Socio-economic differences in children's growth trajectories from infancy into early adulthood: Evidence from four European countries

Authors: *Cathal McCrory[1], Neil O'Leary[1], Silvia Fraga[2], Ana Isabel Ribeiro[2], Henrique Barros[2], Noora Kartiosuo[3], Olli Raitakari[3], Mika Kivimäki[4], Paolo Vineis[5] Richard Layte[6], for the Lifepath Consortium.

Affiliation:

[1]The Irish Longitudinal Study on Ageing, Trinity College Dublin, Ireland

[2]EPIUNIT, Institute of Public Health University of Porto, Porto, Portugal

[3]Research Centre of Applied and Preventive Cardiovascular Medicine (CAPC), University of Turku

[4]Department of Epidemiology & Public Health, University College London, WC1E 6BT London ,UK

[5]MRC-PHE Centre for Environment and Health, School of Public Health, Department of Epidemiology and Biostatistics, Imperial College London, Norfolk Place W21PG London UK

[6]Department of Sociology, Trinity College Dublin, Ireland

* The members of the LIFEPATH Consortium are (alphabetic order): Harri Alenius, Mauricio Avendano, Henrique Barros, Murielle Bochud, Cristian Carmeli, Luca Carra, Raphaele Castagné, Marc Chadeau-Hyam, Françoise Clavel-Chapelon, Giuseppe Costa, Emilie Courtin, Cyrille Delpierre, Angelo D'Errico, Pierre-Antoine Dugué, Paul Elliott, Silvia Fraga, Valérie Gares, Graham Giles, Marcel Goldberg, Dario Greco, Allison Hodge, Michelle Kelly Irving, Piia Karisola, Mika Kivimäki, Vittorio Krogh,Thierry Lang, Richard Layte, Benoit Lepage,Johan Mackenbach, Michael Marmot, Cathal McCrory, Roger Milne, Peter Muennig, Wilma Nusselder, Salvatore Panico, Dusan Petrovic, Silvia Polidoro, Martin Preisig, Olli Raitakari, Ana Isabel Ribeiro, Fulvio Ricceri, Oliver Robinson, Jose Rubio Valverde, Carlotta Sacerdote, Roberto Satolli, Gianluca Severi, Martin Shipley, Silvia Stringhini, Rosario Tumino, Paolo Vineis, Peter Vollenweider, and Marie Zins.

*Corresponding author: Dr. Cathal McCrory
Address: The Irish Longitudinal Study on Ageing (TILDA)
Lincoln Gate
Trinity College Dublin
Dublin 2
Email: mccrorc@tcd.ie
Tel: +353 1 8964263

ABSTRACT

Background

Height is regarded as a marker of early-life illness, adversity, nutrition and psychosocial stress, but the extent to which differences in height are determined by early-life socio-economic circumstances, particularly in contemporary populations, is unclear. This study examined socio-economic differences in children's height trajectories from birth through to 21 years of age in four European countries.

Methods

Data were from six prospective cohort studies – Generation XXI, Growing Up in Ireland (infant and child cohorts), Millennium Cohort Study, EPITeen and Cardiovascular Risk in Young Finns Study - comprising a total of 49,492 children with growth measured repeatedly from 1980 to 2014. We modelled differences in children's growth trajectories over time by maternal educational level using hierarchical models with fixed and random components for each cohort study.

Results

Across most cohorts at practically all ages, children from lower educated mothers were shorter on average. The gradient in height was consistently observed at 3 years of age with the difference in expected height between maternal education groups ranging between -0.55 and -1.53cm for boys, and -0.42 to -1.50cm for girls across the different studies, and widening across childhood. The height deficit persists into adolescence and early adulthood. By age 21, boys from primary educated maternal backgrounds lag the tertiary educated by -0.67cm (Portugal) and -2.15cm (Finland). The comparable figures for girls were -2.49cm (Portugal) and -2.93 cm (Finland).

Conclusions

Significant differences in children's height by maternal education persist in modern child populations in Europe.

Key words: height; children; growth curves; socio-economic status; cohort study

What is already known?

Height is an important marker of health and development reflecting both genetic and environmental influences. Socio-economic inequalities in physical stature are well-established but it remains unclear when these differentials first emerge, and whether they narrow, widen or remain stable over time.

What does this study add?

This study uses data from four European countries (United Kingdom, Ireland, Portugal, Finland) and 6 different cohort studies (Millennium Cohort Study, Growing Up in Ireland infant and childhood cohorts, EPITeen, Generation 21, Cardiovascular Risk in Young Finns) to explore the social patterning of health from infancy into early adulthood. We find evidence that the social gradient in height is evident in early life and widens across childhood. The height deficits persist into early adolescence and early adulthood and the available evidence suggests that the limited amount of catch-up growth that was evident is insufficient to eradicate the gap that opened up in early life. The persistence of social differentials in height among modern European child populations is concerning from a population health perspective.

