecting early life conditions in terms of nutrition and health. Height reflects the combined effects of official household income, unofficial economic activities, disease environment, quality of housing and health burden due to physical work load. Heights are also sensitive to non-monetary income such as subsistence farming, intra-household transfers and public goods (Steckel 1995).

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[8] "Register of Experiments on the Weight, Height & Strength of Men, Made in the Natural Philosophy Classroom, Edinburgh" by James David Forbes, 1834-36. Papers of James David Forbes, msdep7 - Scientific papers, Box 24, no.VIII/24, University of St Andrews Archive collection

[9] Mokyr and Ó Gráda (1996, p.163) pre-empted the Bodenhorn et al. critique of anthropometrics and recommended cross-sectional comparison across groups and regions rather than hazardous time-series inferences.

[10] Meredith & Oxley (2015) show inequality was also evident within the household.

Moreover, a growing body of literature considers individual height as a determinant of socioeconomic inequality. Height has been found to correlate with cognitive and non-cognitive skills, and this relationship is robust to including measures for education (Guven and Lee 2013; Schick and Steckel 2010, 2015); height is associated with better mental and physical health (Case and Paxson 2008); and finally, taller height is able to explain higher education attainment and sorting into higher-status occupations and industries (Persico, Postlewaite and Silverman 2004; Paxson, Case and Islam 2009).

At the core of our study is a rediscovered dataset comprising anthropometric measurements of the middle and upper class students of the U*of*E. We use students' height measurements to infer on the average living conditions and inequality in living conditions around their time of birth, the 1810s.[11] James David Forbes (1809-1868) began measuring the height, weight and strength of students in his natural philosophy class at the U*of*E in 1834.[12] His was motivation came from reading Quetelet's experiments regarding the climatic influence on the physical development in men. Students began their studies quite early and ages in Forbes study ranged from 14 to 20.[13] Forbes (1837) read his paper to the Royal Society of Edinburgh and it was later published in 1837. Forbes study was then later re-printed in the English translation of Quetelet's (1842, pp 113-114) *Treatise on man*.

Forbes (1837) gives a meticulous account of his experiment, whereby he noted each student's age at last birthday, height, weight, and strength himself. Weight was measured using Marriot's spring balance to weigh students and verified that the scales had not undergone any changes in elasticity. He noted that the weight of clothes was included, suggesting that this accounted for 1/18th of the observed weight. Heights were measured in English inches, students were measured wearing shoes and Forbes himself suggests deducting 0.5 inches on average for heels to account for contemporary footwear. We followed Forbes's suggestion and corrected heights and weights accordingly.

In his discussion, Forbes (1837) reflects critically on the findings from voluntarily measuring a population noting that *'I was careful to obtain a fair average of persons of all*

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[11] This data has been indirectly cited in relation to debates surrounding living standards in prefamine Ireland. Mokyr and Ó Gráda (1988, p. 227) cited Kane (1845, pp 400-401) who cited findings from Forbes.

[12] Forbes attended the U*of*E at the age of 14 studying both the arts and sciences and although he did not graduate, he commenced studies to become an advocate in 1830. Forbes was however passionate about science and returned to studies and was elected to the Edinburgh Royal Society at the age of 21. He was elected Professor of Natural Philosophy at the U*of*E in 1832 (at the age of 23) and began lecturing in the 1833-34 academic year. Forbes published extensively, reflecting his wide ranging interests, but is most noted for his research in glaciology, although marred in controversy (Smart 2012).

[13] Forbes himself began his studies at 14.

degrees of height and strength…there is always a tendency in such cases to get too high a development, because diminutive persons are the least likely voluntarily to come forward.' He used the example of Quetelet's (1842) measurement of 80 Cambridge students as a case in point and also to explain why Forbes obtained a lower average height (68.7 versus 69.6 in the Cambridge case). When comparing the natives of the British Isles, Forbes (1837) noted that although he believed the number of observations for the Irish students was 'most imperfect' they led him to conclude 'that the Irish are more developed than the Scotch at a given age, and the English less.'

We re-analyse the original data of the 800 students underpinning Forbes (1837).[14] Descriptive statistics are provided in Table 1. The majority of the students in Forbes' data are from Scotland (66 per cent), followed by England (18 per cent) and Ireland (9 per cent). The remaining students, comprising the 'other' category discussed below, originate from the East Indies (2.5 per cent), South America (2.4 per cent each), West Indies (two per cent) and North America (1.5 per cent). There are also two students each from France, Portugal and Latin America and one student each from Mauritius, Brazil and Germany. The record also lists seven per cent of students from unspecified places of origin, referred to as 'from the colonies &c' by Forbes, which we included in the pooled 'other' category. The average age of students is approximately 19 years, but ages range from 13 to 40 (see Figure 1). The majority of students matriculated in the years 1834 (61 per cent) and 1835 (35 per cent) with the remaining four per cent matriculating in 1836. Consequently, the average year of birth is 1816, with the earliest and latest year of birth being 1794 and 1823, respectively. The average height of students 173.6 cm (68.36 inches), ranging from 122.9 to 197.1 cm (see Figure 2).

To contextualise Forbes's data we sampled data from the U*of*E's matriculation and graduation records. The U*of*E, founded in 1582, is the youngest of the ancient Scottish Universities (St Andrews 1410, Glasgow, 1451, Aberdeen 1495). To put this in context, there was one university in Ireland (Trinity College Dublin, founded in 1592) that only catered to Anglicans. England, while possessing the oldest universities (Oxbridge date back to the eleventh century), at this juncture was yet to gain its university expansion (starting with the University of London, founded in 1836). Edinburgh had a diverse faculty by the early nineteenth century and to graduate with a master of arts required the completion of a 4-year

[14] Forbes (1837, p. 200) contains summary tables of the weight and height of English, Scotch and Irish by ages 15-25 and compares directly with the Belgians recorded by Quetelet. The archival records contain a number for the student, age at last birthday, weight, height and strength. However, names are not recorded so it is not possible to match the experimental data with contemporary matriculation records.

course. In terms of medicine, Edinburgh was regarded as one of the leading medical schools in Europe with a mix of theoretical and clinical training. It was a pioneer in that it was the first University to lecture in English (not Latin), it was associated with the Edinburgh infirmary, and it was a religiously tolerant university that enabled non-Anglicans to attend lectures (Warren 1951). Edinburgh was an important political and cultural centre and its university has played an important role in public and scholarly debates. Given the UofE's historical reputation, its student body is likely to represent the UK's contemporary middle and upper classes. Data from the U*of*E *Matriculation Rolls for Arts, Law and Divinity*[15] state the name of students, where they were from, their year of study and the degree they were matriculated for. When the University was first established divinity and philosophy were at the core of the curriculum. The law faculty was established in the early 18th century, science subjects such as natural philosophy and mathematics were taught within the arts faculty as it was not until the 1890s that the College of Science was established. However, a number of science subjects were also taught within the University's world renowned medical school that attracted students from around the world. One of Edinburgh's most famous alumni from the period under observation was the non-graduating Charles Darwin who enrolled in 1825.

