ORIGINAL ARTICLES

Influence of socioeconomic conditions on growth in infancy: the 1921 Aberdeen birth cohort

A D G Baxter-Jones, A H Cardy, P J Helms, D O Phillips, W C S Smith

Abstract

***Objectives*—To identify environmental influences on infant growth using data from a birth cohort established in 1921.**

***Design*—A longitudinal cohort study.**

***Setting*—Aberdeen 1921–22.**

***Subjects*—Five hundred and sixteen individuals (263 boys and 253 girls) born in Aberdeen during 1921. Health visitor assessments ranged from two to 40 (47% received at least 10 visits). No records were available for infants who died. Individuals were grouped as those who did not breast feed, those who breast fed initially but not at 6 months, and those who were continuing to breast feed at 6 months.**

***Main outcome measure*—Rate of weight gain over the 1st year of life. A random effects model was used to identify environmental factors and conditions contributing to rate of weight gain in the 1st year of life.**

***Results*—Breast feeding rates were about 80% and 50% at 10 days and 6 months, respectively. Breast fed infants were significantly heavier than bottle fed infants at 28 days but this difference disappeared by 12 months. Significant negative effects on rate of weight gain, independent of initial body weight, were found for overcrowding in family homes and maternal parity, whereas social class had no effect.**

***Conclusion*—Studies based on historical cohorts that have controlled socioeconomic variables only in terms of social class (derived from parental occupation) may have been subject to residual confounding. Growth in the 1st year of life is likely to reflect a number of environmental influences, some of which may continue to have effects throughout early life and beyond.**

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Keywords: growth; historical cohort; longitudinal study; breast feeding; Barker hypothesis

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The "programming hypothesis", developed by the Medical Research Council Environmental Epidemiology Unit in Southampton, has received much attention in the literature in recent years.[1–9] The hypothesis suggests that undernutrition during fetal life causes long term changes to the structure and function of the body that predispose it to develop certain chronic diseases in later life.

The study of nutrition and growth during infancy is of particular interest because this is the period of life when growth velocity and the demands of nutritional intake are at their highest. Infants triple in weight during the 1st year, with the most notable change occurring during the 1st months of life. Breast feeding has a very special role in infant feeding and is thought to be superior to formula feeding. Breast milk is the most natural food and has numerous nutritional advantages, it also protects against infections and modulates the infant's immune system.[10] Studies of the relation between infant feeding and growth in the 1st year of life have found that breast fed infants, when compared with formula fed infants, have higher velocities of growth during the 1st months but have lower velocities during the remainder of infancy.[11 12]

Much of the current debate concerns the influence of confounding factors operating around the time of birth and throughout life. The fetal environment, birth weight, and subsequent growth are all affected by a number of environmental factors that influence the quality of life, and these may persist into adulthood.[9] Proponents of "programming" studies consider social class to be an indicator of a range of socioeconomic influences, both known and unknown,[13] and argue that control for social class accounts for any confounding. Although the historical cohorts on which the hypothesis is based fail to demonstrate an association between social class and birth weight,[13 14] a highly consistent correlation has been observed in geographically and temporally diverse populations.[15] The reasons for the failure to demonstrate an effect of social class are unclear, although it has been suggested that this label may not accurately reflect the socioeconomic environment in historical cohorts, that the social background or growth of the child has been misclassified, or that the samples are biased.[16]

To identify and separate the relative contribution of socioeconomic factors from the changes as a result of growth alone, and/or nutritional programming, there is a need to use appropriate modelling techniques that are able to identify environmental influences, including socioeconomic factors, over and above individual variations in growth.[17 18] To our knowledge, few historical cohorts have enough longitudinal measurements to construct reliable growth curves in early life and to examine these in the context of important environmental influences.

Therefore, we set out to establish the influence of various markers of socioeconomic status, while controlling for the effects of infant feeding, on rate of weight gain in the 1st year of life using data from a birth cohort established in 1921 in Aberdeen City. Health visitors maintained detailed records of infants in the city, recording feeding methods, various markers of socioeconomic status, and child growth.

Subjects and methods

Health visitor records were available for 668 individuals (338 boys and 330 girls) born in Aberdeen during the summer and winter of 1921. The health visitors attended the family home as soon as possible after the 10th day from birth and continued to visit until the child was 1 year old.