INTRODUCTION

Height has long served as an important marker of population health and societal development.[1,2] Early childhood represents a critical period in the development of stature. Between conception and birth (i.e. first 40 weeks of life), the foetus develops from a single celled organism into a baby measuring approximately 50 cm in length at time of birth. Approximately one third of all height growth between birth and 20 years of age occurs in the first three years of life.[3] Although up to 80% of the variation in adult height is attributable to genetic factors[4], environmental factors are also important as evidenced by the large secular increases in height that have been observed across most European countries since the mid to late-nineteenth century[1,5,6] with current rates ranging between 0.1 to 0.3 cm per decade.[1] Further evidence of the influence of the environment is provided by natural experiments which have documented the impact of famine on changes in the average height of children[7,8], and other studies which have examined variation in child height by social background.[9-13]

The epidemiological literature has established that adult height is socially patterned and that individuals from more deprived social backgrounds are of significantly shorter stature compared with their more advantaged peers.[14] A conceptual model of how the social environment in childhood influences the biological processes which structure adult health and life expectancy has been put forward by Blane et al.[15]. Building on Strachan and Sheikh's[16] sequential model of life course functioning, Blane et al. have argued that poor material and/or psychological environment in early life can lead to 'stunting' in the development of key biological systems leading to lower health 'capacity' compared to more advantaged individuals. Within this model, shorter height across groups is a proxy for lower 'health capacity' that contributes to social differences in health over the life course.

This model has been supported by evidence from longitudinal studies, although the findings are not entirely consistent. Using the 1958 National Child Development Study (NCDS), Li, Manor and Power[10] found a difference of 2-3cm in height at 7 years of age using different marker variables for SES (social class, large family size, and overcrowded households). This initial gap narrowed as children aged but by adulthood a significant difference remained across social groups. At birth, Howe et al.[9] found that children in the lowest maternal education category were 0.41cm (boys) and 0.65cm (girls) shorter on average compared with children of the highest education group. Unlike Li et al.[10] they report that these differentials remained relatively constant from birth to 10 years of age leading them to conclude that socio-economic differentials in height are due primarily to birth length rather than childhood growth.

Murasco[12] found that a doubling of household income was associated with a small 0.1cm gain in height at 6 years of age increasing to 0.4cm by 14 years of age in a US sample. Like Howe et al.[9], he suggested that height advantage may begin before school entry. In contrast, analyses of the Pelotas birth cohort from Brazil[17] suggested widening inequalities in children's length/height from birth to 4 years of age, with the magnitude of the deficit increasing from 0.2 of a standard deviation (SD) unit at birth, to 0.7 of a SD unit at 4 years of age. Similarly, a Belarussian study found that children born to mothers with higher levels of education were longer at birth and grew faster than children of less educated mothers.[18]

Although, studies have shown that social inequalities in children's length/height are already apparent at time of birth, it remains unclear whether the differences remain stable [9], narrow[11], or widen[18] as children age. Furthermore, many of the recent studies are based on relatively old data from British cohorts.[9-11,19] These studies represent high quality evidence although we know relatively little about the ecological validity of these findings for more contemporary cohorts and other European countries with different institutional and social environments. In this paper we draw on data from four European countries and six different cohort studies to explore the social patterning of height from birth until 21 years of age. Using latent growth models of child height we determine the extent and stability of height differences across social groups defined by the highest level of education of the mother.

METHODS

Sample Selection

Data from four European countries and six different cohort studies are used to explore the social patterning of height from birth until 21 years of age. Five of the cohorts used in the analysis – *Generation XXI* (G21- Portugal)[20], *Growing Up in Ireland (GUI) birth cohort*[21], *Growing Up in Ireland child cohort*[22], *EPITeen* (Portugal)[23] and the *Cardiovascular Risk Factors in Young Finns Study* (YFS - Finland)[24] were part of the LIFEPATH consortium - a European Union funded project exploring social differentials in healthy ageing across the life span. These studies were supplemented by data from the Millennium Cohort Study (MCS - United Kingdom)[25] as the data were freely available from the UK data service. A detailed description of the cohorts is provided in the supplementary appendix.

Predictor variable – Maternal Educational Level

Highest level of maternal education is used as the marker variable for social variation in environmental conditions.[26] It is positively correlated with income, and as such, may determine the type and extent of material resources (e.g. nutrition) that are available to promote healthy growth and development. Education also captures the knowledge related assets of a person and influences the likelihood of them engaging in health compromising behaviours (e.g. smoking) that may be deleterious to healthy child development.[27] A three-level educational classification within each country is used where the lowest educational group represents those with the minimal level of schooling (i.e. primary/lower secondary), the highest educational group represents those with a degree-level qualification or equivalent (i.e. tertiary), and the intermediate group represent those with a higher secondary level qualification. The coding schema applied to derive the 3-level educational classification within each country is shown in online Supplementary Table 1.

Measurement of Height in Childhood and Early Adulthood

In G21, the child's length at birth was extracted from medical records. In GUI, the child's length at 9 months of age was measured using a SECA 210 measuring mat. Height at all other ages and across each of the cohorts was measured using a stadiometer. In GUI and MCS, height measurements were obtained by trained interviewers during the household survey/evaluation. In EPITeen and YFS, measurements were performed by a team of trained medical professionals. At all study sites, children removed their shoes prior to measurement and interviewers/medical professional recorded height to the nearest 0.1cm. The total number of cases with valid height measurements at each survey wave and overall study retention rates by maternal educational status are given in online Supplementary Table 2.

