ORIGINAL ARTICLE

The treatment of parental height as a biological factor in studies of birth weight and childhood growth

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Parental height is frequently treated as a biological variable in studies of birth weight and childhood growth. Elimination of social variables from multivariate models including parental height as a biological variable leads researchers to conclude that social factors have no independent effect on the outcome. This paper challenges the treatment of parental height as a biological variable, drawing on extensive evidence for the determination of adult height through a complex interaction of genetic and social factors. The paper firstly seeks to establish the importance of social factors in the determination of height. The methodological problems associated with treatment of parental height as a purely biological variable are then discussed, illustrated by data from published studies and by analysis of data from the 1958 National Childhood Development Study (NCDS). The paper concludes that a framework for studying pathways to pregnancy and childhood outcomes needs to take account of the complexity of the relation between genetic and social factors and be able to account for the effects of multiple risk factors acting cumulatively across time and across generations. Illustrations of these approaches are given using NCDS data.

Maternal height is an important determinant of birth weight and growth in childhood.[1] A number of studies of birth weight and growth in childhood have treated maternal (and paternal) height as a purely biological factor.[2–8] On multivariate analysis, parental height is frequently retained in the final model, while social variables fail to retain a significant relation with the outcome. The authors conclude that, when adjusted for biological factors, social factors have no effect on the outcome.

This paper draws on evidence from a range of sources to question the validity of treating parental height as a purely biological factor in research related to birth weight and childhood growth. The paper first seeks to establish the importance of social factors in the determination of adult height using UK data. Secular trends in height and the migrant effect are discussed as further evidence for the importance of social and environmental growth determinants. The paper discusses the consequences of treating parental height as a biological factor in the study of birth weight and childhood growth, illustrating the discussion with analysis of birth weight among the first-born infants of the 1958 National Child Development Study (NCDS) cohort members. It concludes with suggested approaches to dealing with parental height in research on the determinants of birth weight and growth in childhood.

ROLE OF SOCIAL FACTORS IN THE DETERMINATION OF ADULT HEIGHT

Social influences on height attained are well documented and established in historical studies[9] and in less developed countries.[10] There is evidence that social differences persist in developed countries, including the UK. Carr-Hill[11] reported no discernible narrowing of either the overall distribution or the gap in height attained between social classes in the period from 1940 to 1980. A social gradient of approximately 5 cm in height attained at 10 years of age between those children living in the most and least deprived areas was reported in Northumberland,[12] and a gradient of 2.0 cm between social classes I and V in a national sample at 5–7 years of age.[13]

Analysis of the data collected when the 1958 birth cohort members were 23 years old[14] shows that 16% of women in social classes IV and V were in the bottom decile of the height distribution compared with 7% of social class I and II women. The equivalent figures for men were 12% for social classes IV and V and 6% for social classes I and II. When four levels of income were used as measures of socioeconomic status in place of social class, a clear gradient was shown across income levels, with only 3% of women in the highest income group in the bottom decile of the height distribution.

Table 1 shows reanalysis of data from the 1970 birth cohort reported by Golding and colleagues.[15] The authors were exploring the relation between unemployment and pregnancy outcomes. Our reanalysis focuses on the risk of short stature (<159 cm) of pregnant women from different social groups. There is a social gradient, with mothers from social classes IV and V being at significantly greater risk of small stature than those from social class III, and these, in turn, being at greater risk than those in social classes I and II. Low social class mothers were 2.5 times more likely to be short stature than mothers in high social classes.

A recent study analysing follow up data from the Boyd-Orr cohort,[16] originally recruited in 1937 and 1939 to survey diet and health in childhood, enables the association between adult height and inadequate childhood nutrition to be examined. Higher childhood inadequate nutrition scores were significantly associated with shorter adult height for men ($p = 0.004$) and women ($p = 0.001$). Adult leg length, a particularly sensitive indicator of childhood growth, was associated with childhood nutrition in the same direction for both sexes.