The health visitors concentrated on the most needy families, 81% of children whose births were registered in Aberdeen in 1921.[19] The timing of visits varied according to need; children who were doing well received fewer visits than those who were failing to thrive or who lived in one of the city's "mother and baby" homes. The number of visits ranged from two to 40 (47% of the sample received at least 10 visits). There were no records for children who died during their 1st year.

The information recorded by the health visitors was abstracted using standardised methods. The records included details of the parents health, age, and occupation. Occupational social class at birth was assigned according to the standard occupational classification of the Office of Population Censuses and Surveys (OPCS 1990) by a clerical officer experienced in this field. In the first instance, social class was estimated from the father's occupation and then from the mother's occupation if there was no mention of the father. Mother's parity was recorded (number of living and dead children, cause and age of death of dead children, number of miscarriages, and number of still births), as were obstetric details of the most recent birth (for example, the use of forceps; prematurity—in 1921 prematurity was not identified by weeks of gestation but as a comment made by the visiting midwife). The records also included details of housing (floor, number of rooms, number of occupants, cleanliness, ventilation, and rent paid) and the infant (health and illness, weight, feeding, dummy use, crib use, and standards of clothing). Living conditions were estimated as a "crowding index" expressed as the ratio of rooms to inhabitants. Although some details were collected on the first visit only (such as information on housing and family size), others were recorded at each visit (for example, child weight, health, financial means of the family, and feeding practices). Infant body weight was recorded in pounds and ounces and subsequently converted to kg. Neonatal weight was the first recorded weight after birth but before 28 days of age. Records of child's feeding included breast feeding, bottle feeding, and the introduction of solid foods. For our analysis, subjects were grouped into one of three feeding groups: no breast feeding, that is, bottle fed (BF0); breast feeding at first visit (BF1); and breast feeding at 6 months (BF2).

Statistical comparisons between feeding groups were performed using one way analysis of variance and Kruskal-Wallis test as appropriate. Secondary analysis included simple factorial models (SPSS version 7.5.2; SPSS Inc, Chicago, Illinois, USA).

To make maximal use of all the longitudinal data available to us we used a multilevel (random effects) modelling approach.[20 21] In brief, multilevel modelling is an extension of ordinary multiple regression where data have a hierarchical or clustered structure. A hierarchy consists of units grouped at different levels, such data hierarchies are neither accidental nor ignorable. Repeated growth measures are one example of hierarchical structured data; here, the assessments are clustered within individuals that represent the level 2 units; with the assessment occasions being the level 1 units. Thus, when individuals are measured on more than one occasion, two levels of variability account for a single individual's departure from the fitted curve (level 1) and the differences between growth curves of different individuals (level 2). The model presented (table 1) shows a complex level 2 variation (random variables) that allows each child to have their own intercept and slope. It is the existence of the two levels of random variation in the model that marks this model out as a multilevel model. Age was calculated about an origin at 156 days, the mean age of the sample. This has the effect that the variance of the intercepts is estimated at a realistic age, rather than one that does not occur in the data, and obviates artefactual correlations between intercepts and slopes. The explanatory variables (table 1) are fixed parameters common to all members of the population; the "constant" value is the average intercept and the remaining variables the estimated slopes for each explanatory variable (for example, age, age squared, sex, and so on). Multilevel models do not require balanced data to obtain efficient estimates. In practice, this means that with repeated measurements, the same number of measurement occasions for each individual are not required; however, all available data are incorporated into the analysis.[20] Our data are taken from those individuals in whom assessment, including body weight, was made in the 1st month and at least once more during the 1st year of life. Births that were recorded as either multiple or premature were excluded. Five hundred and sixteen children (263 boys and 253 girls) fulfilled the above criteria (77% of the total cohort) and are included in our analysis (table 2). Analyses were performed using the multilevel models project software (MlwiN).[21] Fixed parameters were accepted as being significant if the

Table 1 Multilevel regression analysis of weight gain (kg) of infants, adjusted for sex and age

Random variable	Constant	Age
Level 1 (within individuals)		
Constant	0.138 (0.0031)	
Level 2 (between individuals)		
Constant	0.414 (0.027)	
Age	0.0014 (0.00014)	0.000013 (0.000001)
Explanatory variables	*Estimate*	*SEE*
Constant	4.26	0.22
Age	0.023	0.0013
Age^2	−0.000021	0.0000007
Sex	−0.28	0.059
Initial weight	0.86	0.051
BF1–BF2	−0.24	0.054
BF0–BF2	−0.31	0.099
PA	−0.045	0.014
CI	−0.092	0.032
Interaction		
Age*Sex	−0.0013	0.00037
Age*NWT	−0.0010	0.00032
Age*BF0	0.0013	0.00059
Age*PA	−0.00024	0.000086
Age*CI	−0.00034	0.00019