Statistical Analysis

Since the child's calendar age at time of measurement can be some months older or younger than their 'age' cohort, analysis must adjust for this whilst estimating the differential in child height by maternal educational level. Each child can contribute multiple observations so mixed hierarchical models with fixed and random components were used to adjust for the correlation between observations. We fit the following model in boys and girls separately because boys are characterised by faster growth rates compared with girls:

$$y_{ij} = \beta_0 + \beta_1 t_{ij} + \beta_2 x_i + \beta_3 z_i + \beta_4 t_{ij} x_i + \beta_5 t_{ij} z_i + \beta_6 t_{ij}^2 + \beta_7 t_{ij}^2 x_i + \beta_8 t_{ij}^2 z_i + u_{0i} + u_{1i} t_{ij} + e_{ij} \qquad \textbf{\textit{Eq1.}}$$

where $j = 1, \dots, m_i$ (number of observations for individual i), $i = 1, \dots, n$ (number of individuals), x_i is the time-invariant categorical maternal education dummy variable for individual i, in the lowest educated group, and and z_i is the corresponding dummy variable for the secondary educated. t_{ij} is the age of individual i at time j, and y_{ij} represents height in centimetres at t_{ij}. Cross-level linear and quadratic interaction terms between time (t_{ij} - level 1) and maternal education dummy variables (x, z_i- level 2) are given by $t_{ij} x_i$, $t_{ij} z_i$ and $t_{ij}^2 x_i$ $t_{ij}^2 z_{i,}$ respectively. The terms u_i and e_{ij} are residuals representing an unobserved individual effect and an error term for person i at time j, sampled from normal distributions with variances τ^2 and σ^2 respectively. We include a random slope for age where $(u_{0i}, u_{1i}) \sim MVN(0, \Sigma)$ are the random intercept and random coefficient terms respectively distributed according to a multivariate normal distribution, $u_{0i} \perp e_{ij}$ and $u_{1i} \perp e_{ij}$. The conditional expectations and the associated 95% confidence intervals for each educational group at the age at which children were supposed to be measured at each survey wave were derived from the fitted models. From the fixed-effects parameter estimates, we estimated differences in expected height across maternal educational categories using the highest educated as the reference category.

We estimated separate models for each cohort. There were at least 2 but typically 3 observation points between birth and 21 years of age for all cohorts. As GUI comprised both an infant cohort with measurements taken at 9 months, 3 years and 5 years of age, and a childhood cohort with measurements taken at 9 years and 13 years of age, we fit a pooled model and included a dummy variable (fixed effect) for the cohort indicator. Likewise, we fitted a pooled model in YFS and included dummy variables (fixed effect) for each of the different age cohorts.

Two of the studies - MCS and GUI - were nationally representative cohort studies that provided survey weights at each wave of data collection incorporating both a design weight to take account of over/under sampling of particular populations and an attrition weight to take account of non-response at the unit level at subsequent waves. We employed these time-varying survey weights at level 1 of the multi-level model when performing the analyses. Neither G21 nor EPIteen provided survey weights, but examination of the pattern of missingness revealed that children from lower educated backgrounds were more likely to drop out over time. We calculated inverse probability weights for participation in subsequent waves of these surveys using a number of variables (mother's education, mother's age, parity, smoked during pregnancy (G21 only), alcohol during pregnancy (G21 only), marital status (G21 only)) that predicted missingness and utilised these time varying survey weights at level 1 of the multi-level model in the same way as we had for MCS and GUI. As a sensitivity check, we compared results from the attrition weighted and unweighted models but they did not differ appreciably (online Supplementary Tables 3 and 4 for boys and girls respectively). We did not calculate weights for YFS as the data file provided to us for analysis included only mother's education, and age of the child at each measurement occasion, in addition to measured height.

Different variances in height as children age complicates interpretation of whether the educational gradient grows, narrows or remains stable over time. We explored relative differences in height by logging the outcome variable and multiplying the coefficients by 100 to express the difference between educational groups at each age in percentage terms. Given the expected growth curve in each education group is governed by 3 fixed effects parameters: the intercept, and the linear and quadratic change across childhood age, a chi-square omnibus test was performed to assess whether a 9 parameter model (fixed effects) is supported by the data compared to a 3 parameter model (fixed effects). This is essentially testing if the expected growth curves are globally different across education groups. All statistical analyses were undertaken using Stata 14.0 and the hierarchical models were fitted using the xtmixed procedure.

RESULTS

Social patterning of height

Table 1 describes the characteristics of the sample including the mean height and standard deviation for boys and girls at each age by cohort. Tables 2 and 3 (columns A-C) give the expected height and 95% confidence intervals for boys and girls respectively at each age by cohort and level of maternal education derived from the fitted models. A social gradient in boy's heights was evident across each of the cohorts and practically all age groups. An obvious exception to this rule was YFS where boys from secondary backgrounds aged were tallest on average up until 9 years of age. In general, boys whose mothers are in the highest educational category were tallest, while children from the lowest educational backgrounds were smallest. With the exception of G21 (where girls from secondary level backgrounds were tallest), the social distribution of height was similarly patterned for girls.