Data on the number of medical graduates comes from the list of *Edinburgh Medical Graduates*,[16] these data are Latinised names of students, their nationalities, and the title of their dissertations. Table 2 shows the Scottish dominance of the arts, law and divinity schools, the majority of these students came from Edinburgh and surrounding Lothian (48%), the remainder came from the central lowlands and borders (35%), the north (9%),[17] and Highlands & islands (8%). Of the arts, law and divinity students, the majority of students were enrolled as art students (626 in 1830, 502 in 1835). Both law and divinity students were overwhelming Scottish,[18] unsurprising given Scotland's different legal system to the rest of the UK and Scottish Presbyterian traditions. Arts students also tended to be Scottish but here there was some more diversity amongst the student body. However, the graduates of the medical school were much more diverse. The matriculation and graduation data enable us to assess the representativeness of Forbes sample vis-à-vis the student population. Assuming the shares of medical graduates for the 1835 year are consistent for the previous 4 years,[19] the total matriculated student population in 1835, including medical students, would have been c. 1173

[15] Held at the University of Edinburgh Special Collections.
[16] Ibid.
[17] Aberdeen, Angus & Perthshire
[18] 264 of the 279 law students in 1830 and 210 of the 217 law students in 1835 were from Scotland
[19] There were 112, 109, 111, 117 medical graduates in the years 1832, 1833, 1834 and 1835.

and the distribution would have been 68.35 percent Scottish, 15 percent English and 9.9 percent Irish and 6.69 percent other. Thus, indicating that Forbes sample was reasonably representative of the underlying student body in terms of national distribution.

Principal results and robustness

We use multiple indicators to shed light on the living standards during the early nineteenth century UK. Forbes' data allows us to estimate average adult height of Edinburgh students; this indicator reflects net-nutritional standards of this cohorts around the time of birth. Similarly, ages of students range from thirteen years to adulthood, allowing us to compare the growth trajectories of Edinburgh students with growth trajectories of working class samples. We use the following formula to estimate the correlates of individual heights. Formula 1 illustrates the setup we use to estimate heights in a pooled setting, formula 2 refers to single-country setups.

$$Height_i = \alpha + \sigma O_i + \beta A_i + \rho X_i + \varepsilon \quad (1)$$

$$Height_i = \alpha + \beta A_i + \rho X_i + \varepsilon \quad (2)$$

Where *O* represents a vector of regions of origin, i.e. Scotland, England, Ireland and one category comprising all other origins. *A* is a vector of age dummies allowing us to estimate the height growth trajectory. *X* contains controls for time of matriculation and period of birth. In model 1 (Table 3) we estimate differences in height between students from various backgrounds. Irish students in our sample are found to be the tallest, followed by Scots. Students from England and 'other' origins are found to be 1.8 cm and 1.5 cm shorter than Scottish students, respectively. We also analyse height growth trajectories for English, Scottish and Irish students separately. In models 2 to 4 our focus lies on age dummies estimating growth curves for each of these groups. Coefficients and standard errors have the expected signs and standard errors and confirm that Irish students are on average taller than English and Scottish students. These height growth curves (illustrated in Figure 3) suggest that until the age of 18 Irish students are no taller than other groups, but the final difference in height results due to a final growth spurt of Irish students after age 18. On average, students' growth trajectories are not far off modern-day WHO growth standards (Figure 3).

We compare these height trajectories with data of adolescent members of the working class. Heights of adolescents are provided most prominently by Quetelet[20] (1842, p.60) who reports growth curves of the working class youth from Manchester and Stockport. He reports heights by age separately for those performing (child) labour and for those who do not perform factory work. We also rely on Humphrey and Leunig (2009) who report growth curves of adolescent seamen from England and Wales serving in the Navy. Humphrey and Leunig's (2009) seamen are somewhat taller than heights in Quetelet's (1842) working class sample, regardless whether a child was performing manual labour in a factory or not. Height in all non-student samples are found to be substantially shorter compared with students' heights, reflecting inferior biological standards of living in early childhood. Differences in height between the pooled students' height curve and the height of Humphrey and Leunig's (2009) seamen varies between less than six centimetres for thirteen year olds, reaching a maximum at age fifteen (13.9 cm difference) and eleven centimetres for those aged 20. All of these differences are statistically significant at least at the five per cent level. We cannot trace back growth curves until infancy, but our results suggest that height in the samples used in this study is determined earlier than the adolescent growth spurt.[21] In fact, height differences between students and working class samples already exist at the age of 13 and the gap widens during adolescence; catch-up growth only marginally reduces this gap.[22] Comparing these working class samples with modern-day standards allows assessing inequality from a different perspective; middle and upper classes enjoyed superior nutritional and health standards, and the differences in height are substantial in light of these discrepancies.

A more powerful indicator of differences in growth curves is the height-for-age Z score (HAZ). Z-scores allow us to compare a sample population's height with the height of the full population. This method exploits the fact that heights in a population are normally distributed around a mean and its variation can be measured in standard deviations. Z-score is a relative indicator which expresses the difference in height between the sample population and the full population in standard deviations.

$$z = \frac{Xi - \mu}{\sigma} \tag{1}$$

[20] Quetelet reports that the data was measured by 'Mr J. W. Cowell' without making more specific references.
[21] Horrell et al. (2009, p. 107) find that terminal heights of English boys were reached shortly after 21-22 years of age, but find that Irish boys grew taller than English boys and reached their terminal height two years earlier.
[22] Horrell & Oxley (2016) study the growth charts of these children labourers c. 1837 finding clear evidence of stunting of these children compared to modern WHO (2007) growth standards.