In summary, UK data presented above, which are consistent with historical and developing country data, provide convincing empirical evidence of the impact of social, economic, and environmental factors on adult height. Further evidence comes from the secular trends in height which are difficult to explain on purely genetic grounds. Sons born to fathers, and daughters to mothers, who were members of the 1958 British national birth cohort, showed an increase of 3.0 (0.12) cm and 1.2 (0.11) cm respectively in height attained.[17] Secular increases in height have been noted where standards of living and nutrition are improving,[18] and decreases have been linked to deteriorating environmental conditions.[19] The migration

Table 1 Reanalysis of data from Golding *et al* related to maternal height and social class[15]

Social class group	Maternal height <159 cm No. (%)	Odds ratio (95% CI)
RGSC I and II (n=2570)	674(26.2)	1.00 (reference)
RGSC III (n=9964)	3269(32.8)	1.37 (1.24 to 1.52)
RGSC IV and V (n=3224)	1508(46.8)	2.47 (2.21 to 2.77)

χ^2 for trend = 283.1 (p<0.00001).

effect seen particularly among Japanese migrants to the USA[20] lends further credence to the assertion that height is sensitive to social and environmental conditions. All this points to a complex interrelation between genetics and the environment consistent with the following statement by Tanner[21]:

> "Growth is a product of the continuous and complex interaction of heredity and environment. Modern biology has no use for simplistic notions, let alone the obscurantist slogans of the deliberately ignorant. Statements such as 'height is an inherited characteristic' or 'intelligence is the product of social forces' (or vice versa of course) are intellectual rubbish, to be consigned to the trash-can of propaganda"

CONSEQUENCES OF TREATING PARENTAL HEIGHT AS A BIOLOGICAL FACTOR

If height attained results from a complex interaction of genetic, social, and environmental influences, treating parental height as a purely biological factor is likely to lead to a systematic underestimation of social and environmental influences on pregnancy outcomes. A significant proportion of the social effect on pregnancy outcome will be mediated through maternal growth, reflected in maternal height, with the result that the apparent impact of purely biological influences will be inflated and the impact of social factors diminished.

We illustrate this effect with data related to birth weight among live singleton firstborns of 1958 NCDS cohort members. Using linear regression modelling with birth weight as a continuous dependent variable, among 2922 cohort women, manual social class was associated with a 92 g (95% CI 52 to 133) reduction in birth weight. Adding maternal height at 23 years into the model, reduced the effect of social class by almost a third to 66 g (95% CI 25 to 106). Adding a further socially related variable—smoking in pregnancy—into the model reduced the effect of manual social class to 50 g (95% CI 10 to 91). These analyses were carried out in SPSS version 10.[22]

Published studies illustrate the same effect. Brooke and colleagues,[2] based on a study of pregnant women in South London, concluded that smoking had become the single most important risk factor in the reduction of birth weight, and that social influences on birth weight were no longer important once smoking was taken into account. The main outcome, however, was birth weight adjusted for maternal height resulting in an underestimation of the impact of social factors in multivariate analysis. We have discussed elsewhere the consequences of the methodology employed in this study for the understanding of the role of smoking and social factors in the determination of birth weight.[23]

Gulliford and colleagues,[3] reporting data from the National Study of Health and Growth, suggested that social differences in height had disappeared. This assertion was based on analysis in which "biological" factors such as parental height and birth weight were entered into a multivariate model with social class, with the unsurprising result that the influence of social class noted on univariate analysis disappeared.

Nordstrom and Cnattingius,[4] while recognising the role of social factors in maternal height, nonetheless enter height into a regression model for birth weight with socioeconomic factors such as maternal education, and conclude that social factors have little explanatory power in relation to birth weight.

Low level of education is associated with a 99 g (95% CI 29 to 169) reduction in birth weight in their study, which becomes marginally significant (birth weight reduction = 69 g; 95% CI 10 to 128) when maternal height, age, parity, length of gestation, and gender are added to the model. Adding smoking into the model eliminates the effect of education.