Differences in height

Tables 2 and 3 (column d) express the difference in height in cm at each age by sex and cohort contrasting the degree educated reference category with the primary educated. It shows that boys in the lowest educational category in G21 measured -0.05 cm [CI_{95}= -0.24, 0.14] smaller in length at birth compared with the tertiary educated, with the deficit increasing to -0.57 cm [CI_{95}= -0.92, -0.23] by 4 years of age, before declining slightly to -0.49 cm [CI$_{95}$= -0.94, -0.04] by 7 years of age. Boys in the lowest educational category in GUI measured -0.21cm [CI$_{95}$= -0.49, 0.07] smaller at 9 months of age compared with the tertiary educated, increasing to -1.64 cm [CI$_{95}$= -2.46, -0.83] by 13 years of age. Similar patterns were evident in MCS. Boys in YFS measured -1.53 cm [CI$_{95}$ = -2.65, -0.40] smaller at 3 years of age declining to -0.63 cm [CI$_{95}$ = -1.53, 0.27] by 12 years of age but increasing again to -2.15 cm [CI$_{95}$ = -1.42, -0.17] by 21 years of age. Boys in EPITeen were characterised by a substantial amount of catch up growth with the difference declining from -1.95cm [CI$_{95}$= -3.42, -0.48] at 13 years of age to -0.67 cm [CI$_{95}$= -1.84, 0.49] by 21 years of age.

Girls in G21, although marginally smaller at birth and 4 years of age, grow faster than their more advantaged peers thereafter and stand fractionally taller by 0.05 cm [CI$_{95}$= -0.39, 0.50] at 7 years of age compared with the tertiary educated group. Girls in GUI from lower maternal educational backgrounds measured -0.51 cm [CI$_{95}$= -0.81, -0.20] smaller at 9 months of age increasing to -1.58cm [CI$_{95}$= -2.14, -1.01] by 13 years of age. Girls in MCS measured -0.42 cm [CI$_{95}$= -0.61, -0.23] smaller at 3 years of age increasing through -1.01cm [CI$_{95}$= -1.28, -0.74] at 7 years of age, before declining somewhat to -0.94 cm [CI$_{95}$= -1.31, -0.57] by 11 years of age. In EPITeen, girls from lower educated backgrounds lagged the tertiary educated by approximately -2.5cm at 13, 17 and 21 years of age. Girls in YFS from lower educated backgrounds measured -1.50 cm [CI$_{95}$ = -2.62, -0.38] smaller at 3 years of age and the results show that the deficit persists into adolescence and early adulthood with the difference equal to -2.93 cm [-4.42, -1.44] at 21 years of age.

Relative differences in height

In all instances the chi-square omnibus test indicated that the unrestricted model fit the data significantly better than the restricted model. We tested whether educational differences in growth rates existed by fitting linear age*education and quadratic age*education interaction terms on log height. There was a significant negative linear age*education interaction among boys in GUI indicating growing educational inequalities in height as children aged. There was a significant linear age*education and a positive quadratic age*education interaction among boys in G21 and MCS reflecting widening socio-economic inequality in growth rates in early life followed by a modest degree of catch-up growth. These relationships can be easily deduced from Table 2 (column E) which shows the relative difference in growth rates in percentage terms at each age by cohort (Contrasts for all educational groups are shown graphically in Supplementary Figures S1-S5. In G21, the relative difference in log height increased from -0.11% to -0.76% between birth and 4 years of age, declining to -0.37% by 7 years of age. In MCS, the differential increased from -0.61% at 3 years of age through -0.85% and -0.98% at 5 and 7 years of age, declining slightly to -0.95% by 11 years of age. EPITeen and YFS have data for children as they transition from adolescence into early adulthood. Boys in EPITeen were characterised by a substantial degree of catch up growth, with the relative differential in log height decreasing from -1.25% to -0.39% between 13 and 21 years of age, although neither the linear nor quadratic interaction term were significant. Neither the linear nor quadratic interaction terms were significant among boys in YFS.

Results for girls are shown in Table 3 (column e). There was a significant negative linear age*education and a positive quadratic age*education interaction among girls in MCS. In MCS, the relative differential increased from -0.46% at 3 years of age through -0.73% and -0.86% at 5 and 7 years of age respectively, declining to -0.65% by 11 years of age. There was a significant positive quadratic age*education interaction among girls in G21 reflecting catch-up growth by children of the lower educated. There was no evidence of catch-up growth among girls in EPITeen with the relative differential remaining relatively constant at about -1.6% between 13 and 21 years of age. Similarly, girls in YFS also lag their more advantaged peers in terms of height and the results indicate that they do not eradicate the gap as they transition from childhood into adolescence and early adulthood and reach full height maturity. Girls from lower educated backgrounds in YFS lag their more advantaged peers by -0.67% at 3 years of age increasing to -1.21% at 12 years of age and -0.95% at 21 years of age.

Sensitivity Analyses

As a check on the robustness of the results, we replicated the analyses using household income tertiles as the marker of socio-economic position. The results of these analyses are shown in Supplementary Tables 5 and 6 for boys and girls respectively. The social gradient in height is also evident across household income tertiles although the gradient was less steep in GUI and EPITeen when using income tertiles compared with maternal education, and steeper in MCS. YFS are omitted from the supplementary analyses because we did not have information available concerning household income in the file made available for analysis.