Formula one illustrates the conversion of height values that are measured in centimetres (X_i) into z-scores using the mean of a reference population (μ) and the standard deviation of a reference population's height. Z-scores are easy to read and can be compared across samples if computed consistently. The proportions of a Gaussian normal distribution suggest that 68 per cent of all heights in a population are located between the z-score range of -1 and +1. Generally, a negative z-score indicates that the sample population's height is below modern WHO standards.[23] Likewise, a z-score of -1.96 splits the upper 97.5 per cent and the lower 2.5 per cent of a modern, healthy WHO reference population.[24]

We treat all aforementioned height samples accordingly and present the results in figure 4. Not surprisingly, z-scores for working class samples are well under the modern WHO growth standards. Manchester boys' z-scores are consistently below -2, indicating undernourishment. In all likelihood these children would not recover from this degree of stunting and would become stunted adults. Similarly, individuals from the seamen sample were slightly better off, with z-scores improving somewhat during adolescence; however, this group would neither fully recover from stunting as their z-score of approximately -1.5 at age nineteen suggests. These results are generally in line with heights and z-scores presented by Horrell and Oxley (2016) and Gao and Schneider (2019).

In contrast, Forbes' student sample does not indicate substantial stunting. Z-score values improve from approximately -1.5 at age 13 to -1 at age 14. After age 14, z-scores suggest only marginal height differences between this student sample and modern WHO growth standards. At ages 18 and 19 these differences become negligible, with the height of Irish students at the UofE surpassing modern height standards.

Moreover, we use the strategy illustrated in formulas 1 and 2 to estimate the of Body Mass Index (BMI henceforth) development during adolescence. Again, Scottish students serve as our reference category, with Irish students having a somewhat higher BMI. English students, in contrast, are not found on average to have a similar BMI as Scots. Students from outside the United Kingdom were found to have the lowest BMI. A series of age-dummies helps to estimate BMI of Scottish (model 2), Irish (3) and English (4) students. These growth curves are illustrated in Figure 5, and these curves represent estimated BMI trends after controlling for birth cohort effects and time of enrolment. The basic result of this exercise (Table 4) is that BMI development of students and working class children mirrors that of height development. Height is usually interpreted as a proxy for nutritional and health standards around time of birth, while BMI represents nutritional and health standards at the time of

[23] Height-for-age table for boys can be accessed at www.who.int (last accessed 13 May 2019)

[24] See Horrell and Oxley (2016) for a blueprint of a historical study using this methodology.

measurement. The results presented in this study suggests that the working class was disadvantaged around time of birth, and that this situation did not change until late adolescence and early adulthood.

As noted, height inequality was greater in Ireland than in Scotland and England. Within the anthropometric literature it is widely documented that the Irish were tall despite the relative poverty, a result attributed to the superior nutritional diet composed primarily of potatoes and butter milk (Clarkson and Crawford 2001); of this dairy, milk in particular, consumption has been deemed a more significant contributor to physical growth in other studies (Baten 2009, de Beer 2012). Mokyr and Ó Gráda (1988, p.227) noted that the average Irish recruit in the early 1800s to the East India Company was a third of an inch taller than his British counterpart, and that there was an increase in this differential a half century later when compared with Admiralty recruits. Mokyr and Ó Gráda (1996) show that Scottish soldiers were supplying taller recruits to the East India Company, with the Irish in second place. Ó Gráda (1991, 1996) reports data from Irish prisoners, particularly prisoners in Munster which had a rural premium. Height estimates from these studies for comparable birth periods, show that the heights of East India Company Irish recruits were tallest in the immediate Napoleonic wars at 171.81 cm, those recruited in the 1840s were 167.36 cm. In the study of Clonmel prisoners from the 1840s, those aged over 30-34 were 169 cm and literates were 170.7cm. Both groups were considerably shorter than the Irish students in Edinburgh (179.2 cm). The height premium enjoyed by the middle and upper class can perhaps be explained by the same diet, all strata of Irish society drank milk and ate potatoes but the upper class ate the better and more expensive early varieties (Bourke 1993), and had lower workload demands on physical development.[25]

Conclusion

Using a rediscovered data of the heights of U*of*E students, this study offers a snapshot into contemporary anthropometric indicators of a somewhat overlooked group, the middle class. In conjunction with more conventional anthropometric sources used by economic historians, these student data suggest varying levels of inequality within British society. Ireland shows evidence of higher levels of inequality compared with England and Scotland. These findings are the result of the analysis of height growth patterns and weight measurements of a middle

[25] Meredith and Oxley (2015) found that Irish prisoners in London and Paisley had different terminal heights, with the Irish in London being shorter than the Irish in Paisley. They attribute this to differences in regional origin of migrants but also the possibility that the urban environment in London may have adversely affected growth. The height of those aged 25-35 in London was 167.39 cm versus 170.43 cm in Paisley, both appear shorter than the prisoners in Ireland (Ó Gráda 1991, 1996).

and upper class sample of students matriculated at the University of Edinburgh in the 1830s and a series of working class samples that serve as a lower benchmark.

These results meet our expectations in that better off strata enjoyed superior levels of nutrition, health and housing and lower levels of labour and these superior living conditions resulted in superior body growth. What is more striking is the fact that students born two centuries before modern WHO_{2007} standards were developed, Edinburgh students already showed height growth that is akin to modern-day standards. This in itself is a remarkable achievement in light of the absence of modern medical technologies and only rudimentary knowledge of the role of germs and hygiene. We treat this finding as evidence that height advantages enjoyed by the middle and upper class during the Industrial Revolution must be the result of general living conditions, especially superior nutrition and minimal child labour.