The unadjusted odds ratios for low birth weight at term by social class in the Cardiff Births Survey (1970–79)[5] show the expected gradient with social class I as the reference, from 1.36 (95% CI 0.91 to 2.04) in social class II, 1.87 (95% CI 1.32 to 2.65) in social class III, 2.22 (95% CI 1.53 to 3.23) in social class IV, and 2.63 (95% CI 1.79 to 3.87) in social class V. Adjusted in a logistic regression model containing a range of socially related variables including maternal height, prepregnancy weight, and smoking, the odds ratios for all social classes except social class V become insignificant and that for social class V is reduced to 1.67 (95% CI 1.11 to 2.51)

A study in Thailand,[7] a country in which the health effects of socioeconomic factors are likely to be greater than in the UK and other developed countries, uses the same methodology to argue that social differences in birth weight are accounted for by a range of variables, including maternal height, that are themselves strongly socially patterned. Adjustment for these factors reduces the difference in birth weight between the highest and lowest income groups from 86 g to 56 g.

The consequences of treating parental height in this way are considerable. If social factors are perceived as no longer important in the determination of birth weight or height attained, there is little scope for improvement in these outcomes through social and economic policy changes designed to minimise adverse social and environmental conditions. The policy focus shifts instead either to a complacent view that the observed social differences are essentially biological and therefore not open to change, or to efforts to change individual health related behaviour. A welcome policy shift towards the eradication of child poverty has taken place in the UK, but social and economic policy in some developed[24] and less developed countries[25] continues to disadvantage the poor, especially women and children.

SUGGESTED FRAMEWORK FOR STUDYING SOCIOBIOLOGICAL PATHWAYS IN PREGNANCY AND CHILDHOOD RESEARCH

Pregnancy outcomes, such as birth weight and gestational age, as well as growth in childhood are the culmination of complex pathways, reflecting an interaction between inherited and environmental factors. Socioeconomic status cannot be treated in the same way as maternal height and smoking. It is a distal factor exerting its effect through intermediate or mediating variables such as maternal growth and health related behaviour.[26] The challenge is to study the mechanisms by which these mediators exert their effects.[27] Birth weight is

Table 2 Additive effects of social class and maternal height among the live singleton firstborns of 1958 National Childhood Development Study cohort female members

Maternal height group	Mean birth weight in g (95% CI) in non-manual social class at infant's birth [n]	Mean birth weight in g (95% CI) in manual social class at infant's birth [n]
Tall (>170 cm)	3500 (3423 to 3572) [n=218]	3330 (3246 to 3414) [n=192]
Medium (155–170 cm)	3314 (3278 to 3350) [n=914]	3259 (3225 to 3293) [n=1065]
Short (<155 cm)	3146 (3066 to 3194) [n=182]	3093 (3037 to 3149) [n=351]
All	3321 (3291 to 3351) [n=314]	3231 (3203 to 3259) [n=1608]

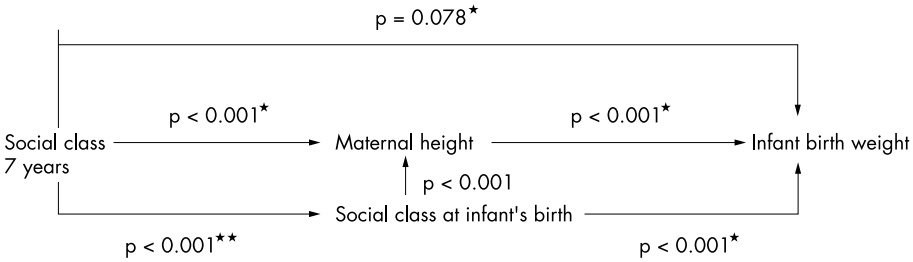

Figure 1 Preliminary path analysis from maternal social class at 7 years to infant's birth weight among 2922 NCDS cohort female members. *Linear regression model; **logistic regression model.

strongly correlated with the mother's own birth weight and her father's social class, independent of exposures in childhood and during the index pregnancy.[28] Maternal height at 4–6 years of age had a significant effect on her infant's birth weight, suggesting that poor growth in early childhood associated with low socioeconomic status extends its influence into the next generation.[29]