DISCUSSION

The period from conception through to early adult life is one of rapid growth and development and social exposures occurring during this stage can influence attained growth. Given that most height growth is complete by 21 years of age, height may serve as a useful barometer for exploring social inequalities in health during what Blane et al.[15] refers to as the 'build-up' phase. This paper has documented the social epidemiology of children's height growth from infancy into early adulthood using data from a number of European cohorts. A fairly consistent finding to emerge across countries is that height is socially patterned and that children from mothers with lower educational backgrounds are of significantly shorter stature at almost all ages compared with children from higher educational backgrounds.

We found evidence across a number of the cohorts – GUI, MCS, and G21 (boys only) that the socio-economic differential widens across childhood when expressed as the lag in growth relative to the tertiary educated; a finding which conflicts with that of Howe et al.[9] who found that the socio-economic differential remains stable across childhood. The widening educational differential that we observed across childhood may be accounted for by differences in the tempo of growth, with children from higher educational backgrounds growing more rapidly and maturing earlier. Being taller on average at these ages may reflect favourable genetic, gestational, or environmental influences (or a combination of all of these). This need not necessarily represent a major problem if children from more disadvantaged backgrounds demonstrate catch-up growth, and there are no lingering deficits from slower growth in earlier life. However, we have shown that the extent of catch-up growth in later life is insufficient to eradicate the differences in height that emerge at an earlier age. Across each of the cohorts for whom we have data extending from adolescence into adulthood (EPITeen and YFS), we see that children from lower educational backgrounds continue to lag their more advantaged peers in stature as they reach full height maturity. The importance of these early emerging differences in children's height for later life health is evidenced by the fact that stature is inversely associated with all-cause, cardiovascular, and respiratory disease mortality among men and women.[28,29]

It could be argued that parental height explains differences between different social groups. Studies have demonstrated correlations in the height of spousal pairs ranging from 0.20 to 0.30 so it is perhaps unsurprising that taller parents produce taller children[30]. Consistent with this position, Galobardes et al.[31] found that mid-parental height (average of mother and father's height) fully explained the initial difference in children's height. Others by contrast have found that parental height is not a sufficient explanation for socio-economic differences in height[18], although the latter study is from a low to middle income country. In any event, one could argue that this explanation is not particularly convincing because it simply shifts the debate back a generation and makes one query whether it was more advantageous environmental exposures in the parent's generation that led to the development of taller parents (i.e. intergenerational reproduction of inequalities).

Limitations

This study has a number of limitations. Perhaps the most serious is that none of the cohorts have data from birth through to early adulthood. The measurement points for G21, MCS and GUI tend to be heavily concentrated in early childhood and late childhood, while EPITeen focuses exclusively on the period from adolescence into early adulthood. Although YFS has data extending from 3 to 21 years of age, it differs from the other cohorts in that children were aged between 3-18 years of age upon entry to the study, which means that the number of children measured at each age point varies across the study. Only a subset of the sample had their heights measured in 1989 and 1992, and there were no survey waves commissioned in 1995 and 1998. Allied to these limitations is the substantial amount of missing information on height and/or loss to follow up across the various cohorts (Supplementary Table 2) which may lead to selection bias, particularly since those from lower educational backgrounds were more likely to drop-out over time. In mitigation, we tried to limit the impact of loss to follow-up in these cohorts through the use of inverse probability weights (where possible). Finally, there were different proportions within each maternal education groups in each country which may raise questions as to whether these differences in classification / data collection reflect true differences in education across countries.

Strengths

Balanced against these limitations are a number of strengths. We utilised data from 6 different child cohorts across 4 European countries with a total number of almost 50,000 cases and 15 different measurement occasions to explore how social environment shapes children's height development from birth into early adulthood in modern cohorts. We estimated individual growth trajectories using growth curve models, which use data from all eligible children under a missing at random assumption, allow for the change in scale and variance of height over time, and take account of the actual age at which children were measured [9,18]. Characterising the extent to which the growth of children from lower educational backgrounds is lagged relative to those from tertiary level backgrounds using log height allowed us to examine whether the differential varies over time, and whether these patterns are common across countries or are a feature of countries.

Conclusions

Socio-economic differentials in children's height remain a feature of modern European child populations. This paper shows that the differences emerge early, widen across childhood, with little evidence to suggest that children from lower maternal educational backgrounds eradicate the gap to any appreciable degree as they age in either absolute or relative terms. Shorter stature in adolescence and early adulthood might therefore represent a hard end-point of less advantaged childhood social environment. These findings are concerning from a population health perspective and reinforce the need to examine the factors contributing to the persistence of inequalities in what is a simple but powerful marker of childhood health. To this end, future research with these cohorts will be directed towards understanding the complex array and inter-play of genetic and environmental factors in determining the growth rates of children from different socio-economic backgrounds.

Contributorship

CMC, RL and PV conceived the study. CMC and RL wrote the first and successive drafts of the manuscript. NOL advised on the statistical approach to modelling. Cathal McCrory modelled and analysed the data. SF, AIR, HB, NK, OR, MK collected the data. All authors revised the manuscript for important intellectual content. CMC is responsible for the overall manuscript.