References

1. A'Hearn, B., (2003). Anthropometric evidence on living standards in northern Italy, 1730–1860. *The Journal of Economic History*, *63*(2), pppp351-381.
2. Allen, R. C. (2009). Engels' pause: technical change, capital accumulation, and inequality in the British industrial revolution. *Explorations in Economic History*, 46, pp 418-435.
3. Allen, R. C. (2019). Class structure and inequality during the industrial revolution: lessons from England's social tables, 1688-1867. *Economic History Review*, 72(1), pp 88-125.
4. Alter, G., Neven, M. and Oris, M., 2004. Stature in transition. *Social Science History*, *28*(2), pppp231-247.
5. Baten, J., (2000). Economic development and the distribution of nutritional resources in Bavaria, 1797–1839: an anthropometric study. *Journal of Income Distribution*, *9*(1), pp89-106.
6. Baten, J. (2009). Protein supply and nutritional status in nineteenth century Bavaria, Prussia and France. *Economics and Human Biology.* 7(2), pp 165-180.
7. de Beer, H. (2012). Dairy products and physical stature: A systematic review and meta-analysis of controlled trials. *Economics and Human Biology*. 10(3), pp 299-309.
8. Bodenhorn, H., Guinnane, T. and Mroz, T. A. (2017). Sample-selection biases and the industrialisation puzzle. *The Journal of Economic History*, 77(1), pp 171-207.
9. Bourke, A. (1994). The visitation of God? The potato and the great Irish famine (edited by Jaqueline Hill and Cormac Ó Gráda). Dublin: Lilliput Press.
10. Case, A., and C. Paxson. (2008). Stature and Status: Height, Ability, and Labor Market Outcomes. *Journal of Political Economy*, 116 (3): 499-532.
11. Case, A., Paxson, C., and Islam, M. (2009). Making sense of the labor market height premium: Evidence from the British Household Panel Survey. *Economics Letters*, 102(3), pp 174-176
12. Cinnirella, F., 2008. On the road to industrialization: nutritional status in Saxony, 1690–1850. *Cliometrica*, *2*(3), pp 229-257.
13. Cinnirella, F., 2008. Optimists or pessimists? A reconsideration of nutritional status in Britain, 1740–1865. *European Review of Economic History*, *12*(3), pp 325-354.
14. Clark, G., Huberman, M. and Lindert, P.H., (1995). A British food puzzle, 1770-1850. *Economic History Review*, 48(2), pp 215-237.
15. Clark, G., (2001). Farm wages and living standards in the industrial revolution: England, 1670–1869. *The Economic history review*, *54*(3), pp 477-505.
16. Clarkson, L. and Crawford, M. (2001). Feast and Famine: Food and nutrition in Ireland, 1500-1920. Oxford: Oxford University Press.
17. Devine, T. M. (2004). Scotland. In R. Floud and P. Johnson, *The Cambridge Economic History of Modern Britain*, vol. I, pp 388–416. Cambridge: Cambridge University Press.
18. Drukker, J.W. and Tassenaar, V., (1997). Paradoxes of modernization and material well-being in the Netherlands during the nineteenth century. In *Health and welfare during industrialization* (pp 331-378). University of Chicago Press.
19. Eknoyan, G. (2007). Adlophe Quetelet (1796-1874) - the average man and indices of obesity. *Nephrology Dialysis Transplantation*, 23 , pp 47-51.
20. Feinstein, C.H., (1998). Pessimism perpetuated: real wages and the standard of living in Britain during and after the industrial revolution. *Journal of Economic History*, *58*, pp625-658.
21. Forbes, D. J. (1837). On the results of experiments made on the weight, height, and strength of above 800 individuals. *London and Edinburgh Philosophical Magazine and Journal of Science*, 10.
22. Floud, R. and Harris, B. (1997). Health, Height, and Welfare: Britain, 1700-1980. In Richard H. Steckel and Roderick Floud, Eds. Health and Welfare during Industrialization Chicago: University of Chicago Press.
23. Floud, R., & Wachter, K. W. (1982). Poverty and physical stature: Evidence on the standard of living of London boys 1770–1870. Social Science History, 6, 422–452.
24. Floud, R.C., Watcher, K.W. and Gregory, A.S., (1990). Height, health and history: Nutritional status in Britain, 1750-1980.
25. Floud, R.C. Fogel, R. W., Harris, B., and Hong, S. C. (2011). The Changing Body: health, nutrition, and human development in the Western World since 1700. Cambridge: Cambridge University Press.
26. Gao, P., & Schneider, E. B. (2019). The growth pattern of British children, 1850-1975. LSE Economic History Working Papers. No: 293
27. Guven, C. and Lee, W. S. (2013). Height and cognitive function at older ages: Is height a useful summary measure of early childhood experiences? *Health Economics*, 22(2), pp 224-233.