In his study of Aberdeen women in 1948–52,[30] Baird reported that risk factors are also likely to accumulate and have an additive effect on birth weight. The low birthweight rate (⩽2500 g) was 5.5% among tall (⩾162 cm) women and 13.3% among short (<154 cm) women; however, when the cumulative effects of level of health were added, tall healthy women had a rate of 2.7% compared with 18.1% among short unhealthy women. A similar additive effect on birth weight is shown in our analysis of birth weight of live singleton firstborns among NCDS cohort members (table 2). In this analysis, using a similar method to Baird,[30] we wanted to explore the additive, rather than the competitive effects, of socially related variables on birth weight. The effect is striking: there was a 92 g difference in mean birth weight between manual and non-manual social classes, which increased to 357 g between non-manual women in the highest height decile and manual women in the lowest height decile. It should be noted that there is graded effect on birth weight associated with both height and social class (table 2) and that, although there is only a 53 g birth weight difference between the infants of short (<155 cm) non-manual and manual women, height <155 cm is much more prevalent among women in the manual group (21.8% *v* 13.8%).

A framework for studying pathways to pregnancy and childhood outcomes needs to take account of these graded effects associated with the clustering of adverse risk factors among the disadvantaged, and be able to account for the effects of multiple risk factors acting cumulatively across time and across generations. In relation to birth weight, the mother's experience as a fetus and as an infant and young child needs to be considered in relation to, and in addition to, risk factors in the index pregnancy. In the same way, the effects of risk factors on childhood growth can only be understood in the relation to the formative influences on parental height and growth.

Analytical techniques being developed in life course epidemiology,[31] are able to account for cumulative effects over time and over generations. We used these methods to explore the effects of cumulative social class at three points in the life course of female NCDS cohort members (the woman's own birth, mid-childhood (7 or 11 years), at the time of the infant's birth). We constructed a categorical variable: non-manual social class at all three points; non-manual on two occasions and manual social class once; manual on two occasions and non-manual once; manual social class at all three points. Compared with a birth weight difference of 92 g between manual and non-manual social class at birth, there was a difference of 125 g between high and low cumulative social class. High cumulative social class (non-manual × 3) and height in the highest decile confers an advantage of 424 g in birth weight over low cumulative social class (manual × 3) and height in the lowest decile.

Path analysis[32] enables the direct and indirect effects of risk factors to be taken into account. As Susser and Levin point out,[32] path analysis has limitations as an a priori concept of the relation between variables is a prerequisite for constructing models from the data. However, there are accepted methods for checking model validity, for example by cross validation in samples other than the one from which the original model was derived.[33] Path analysis has been used to show that, despite the lack of direct association between stress and low birth weight in many studies, an indirect effect can be shown through smoking and other addictive behaviours.[34] Path analysis is also being used in a major ongoing Canadian study of social disparities in preterm birth to augment more traditional logistic regression analysis.[27] We are planning to use path analysis to explore biosocial pathways to birth weight among the offspring of NCDS female cohort members. Preliminary analysis suggests that it will contribute to an understanding of the direct and indirect effects of social factors over the woman's life course on the birth weight of her infant. Figure shows a partial path analysis based on regression models, indicating that social class at 7 years does not have a direct effect on infant birth weight, but exerts its effect indirectly through height at 23 years and social class at the time of the infant's birth. Social class at the time of the infant's birth probably has both a direct and indirect effect on

infant birth weight through maternal height, although it is possible that maternal height partly determines social class at infant's birth. These issues are so far unresolved, but this "unfinished" pathway indicates the potential value of this analytical approach.

The analytical techniques described above are not alternatives to multivariate analysis, but complementary methods that allow relations between exposures and outcomes to be investigated in greater depth, and may assist in avoiding over-interpretation of statistical methods aimed at accounting for confounding variables.

CONCLUSIONS

Overwhelming empirical evidence briefly reviewed here confirms that the concept of parental height as a purely biological or genetic factor is fallacious. This fallacy has significant effects on research conclusions related to pregnancy outcomes and childhood growth. These outcomes are the culmination of complex biosocial pathways involving multiple risk factors acting cumulatively over time and across generations. To conclude that social factors have no influence on birth weight or childhood growth because they are eliminated in multivariate models also containing parental height, is not only to deny that parental height results from a combination of inherited and environmental influences, but also to deny the complexity of pathways stretching back into parental childhood and beyond.

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