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Competing interests: None declared

Ethics approval:

Generation 21 was approved by the University of Porto Medical School/ Hospital S. João Ethics Committee and signed informed consent was required for all participants. Ethical approval for the Growing Up in Ireland child cohort was provided by the Health Research Board (HRB) of Ireland’s standing Research Ethics committee. Ethical approval for the Growing Up in Ireland infant cohort was provided by a Research Ethics committee convened by the Department of Health and Children. Ethical approval for the Millennium Cohort Study was provided by the NHS Research Ethnics Committee (MREC). EPITeen was approved by the Ethics Committee of the Hospital S. João and the Ethics Committee of the Institute of Public Health from the University of Porto. Cardiovascular Risk in Young Finns was approved by local ethics committees.

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Table 1: Mean Observed Length/Height in Centimetres at each Age by Sex and Cohort

Generation 21 (Portugal)						
	Boys			**Girls**		
	Mean (SD)	*Range*	*N*	*Mean (SD)*	*Range*	*N*
Birth	48.98 (2.52)	31.0 | 55.5	4373	48.22 (2.53)	31.0 | 55.0	4201
4 years	105.90 (5.07)	82.4 | 127.4	3012	104.76 (4.99)	87.50 | 123.5	2922
7 years	124.19 (5.37)	104.5 | 147.3	3005	123.08 (5.33)	100.7 | 144.4	2829
Growing Up in Ireland (Ireland)						
	Boys			**Girls**		
Infant cohort	*Mean (SD)*	*Range*	*N*	*Mean (SD)*	*Range*	*N*
9 months	73.70 (3.35)	40.0 | 87.0	5595	71.93 (3.24)	40.0 | 85.0	5362
3 years	96.83 (3.80)	82.5 | 112.0	4850	95.54 (3.86)	80.8 | 110.0	4724
5 years	111.97 (4.56)	100.0 | 124.0	4510	110.91 (4.66)	100.0 | 124.0	4388
Child cohort						
9 years	137.56 (6.31)	117.0 | 157.5	3968	136.55 (6.28)	109.2 | 157.3	4188
13 years	162.33 (8.31)	143.0 | 180.0	3601	160.20 (6.31)	143.0 | 180.0	3772
Millennium Cohort Study (United Kingdom)						
	Boys			**Girls**		
	Mean (SD)	*Range*	*N*	*Mean (SD)*	*Range*	*N*
3 years	96.11 (4.11)	82.0 | 112.0	6916	94.90 (4.15)	79.0 | 112.0	6740
5 years	111.23 (4.99)	92.0 | 130.0	6934	110.19 (4.91)	92.4 | 128.0	6693
7 years	124.04 (5.61)	104.0 | 145.8	6592	123.10 (5.54)	103.8 | 144.5	6439
11 years	145.99 (7.00)	121.8 | 171.6	6270	146.78 (7.43)	120.2 | 173.1	6174
EPITeen (Portugal)						
	Boys			Girls		
	Mean (SD)	*Range*	*N*	*Mean (SD)*	*Range*	*N*
13 years	162.24 (8.15)	136.9 | 188.5	985	158.15 (6.34)	134.1 | 176.0	1052
17 years	173.51 (6.40)	154.8 | 194.1	783	161.19 (6.15)	137.9 | 178.4	844
21 years	175.03 (6.70)	156.5 | 196.0	555	161.90 (6.22)	144.5 | 180.4	599
Young Finns (Finland)						
	Boys			Girls		
3 at baseline	*Mean (SD)*	*Range*	*N*	*Mean (SD)*	*Range*	*N*
3 years	99.88 (4.31)	89.5 | 112.5	284	99.08 (4.16)	86.8 | 111.9	277
6 years	120.49 (5.47)	106.0 | 136.4	252	119.43 (5.20)	103.9 | 135.6	238
9 years	137.83 (6.34)	122.0 | 155.1	240	136.62 (6.30)	115.9 | 156.9	244
6 at baseline						
6 years	120.69 (5.59)	104.0 | 138.1	277	118.93 (5.07)	102.3 | 134.2	301
9 years	138.04 (6.47)	122.3 | 158.2	251	136.30 (5.98)	121.3 | 156.1	266
12 years	154.51 (7.55)	136.0 | 175.5	236	155.33 (7.15)	132.2 | 174.9	245
9 at baseline						
9 years	136.15 (5.90)	122.9 | 151.4	322	135.60 (6.40)	108.3 | 131.2	322
12 years	152.54 (7.52)	134.8 | 173.1	291	154.14 (7.18)	137.3 | 173.1	277
15 years	172.33 (7.84)	146.0 | 194.1	242	164.02 (6.27)	145.6 | 185.8	245