28. Heyberger, L. (2005*). La révolution des corps. Décroissance et croissance staturale des habitants des villes et des campagnes en France, 1780-1940*. Strasbourg / Belfort: Presses
29. Hoffman, P.T., Jacks, D.S., Levin, P.A. and Lindert, P.H., (2002). Real inequality in Europe since 1500. *The Journal of Economic History*, *62*(02), pp322-355.
30. Horrell, S. and Humphries, J. (1995). "The exploitation of little children": Child labour and the family economy in the industrial revolution. *Explorations in Economic History*. 32: 485-516.
31. Horrell, S., Meredith, D., and Oxley, D. (2009). Measuring misery: body mass, ageing and gender inequality in Victorian London. *Explorations in Economic History*. 46: pp 93-119.
32. Horrell, S. and Oxley, D. (2016). Gender bias in nineteenth-century England: evidence from factory children. *Economics and Human Biology*, 22: 47-64.
33. Humphries, J. and Leunig, T., (2009). Cities, market integration, and going to sea: stunting and the standard of living in early nineteenth-century England and Wales. *The Economic History Review*, *62*(2), pp 458-478.
34. Kane, R. (1845). *The industrial resources of Ireland*. Dublin: Hodges and Smith.
35. Kelly, M. and Ó Gráda (2013). Numerare Est Errare: Agricultural output and food supply in England before and During the Industrial Revolution. *Journal of Economic History*. 73(4): 1132-1163.
36. Koepke, N., Floris, J., Pfister, C., Ruhli, F. J., Staub, K. (2018). Ladies first: Female and male adult heights in Switzerland, 1770-1930. *Economics and Human Biology*. 29, pp 76-87.
37. Komlos, J., (1985). Stature and nutrition in the Habsburg monarchy: the standard of living and economic development in the eighteenth century. *The American Historical Review*, *90*(5), pp1149-1161.
38. Komlos, J. (1987). The height and weight of West Point Cadets: dietary change in Antebellum America. *Journal of Economic History*, 47 (4), pp 897-927.
39. Komlos, J., (1993). The secular trend in the biological standard of living in the United Kingdom, 1730-18601. *The Economic History Review*, *46*(1), pp 115-144.
40. Komlos, J., (1998). Shrinking in a growing economy? The mystery of physical stature during the industrial revolution. *The Journal of Economic History*, *58*(3), pp779-802.
41. Komlos, J., (2003). An anthropometric history of early-modern France. *European Review of Economic History*, *7*(02), pp159-189.
42. Komlos, J., (2007). On English pygmies and giants: the physical stature of English youth in the late 18th and early 19th centuries. *Research in Economic History*, *25*, pp149-168.
43. Lindert, P.H. and Williamson, J.G., (1983). English workers' living standards during the industrial revolution: a new look. *The Economic History Review*,*36*(1), pp1-25.
44. Lindert, P. H. (1986). Unequal English Wealth since 1670. Journal of Political Economy, 94 (6): 1127-1162
45. Lindert, P.H., (2000). When did inequality rise in Britain and America?. *Journal of Income Distribution*, *9*(1), pppp11-25.
46. Meredith, D., and Oxley, D. (2014). Food and Fodder: Feeding England, 1700-1900. *Past and Present*, 222, pp 163-214.
47. Meredith, D., and Oxley, D. Oxley (2015). Blood and bone: body mass, gender and health inequality in nineteenth-century British families, *The History of the Family*, 20:2, 204-230, DOI: 10.1080/1081602X.2015.1036902
48. Mokyr, J., (1988). Is there still life in the pessimist case? consumption during the industrial revolution, 1790—1850. *The Journal of Economic History*,*48*(01), pppp69-92.
49. Mokyr, J. and Ó Gráda, C. (1988). Poor and getting poorer? Living standards in Ireland before the Famine. *The Economic History Review*. 41 (2), pp 209-235.
50. Mokyr, J. and Ó Gráda, C. (1990). The heights of the British and Irish c. 1800-1815: evidence from recruits to theEast India Company's army. *UCD Cetnre for Economic Research Working paper series*. WP90/3.
51. Mokyr, J. and Ó Gráda, C. (1996). Height and Health in the United Kingdom 1815-1860: Evidence from the East India company army. *Explorations in Economic History*, 33, pp 141-168.
52. Morin, A. A., Geloso, V., Kufenko, V. (2017). The heights of French-Canadian convicts, 1780s-1820s. *Economics and Human Biology*. 26: 126-136.
53. Murray, J. E. (1997). Standards of the Present for People of the Past: Height, Weight, and Mortality among Men of Amherst College, 1834-19149. *Journal of Economic History* . 57(3): 585-606.
54. Ó Gráda, C. (1991). The heights of Clonmel prisoners 1845-9: some dietary implications. *Irish Economic and Social History*. 18(1): 24-33.

Ó Gráda, C. (1996). Anthropometric history. What's in it for Ireland? *Historie & Mesure*. 11, pp 139-166.
55. Persico, N., Postlewaite, A., Silverman, D. (2004). The effect of adolescent experience on labor market outcomes: The case of height. Journal of Political Economy. 112 (5): 1019-1053.

56. Piketty, T. (2014). *Capital in the twenty first century*. Belknap Press of Harvard University Press. Cambridge, Massachusetts.
57. Potter, J. (1962). 'Optimism' and 'pessimism' in interpreting the industrialrevolution: An economic historian's dilemma. Scandinavian Economic History Review, 10:2: 245-261,
58. Quetelet, M. A. (1842). *A treatise on man and the development of his faculties,* translation of Quetelet (1835) *Sur L'Homme, et le Dévelopment de sus Facultés* by Dr. R. Knox. Edinburgh: William and Robert Chambers
59. RCPCH (2012): Childhood and Puberty Close Monitoring (CPCM) chart, 2-20 years. Accessed 21 February 2017; http://www.rcpch.ac.uk
60. Ramon-Muñoz, R. and Ramon-Muñoz, J.M. (2016). "The Biological Standard of Living in Nineteenth-Century Industrial Catalonia: A Case Study", Revista de Historia Industrial, 64, 77-118.
61. Sandberg, L.G. and Steckel, R.H., (1987). Heights and economic history: the Swedish case. *Annals of Human Biology*, *14*(2), pppp101-109.
62. Schick, A. and Steckel, R. H. (2010). Height as a Proxy for Cognitive and Non-Cognitive Ability. NBER working paper. 16570.
63. Schick, A. and Steckel, R. H. (2015). Height, Human Capital, and Earnings: The Contributions of Cognitive and Noncognitive Ability. *Journal of Human Capital. 9 (1) pppp 94-115*
64. Steckel, R.H., 1995. Stature and the Standard of Living. *Journal of economic literature*, *33*(4), pppp1903-1940.
65. Smart, R. N. (2012), Forbes, James David (1809–1868). *Oxford Dictionary of National Biography*, Oxford University Press, (2004); online edn, Jan 2012 [http://www.oxforddnb.com/view/article/9832, accessed 8 Aug 2016]
66. Warren, M. D. (1951). Medical Education during the Eighteenth Century. *Postgraduate Medical Journal.*

Tables and Figures

Table 1: Descriptive statistics

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
Age at last birthday	841	18.94	3.234	13	40
Anthropometrics					
Weight (lbs)	839	132.7	19.08	74.6	200.2
Height (inches)	840	68.36	2.998	48.40	77.60
Height (cm)	840	173.6	7.615	122.9	197.1
Origin					
Scotland	841	0.662	0.473	0	1
England	841	0.177	0.382	0	1
Ireland	841	0.088	0.283	0	1
West Indies	841	0.020	0.141	0	1
North America	841	0.016	0.123	0	1
East Indies	841	0.025	0.156	0	1
Mauritius	841	0.001	0.0345	0	1
Brazil	841	0.001	0.0345	0	1
South America	841	0.002	0.0487	0	1
Germany	841	0.001	0.0345	0	1
France	833	0.002	0.0490	0	1
Portugal	841	0.002	0.0487	0	1
Other	841	0.070	0.260	0	1
Age at measurement					
13	841	0.006	0.0769	0	1
14	841	0.023	0.152	0	1
15	841	0.064	0.245	0	1
16	841	0.118	0.322	0	1
17	841	0.132	0.339	0	1
18	841	0.166	0.373	0	1
19	841	0.131	0.337	0	1
20	841	0.118	0.322	0	1
>20	841	0.242			
Year of birth	841	1,816	3.473	1,794	1,823
Year of matriculation					
1834	841	0.608	0.489	0	1
1835	841	0.351	0.477	0	1
1836	841	0.042	0.200	0	1

Table 2: University of Edinburgh Matriculation and Graduation records, 1830 & 1835

Year	Total	Scottish	English	Irish	Other
Arts, Law and Divinity matriculation roll					
1830	931	861	41	8	20
1835	725	656	46	1	21
Medical graduates					
1830	107	39	21	40	7
1835	117	38	34	30	15

Sources: *Matriculation Rolls for Arts, Law and Divinity vol IV 1830-1858* and *Edinburgh Medical Graduates, 1705-1866*. Centre for Research Collections, University of Edinburgh.