Values are means (standard error of the estimate (SEE)). Weight was expressed in kg. For statistical accuracy age is measured about an origin of 156 days. Sex: 0 for boys; 1 for girls.
BF2, breast feeding at 6 months; BF1, breast feeding at first visit; BF0, no breast feeding. BF2 is used as base measurement, and for statistical analysis other feeding groups are compared with it. CI, crowding index; NWT, neonatal weight, PA, maternal parity.

estimate of the slope was greater than twice the standard error of the estimate.[20 21]

Results

The physical characteristics and markers of socioeconomic status of the three feeding groups at the time of the initial measurement and final measurement are shown in tables 2 and 3, respectively. Boys in the BF2 group were heavier ($p < 0.05$) at first assessment than those in the BF1 and BF0 groups (table 2). Infants in the BF2 group were about 1 day younger than the other two groups at first measurement—11.3 compared with 12.5 and 12.8 days, respectively ($p < 0.05$). When the effect of age was accounted for (ANCOVA), the difference in initial body weights between the groups remained ($p < 0.05$). By the time of the last visit (mean, 278.9 days; SD, 82.7) there was no significant difference in age between BF0 and BF2 groups ($p > 0.05$), and there was also no significant difference in weight ($p > 0.05$). In contrast, the BF2 group was significantly heavier ($p < 0.05$) and older ($p < 0.05$) at their last visit compared with the BF1 group. Girls showed a slightly different pattern, with no significant differences between groups BF2 and BF1 in neonatal weight or initial age ($p > 0.05$). However, like their male counterparts, neonatal weights of the BF0 group were significantly less than the BF1 and BF2 groups ($p < 0.05$). Again, infants in the BF0 group had caught up for body weight by the end of their 1st year of life, with no significant difference in weight between the BF0 and BF2 groups ($p > 0.05$). No significant differences were found between the groups with regard to socioeconomic markers, apart from mother's parity in girls (table 3).

Table 1 summarises the results from the multilevel model. Because the BF2 group had the highest values for weight, this group was chosen as the reference feeding group. The random variables show the covariance matrix for the model of weight with age. The curves were fitted with quadratic polynomials, the quadratic term being fixed, not random. At level 1 the significant within individual variation for body weight indicates that the fitted quadratics did not fit perfectly. The level 2 random parameters show that individuals differed both in their fitted weights at 156 days (intercept) and in their rates of weight gain (slope), the two being positively correlated.

After each explanatory variable was adjusted for other explanatory variables (table 1), it can be seen that age, age squared, sex, neonatal weight, mother's parity, and crowding index all

Table 2 Physical characteristics at first and last visit by feeding groups and sex

	n	Age at first visit (days)	Neonatal weight (kg)	Age at last visit (days)	Weight at last visit (kg)	Mothers age at birth (years)
Boys						
BF2	145	11.3 (2.1)	4.1 (0.6)	280.5 (68.4)	8.9 (0.7)	28.3 (5.9)
BF1	91	12.3 (3.4)*	3.8 (0.6)*	248.6 (95.1)*	8.3 (1.6)*	26.9 (6.2)
BF0	27	12.8 (5.1)	3.7 (0.7)	292.0 (72.9)*	8.6 (0.8)	29.7 (7.1)
Girls						
BF2	153	11.2 (2.7)	3.8 (0.6)	298.3 (63.0)	8.5 (0.8)	28.5 (6.1)
BF1	74	11.5 (2.7)	3.8 (0.5)	287.9 (83.3)	8.3 (1.2)*	26.4 (5.7)*
BF0	26	13.4 (4.1)*	3.5 (0.5)*	305.4 (66.7)	8.7 (0.7)*	27.3 (6.8)

Values are mean (SD).
*Significant difference from preceding state ($p < 0.05$) by least significant difference comparisons.
BF2, BF1, and BF0 are incidence of breast feeding at 6 months, at first visit, and never, respectively.