12 at baseline						
12 years	152.17 (8.13)	131.3 | 177.3	322	153.84 (7.26)	132.1 | 171.0	329
15 years	172.48 (8.30)	144.3 | 194.7	252	163.81 (5.96)	147.1 | 178.2	286
18 years	178.94 (6.79)	162.3 | 201.2	182	165.42 (6.00)	150.6 | 178.8	230
15 at baseline						
15 years	171.22 (7.70)	143.9 | 192.2	287	163.98 (5.58)	147.7 | 181.4	314
18 years	177.96 (6.07)	162.7 | 196.0	201	165.67 (5.73)	150.2 | 182.5	237
21 years	179.15 (6.65)	163.2 | 199.1	156	165.99 (5.99)	150.2 | 182.9	179
18 at baseline						
18 years	177.92 (5.98)	162.0 | 192.5	257	164.6 (5.56)	149.5 | 178.6	280
21 years	177.88 (6.25)	163.9 | 194.2	154	165.49 (5.68)	150.6 | 179.2	180

Table 2: Expected Length/Height in Centimetres at each age across Categories of Maternal Education by Cohort (Boys Only)

	Column A	**Column B**	**Column C**	**Column D**	**Column E**
	Primary	Secondary	Tertiary	Difference (Primary vs Tertiary)	Difference (Primary vs Tertiary)
	Mean (95% CI)	*Mean (95% CI)*	*Mean (95% CI)*	*Mean (95% CI)*	*Log height*
G21 (n=4377)					
Birth (2005/2006)	48.93 [48.83, 49.03]	49.18 [49.03, 49.33]	48.99 [48.83, 49.15]	-0.05 [-0.24, 0.14]	-0.11%
4 years (2009/2011)	102.36 [102.16, 102.57]	102.83 [102.54, 103.11]	102.94 [102.66, 103.22]	-0.57 [-0.92, -0.23]	-0.76%
7 years (2012/2014)	123.28 [123.01, 123.55]	123.60 [123.21, 123.98]	123.77 [123.41, 124.13]	-0.49 [-0.94, -0.04]	-0.37%
GUI (n=9782)					
9 months (2008/2009)	71.99 [71.71 ,72.26]	72.09 [71.90, 72.28]	72.20 [72.04, 72.35]	-0.21 [-0.49, 0.07]	-0.27%
3 years (2010/2011)	93.05 [92.79, 93.31]	93.49 [93.33, 93.66]	93.60 [93.46, 93.74]	-0.55 [-0.83, -0.27]	-0.61%
5 years (2013)	110.24 [109.94, 110.55]	110.94 [110.76, 111.13]	111.07 [110.92, 111.21]	-0.82 [-1.16, -0.48]	-0.84%
9 years (2007/2008)	140.29 [139.89, 140.69]	141.39 [141.13, 141.65]	141.58 [141.39, 141.78]	-1.29 [-1.73, -0.85]	-1.07%
13 years (2011/2012)	164.57 [163.85, 165.30]	165.90 [165.42, 166.38]	166.22 [165.80, 166.63]	-1.64 [-2.46, -0.83]	-1.02%
MCS (n=8294)					
3 years (2003/2004)	94.93 [94.81, 95.05]	95 .14 [94.92, 95.37]	95.52 [95.36, 95.67]	-0.58 [-0.78, -0.39]	-0.61%
5 years (2006/2007)	109.21 [109.08, 109.35]	109.64 [109.39, 109.89]	110.15 [109.97,110.33]	-0.94 [-1.16, -0.71]	-0.85%
7 years (2008/2009)	122.26 [122.10, 122.42]	122.82 [122.52, 123.12]	123.45 [123.23,123.66]	-1.19 [-1.45, -0.92]	-0.98%
11 years (2012/2013)	144.65 [144.44, 144.86]	145.19 [144.81, 145.57]	146.03 [145.76,146.30]	-1.38 [-1.72, -1.04]	-0.95%
EPITeen (n=931)					
13 years (2003/2004)	157.59 [156.72, 158.46]	159.13 [158.04, 160.21]	159.54 [158.36, 160.73]	-1.95 [-3.42, -0.48]	-1.25%
17 years (2007/2008)	173.35 [172.68, 174.02]	174.31 [173.44, 175.19]	174.43 [173.56, 175.30]	-1.08 [-2.18, 0.02]	-0.65%
21 years (2011/2013)	176.09 [175.39, 176.79]	176.97 [176.00, 177.95]	176.76 [175.83, 177.69]	-0.67 [-1.84, 0.49]	-0.39%
YFS (n=1525)					
3 years	94.25 [93.45, 95.05]	96.48 [95.36, 97.60]	95.78 [94.77, 96.79]	-1.53 [-2.65, -0.40]	-1.28%
6 years	117.59 [117.09, 118.10]	118.85 [118.05, 119.64]	118.55 [117.86, 119.25]	-0.96 [-1.74, -0.18]	-0.98%
9 years	137.37 [136.94, 137.80]	138.03 [137.23, 138.83]	138.03 [137.5, 138.71]	-0.66 [-1.45, 0.13]	-0.78%

12 years	153.58 [153.11, 154.05]	154.02 [153.13, 154.92]	154.21 [153.44, 154.98]	-0.63 [-1.53, 0.27]	-0.67%
15 years	166.23 [165.68, 166.77]	166.83 [165.79, 167.87]	167.09 [166.19, 168.00]	-0.87 [-1.92, 0.19]	-0.65%
18 years	175.30 [174.63, 175.98]	176.45 [175.11, 177.79]	176.68 [175.48, 177.87]	-1.37 [-2.74, 0.00]	-0.72%
21 years	180.81 [179.87, 181.76]	182.88 [180.98, 184.78]	182.96 [181.21, 184.71]	-2.15 [-4.12, -0.17]	-0.88%