Note: Those included in the other category were primarily from the West Indies, India, North America (US & Canada) and the Cape of Good Hope. However, there were occasional students from Rio de Janerio, Paris, Riga, Sicily, Spain, Switzerland, St Petersburg, Turin.

Table 3: Correlates of height of Edinburgh students, by region of origin

	(1) Pooled	(2) Scotland	(3) Ireland	(4) England
Origin				
England	-1.81***			
	(-18.60)			
Ireland	0.98***			
	(8.76)			
Scotland	*reference*			
Other	-1.49***			
	(-10.53)			
Age at measurement				
13	-28.53***	-27.32***		
	(-25.39)	(-7.18)		
14	-20.06***	-18.56***		
	(-13.82)	(-6.40)		
15	-10.65***	-8.95***		
	(-5.96)	(-4.14)		
16	-8.19***	-7.02***	-6.81	-7.12
	(-7.85)	(-3.83)	(-1.43)	(-1.53)
17	-5.92*	-3.92**	-9.86**	-6.82
	(-3.14)	(-2.18)	(-2.57)	(-1.61)
18	-3.88*	-2.61	-5.83	-2.77
	(-3.10)	(-1.43)	(-1.22)	(-0.62)
19	-3.78***	-3.15*	-2.41	-2.93
	(-6.23)	(-1.67)	(-0.55)	(-0.67)
20	-1.09	-0.21	-0.98	-1.43
	(-1.51)	(-0.17)	(-0.30)	(-0.78)
Full adult height	*reference*	*reference*	*reference*	*reference*
Constant	177.87***	176.49***	180.17***	176.82***
	(145.35)	(105.81)	(52.80)	(44.03)
Observations	840	557	74	148
R-squared	0.33	0.38	0.29	0.13

Note: The dependent variable is final adult height. Birth periods are binary variables identifying if an individual was born during one of the three nominated time periods. Control variables include age at measurement, time of enrolment and place of origin (model 1). Reference category refer to a fully grown, Scottish student, born during 1815 to 1819 who joined the U*of*E in 1835. We followed Forbes's suggestion and corrected heights by deducting 0.5 inches. Robust t-statistics in parentheses; standard errors are corrected for clustering by clustering by place of origin. *** p<0.01, ** p<0.05, * p<0.1

Table 4: Correlates of BMI of Edinburgh students, by region of origin

		(1) Pooled	(2) Scotland	(3) Ireland	(4) England
Origin					
England		0.09			
		(2.02)			
Ireland		0.34***			
		(5.99)			
Scotland		reference			
Other		-0.16***			
		(-7.65)			
Age at measurement					
	13	-0.17	-0.05		
		(-0.93)	(-0.04)		
	14	-3.85***	-3.59***		
		(-17.09)	(-3.53)		
	15	-2.69***	-2.43***		
		(-10.36)	(-3.21)		
	16	-1.72**	-1.41**	-2.50*	-2.36**
		(-5.83)	(-2.19)	(-1.90)	(-2.26)
	17	-1.24**	-0.99	-1.10	-2.11***
		(-4.78)	(-1.57)	(-0.89)	(-2.76)
	18	-0.72	-0.39	-0.89	-1.73**
		(-2.23)	(-0.62)	(-0.72)	(-2.31)
	19	-0.81**	-0.61	-1.36	-1.16
		(-4.34)	(-0.92)	(-1.06)	(-1.32)
	20	-0.13	0.45	-1.08*	-0.74
		(-0.30)	(1.03)	(-1.99)	(-1.58)
	Adult	reference			
Constant		21.48***	21.19***	21.43***	22.59***
		(73.10)	(36.73)	(20.38)	(39.11)
Observations		840	557	74	148
R-squared		0.15	0.13	0.31	0.18

Note: The dependent variable is individual BMI. Birth periods are binary variables identifying if an individual was born during one of the three nominated time periods. Control variables include age at measurement, time of enrolment and place of origin (model 1). Reference category refer to a fully grown, Scottish student, born during 1815 to 1819 who joined the U*of*E in 1835. Robust t-statistics in parentheses; standard errors are corrected for clustering by clustering by place of origin. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Figure 1: Age distribution of students

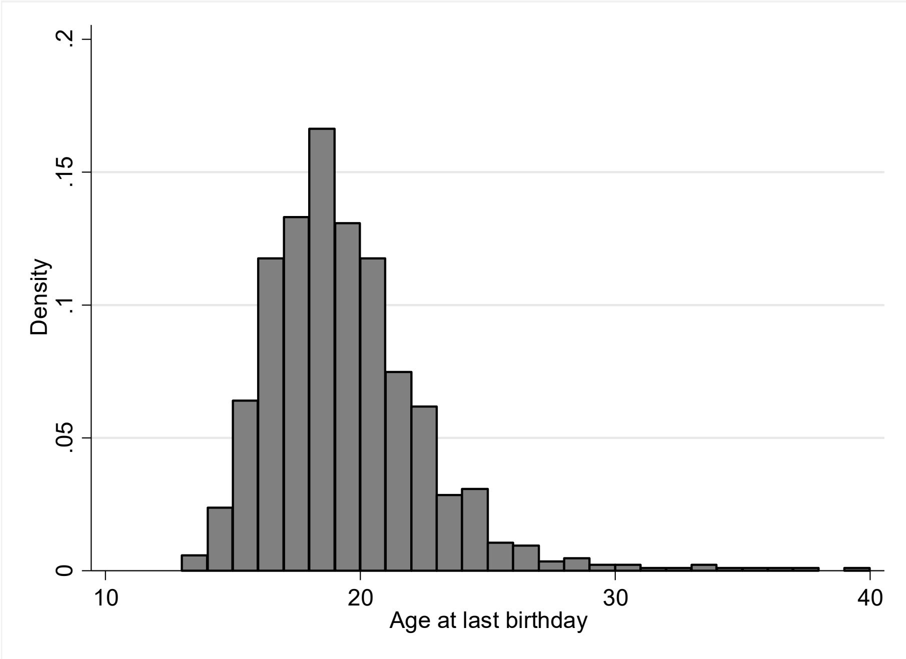


Figure 2: Height distributions of Scottish, English and Irish students aged 19 and above