Table 3 Markers of socioeconomic status at first visit by feeding groups and sex

	n	Social class	Mother's parity	Dwelling rooms	Dwelling inhabitants	Crowding index (rooms/inhabitants)
Boys						
BF2	145	4 (2–8)	2 (0–10)	2 (1–5)	5 (3–9)	3 (1.3–6)
BF1	91	4 (2–8)	1 (0–12)	2 (1–4)	5 (2–12)	2.5 (1–8)
BF0	27	4 (3–6)	1 (0–10)	2 (1–5)	6 (3–11)	2.8 (1–4.5)
Girls						
BF2	153	4 (2–8)	2 (0–13)*	2 (1–4)	5 (3–12)	3 (1–6)
BF1	74	4 (2–8)	1 (0–11)	2 (1–4)	4 (2–11)	2.5 (1–5.5)
BF0	26	5 (2–8)	2 (0–7)	2 (1–4)	5 (3–8)	2.5 (1.5–4)

Values are medians (range).
*Significant difference between states ($p < 0.05$) by Kruskal-Wallis test.
BF2, BF1, and BF0 are incidence of breast feeding at 6 months, at first visit, and never, respectively.

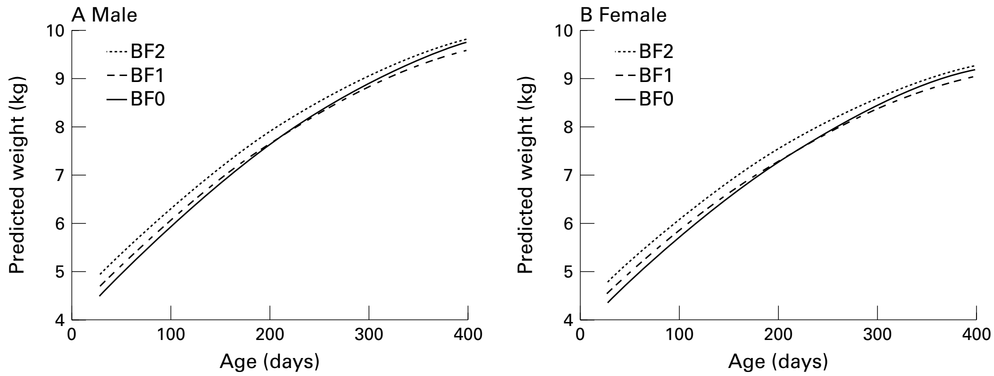

Figure 1 Predicted weight gain for the three feeding groups against age in boys and girls. The three groups are: BF2, breast feeding at 6 months; BF1, breast feeding at first visit; BF0, no breast feeding. Initial weight (0-28 days), mother's parity, and crowding index were corrected to their respective median values (tables 2 and 3). Note the catch up in the bottle fed group.

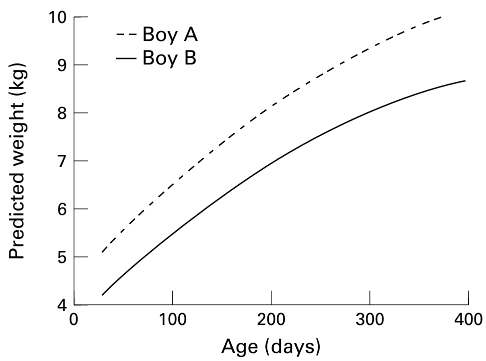

Figure 2 Predicted weight gain for a boy A who was still being breast fed at 6 months, with a maternal parity of 0, and crowding index of 1.3; compared with a boy B who had never been breast fed, had a maternal parity of 10, and an overcrowding index of 4.5. The difference in weight at 28 days reflects weight gain from birth. The birth weight for both examples was the average neonatal weight of the whole sample (3800 g).

had significant effects on weight gain, in that the slope coefficients for these variables were greater than their respective standard error estimate. Boys were heavier than girls and this difference increased with age, indicated by the significant negative interaction of sex with age. There was also a significant negative interaction between neonatal weight and age. Those in the BF2 group were heavier than those in the BF1 and BF0 groups. A significant positive interaction was found between age and BF0, confirming that the difference in body weight between the BF2 and BF0 groups decreased with increasing age as a consequence of the relatively greater weight gain in the BF0 group (table 1; fig 1). No significant interaction was found between age and BF1. Negative interactions between age and parity, and age and crowding index, were also found, indicating that the negative effects of these socioeconomic markers increased with time. When social class status and mother's age at birth were added to the model they were not found to be significant independent predictors of the rate of weight gain and were therefore excluded from the final model.