Calendar year(s) of assessment at each measurement occasion is shown in brackets

Table 3: Expected Length/Height in Centimetres at each age across Categories of Maternal Education by Cohort (Girls Only)

	Column A	**Column B**	**Column C**	**Column D**	**Column E**
	Primary	Secondary	Tertiary	Difference (Primary vs Tertiary)	Difference (Primary vs Tertiary)
	Mean (95% CI)	*Mean (95% CI)*	*Mean (95% CI)*	*Mean (95% CI)*	*Log height*
	Column A	*Column B*	*Column C*	*Column D*	*Column E*
G21 (n=4201)					
Birth (2005/2006)	48.20 [48.10, 48.30]	48.30 [48.12, 48.47]	48.24 [48.08, 48.40]	-0.04 [-0.23, 0.15]	-0.09%
4 years (2009/2011)	101.27 [101.07 101.48]	101.90 [101.57, 102.22]	101.37 [101.09, 101.65]	-0.10 [-0.44, 0.25]	-0.30%
7 years (2012/2014)	122.37 [122.11, 122.63]	123.07 [122.67, 123.47]	122.32 [121.96, 122.68]	0.05 [-0.39, 0.50]	0.03%
GUI (n=9798)					
9 months (2008/2009)	70.16 [69.86 ,70.46]	70.55 [70.35, 70.75]	70.67 [70.52, 70.82]	-0.51 [-0.81, -0.20]	-0.76%
3 years (2010/2011)	91.88 [91.60, 92.15]	92.28 [92.11, 92.44]	92.53 [92.40, 92.66]	-0.65 [-0.95, -0.36]	-0.84%
5 years (2013)	109.38 [109.07, 109.69]	109.81 [109.62, 110.00]	110.18 [110.04,110.33]	-0.80 [-1.15, -0.46]	-0.88%
9 years (2007/2008)	139.30 [138.94, 139.66]	139.86 [139.62, 140.10]	140.46 [140.28, 140.64]	-1.15 [-1.55, -0.76]	-0.92%
13 years (2011/2012)	162.45 [161.92, 162.97]	163.22 [162.86, 163.57]	164.02 [163.72, 164.33]	-1.58 [-2.14, -1.01]	-0.88%
MCS (n=7917)					
3 years (2003/2004)	93.79 [93.67, 93.91]	94.06 [93.82, 94.29]	94.21 [94.06, 94.37]	-0.42 [-0.61, -0.23]	-0.46%
5 years (2007/2008)	108.12 [107.98, 108.25]	108.45 [108.20, 108.71]	108.91 [108.73, 109.09]	-0.79 [-1.02, -0.57]	-0.73%
7 years (2008/2009)	121.52 [121.36, 121.68]	121.88 [121.58, 122.18]	122.53 [122.31, 122.74]	-1.01 [-1.28, -0.74]	-0.86%
11 years (2012/2013)	145.56 [145.34, 145.79]	145.83 [145.41, 146.25]	146.50 [146.21, 146.80]	-0.94 [-1.31, -0.57]	-0.65%
EPITeen (n=1012)					
13 years (2003/2004)	156.50 [155.94, 157.07]	157.66 [156.90,158.41]	158.96 [158.15, 159.77]	-2.46 [-3.44, -1.47]	-1.59%
17 years (2007/2008)	160.37 [159.84, 160.91]	161.45 [160.70,162.19]	162.93 [162.17, 163.68]	-2.55 [-3.48, -1.62]	-1.60%
21 years (2011/2013)	161.12 [160.58, 161.66]	162.19 [161.42, 162.96]	163.61 [162.84, 164.38]	-2.49 [-3.43, -1.55]	-1.55%
YFS (n=1655)					
3 years	93.08 [92.39, 93.77]	94.57 [93.58, 95.56]	94.58 [93.62, 95.55]	-1.50 [-2.62, -0.38]	-0.67%
6 years	117.22 [116.77, 117.68]	118.18 [117.46, 118.90]	118.63 [117.94, 119.32]	-1.41 [-2.20, -0.62]	-0.94%
9 years	136.57	137.24	138.02	-1.45	-1.12%

	[136.20, 136.93]	[136.57, 137.91]	[137.39, 138.64]	[-2.17, -0.73]	
12 years	151.12 [150.74, 151.49]	151.74 [151.03, 152.45]	152.74 [152.08, 153.40]	-1.62 [-2.38, -0.86]	-1.21%
15 years	160.87 [160.45, 161.29]	161.69 [160.88, 162.50]	162.80 [162.06, 163.54]	-1.93 [-2.78, -1.08]	-1.21%
18 years	165.84 [165.34, 166.34]	167.08 [166.04, 168.12]	168.20 [167.26, 169.14]	-2.36 [-3.42, -1.31]	-1.12%
21 years	166.00 [165.34, 166.67]	167.92 [166.44, 169.39]	168.93 [167.59, 170.28]	-2.93 [-4.42, -1.44]	-0.95%

Calendar year(s) of assessment at each measurement occasion is shown in brackets