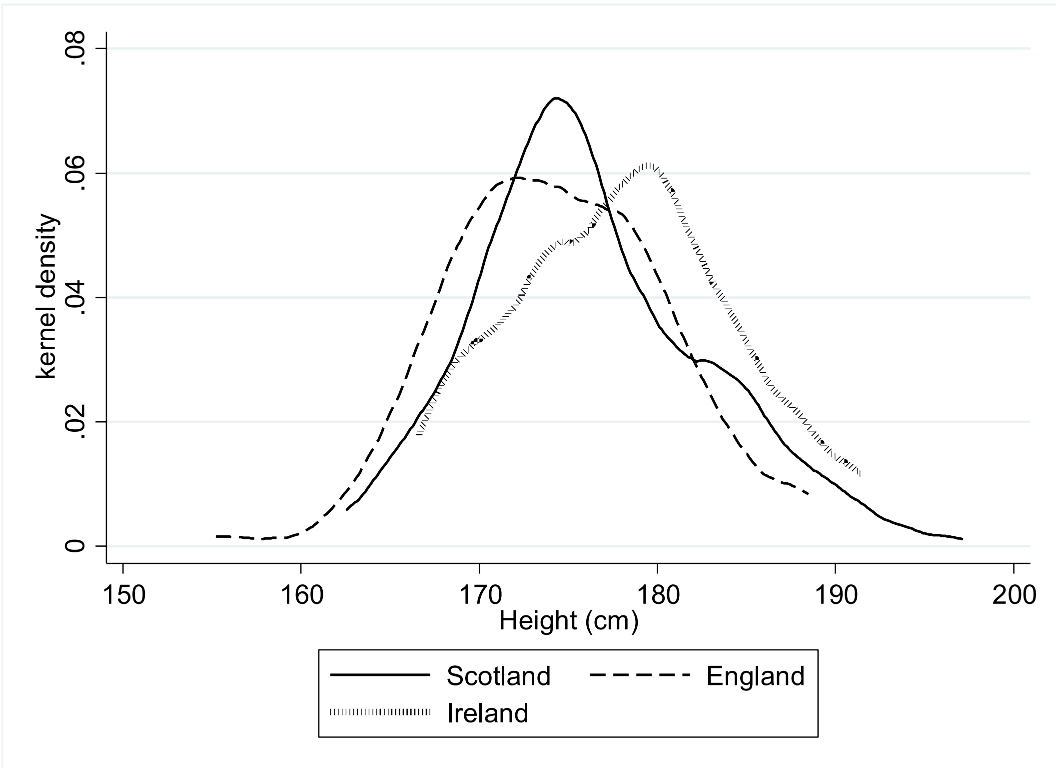
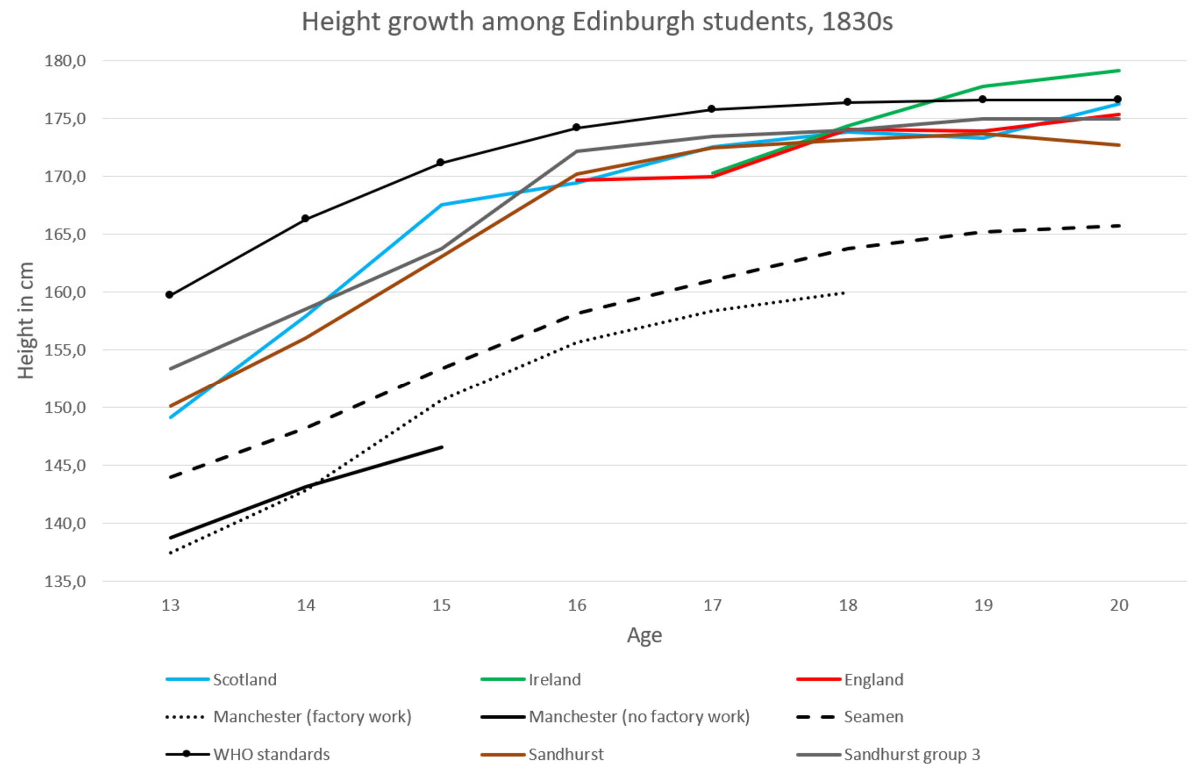


Figure 3: Height growth among adolescents in the UK, 1830s



Sources: see text. Student heights and height of working class samples are statistically different at least at the 5% level. We followed Forbes's suggestion and corrected heights by deducting 0.5 inches. Quetelet's heights were measured with shoes, but we corrected for this bias using Quetelet's (1842, p.60) own recommendation ('… the thickness of the soles for boys would probably be from one-half to one-third of an inch…').