The final model, which included all the significant predictors described above, was then used to predict average weight gain for the sexes and the three feeding groups. Before these predictions were made, initial weight, crowding index, and mother's parity were controlled for by correcting to their respective mean values (tables 2 and 3). Figure 1 shows the results, where the significant differences between the sexes can be seen together with the differences between feeding groups. Note that the difference between the BF2 and BF0 groups decreased with increasing age, so much so that by 1 year of age there was no significant difference between these two groups. To illustrate the significant effects of socioeconomic markers, the model was used to predict the average growth curve for a boy A (fig 2) who was still being breast fed at 6 months, with a maternal parity of 0, and crowding index of 1.3; compared with a boy B (fig 2) who had never been breast fed, had a maternal parity of 10, and an overcrowding index of 4.5. Both scenarios reflect the extremes of the observed distribution of these factors and serve to illustrate their influence on both prenatal and postnatal growth.

Discussion

Our results mirror those reported previously, albeit in more recent cohorts, showing that at 28 days infants who were breast fed were significantly heavier than those who were bottle fed, and that by 12 months this difference disappears.[11 12] This feature can be seen in the random effects model (table 1; fig 1) as a significant positive interaction between age and bottle feeding. The fact that the early and late effects of bottle and breast feeding established in recent studies[11 12] are also apparent in the 1921 cohort gives confidence in the historical data presented here.

Our results also show that weight gain should be viewed in the context of socioeconomic status. We show that parental social class adds nothing to the prediction of infant weight when other socioeconomic markers are included in the model, mirroring the findings of others working with historical cohorts, who found that parental social class was a poor predictor of infant weight.[13 16] However, as pointed out by others, social class defined by parental occupation alone might not adequately reflect socioeconomic factors that are likely to influence growth and nutrition throughout childhood and influence health throughout adult life.[3 15 16] The significant effect of other indices of environmental exposures, such as the level of overcrowding in the family home, confirms that social class is not in itself sufficiently discriminating, at least in Aberdeen during the 1920s. It is likely that studies from other parts of the UK that have attempted to control for socioeconomic variables only in terms of social class have been subject to residual confounding.

Adverse environmental conditions, reflected in overcrowded housing, appeared to have cumulative effects in the model (increasing with time): these findings add to the evidence that programming in fetal and infant life are not the only factors that need to be considered when examining associations between chronic disease in later life and early life experience. If housing conditions have such a strong independent influence, the implications both for programming studies and for potential interventions in improving health are considerable.

There are a number of features concerning the ascertainment and continuation of this cohort that are worthy of comment. The method of ascertainment was through health visitors. These posts were established at the beginning of the century to promote and maintain infant and child health; hence the bias towards the lower socioeconomic groups. Despite this bias, the cohort analysed represented 47% of all live births in Aberdeen City during the period of study and any bias towards lower socioeconomic groups would be common to most or all historical cohorts followed up by health visitors during the early years of the present century. Indeed, this bias would have the effect of focusing on those groups most at risk of intrauterine and early infant malnutrition and, therefore, susceptible to fetal and early life programming and to the continuing effects of adverse environmental factors. The modest size of the cohort, 516 individuals, is balanced by the high density of measurements available over the 1st year of life, ranging from two to 40 in number, with 47% having more than 10 assessments over this period.

None of the infants had birth weight recorded. Weights were initially measured at the first health visitor contact, which was within the 1st month of life, with a mean of 10 days. Most infants regain birth weight by the beginning of the 2nd week of life, after the initial fall caused by fluid loss and the establishment of adequate nutrition. Therefore, it is likely that the first weights recorded would be similar or slightly above birth weights, had they been recorded. The initial breast feeding rates of about 80% at the first visit and 50% at 6 months would be impressive in the present age, considering the relative disadvantage of the population under study. However, this must be put into historical context, and it is likely that poor families would prefer breast feeding because this would have been inexpensive and a more convenient form of nutrition. There is circumstantial evidence that mothers of those infants judged to be of lower birth weight may have been encouraged to bottle rather than breast feed because initial weights were lowest in this group of infants. The alternative interpretation (which appears to be unlikely) would be that breast fed infants had already established a significant weight gain advantage in the very short period from birth to first measurement.

Our study has identified some of the confounders not adequately described by the categorisation of families within social class groupings most often used in historical cohorts. Of particular relevance and worthy of further investigation and intervention in more recent birth cohorts are the influences of overcrowding in the family home and the established benefits of breast feeding.

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