Figure 4: Z-scores and malnutrition in nineteenth century UK

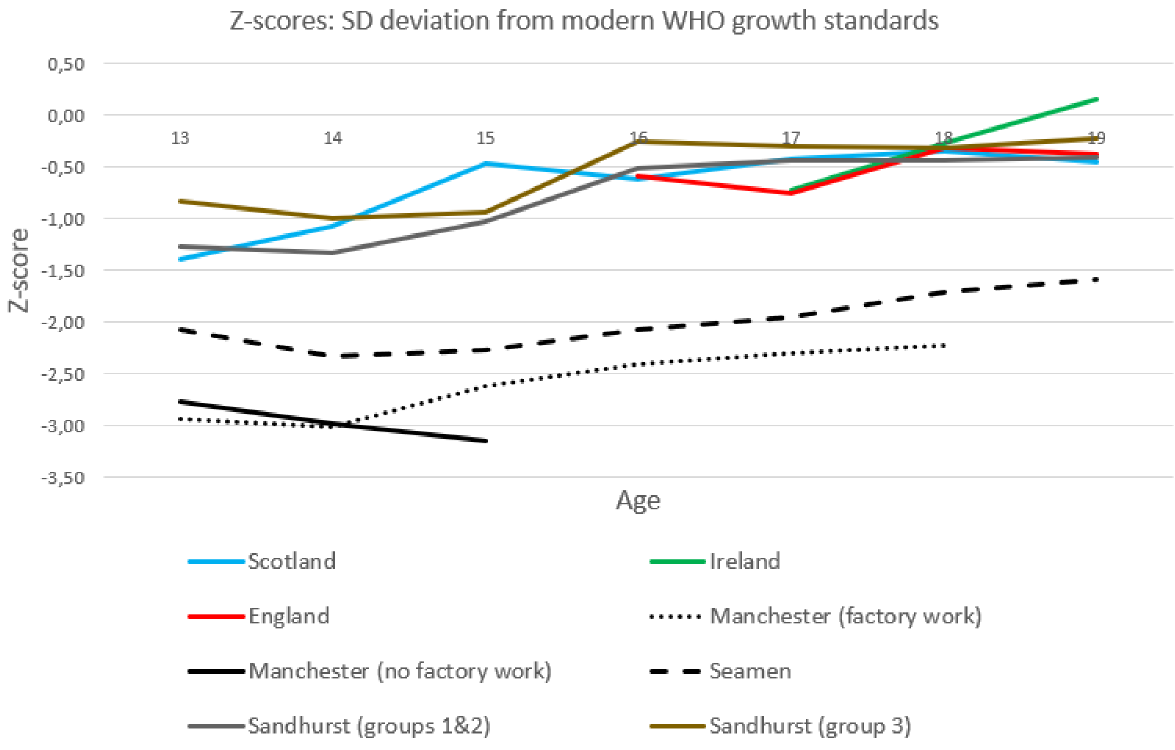
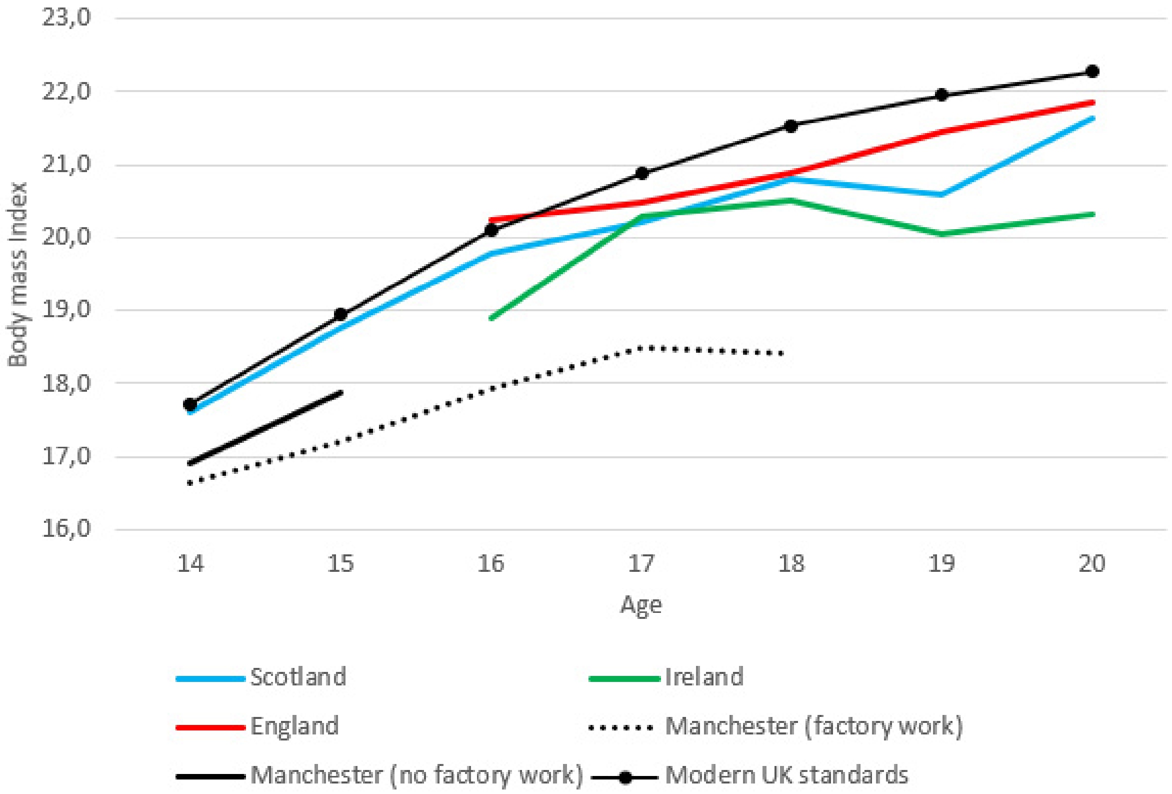


Figure 5: Body Mass Index among adolescent samples in the UK



Sources: see text. Student weight and weight of working class samples are statistically different at least at the 5% level. Quetelet's weights were measured with light clothes, but Quetelet's (1842, p.65) apparently did not see the necessity to correct for this bias. We deducted one kilo to take into account clothing.