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Poverty, birthweight, and infant weight gain in Hertfordshire, 1923–1939

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Objective To investigate the association between poverty, birthweight, and infant weight gain in Hertfordshire, 1923–1939.

Design Cohort study based on the Hertfordshire Health Visitors' Register (HHVR).

Setting The population of Hertfordshire, and a sub-sample of five Hertfordshire towns—Hoddesdon, Berkhampstead, Hertford, Hitchin, and Bishops Stortford—extracted from the HHVR.

Subjects Some 71 201 live birth entries in the HHVR and a sample of 13 649 live birth entries for the five towns.

Measure of poverty Rateable value of birth addresses reflecting market and rental value of housing

Main outcome measures Birthweight, and infant weight gain (z score of weight at one year minus z score of birthweight).

Results In Hertfordshire as a whole there was a reduction in mean birthweight from 7.7 pounds (lbs) in 1923 to 7.4 lbs in 1939. Over the same time period there was an increase in mean infant weight gain, although with a degree of variation within the trend. In the sample of five towns there was no association between rateable value and birthweight, but a significant association between rateable value and both weight at one year, and weight gain during the first year of life.

Conclusion In Hertfordshire average birthweight declined, whereas weight gain during the first year of life tended to increase, at a time when, nationally, calorific intake and per capita consumption of a range of nutritional ingredients was rising. Poverty, as measured by rateable value, did not correlate with birthweight but was associated with weight gain during the first year of life. These findings suggest that nutritional poverty had a more significant influence on post-natal weight gain than it did on birthweight.

Keywords Birthweight, infant weight gain, poverty, rateable value, nutrition

Since the beginning of the 20th century, a range of evidence has emerged for a link between infant development and adult mortality. Kermack, McKendrick, and McKinley reviewing data for England, Wales, Scotland, and Sweden in 1934 found a cohort association between high levels of childhood and adult mortality during the 19th and early 20th centuries.[1] Subsequently Forsdahl, Buck, Simpson, Barker, and others observed a geographical association between high infant mortality rates at the beginning of the 20th century, and elevated death rates from coronary heart disease in the 1960s and 1970s.[2–4] More recently, Barker *et al.* found, at the individual level, a link between low birthweight and weight at one year in the period 1911–1939 and a range of later adult diseases, including higher mortality from strokes, heart disease, and certain types of cancer in Hertfordshire.[5] Barker *et al.* have focused on the influence of maternal nutrition on birthweight

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and weight at one year. They have emphasized the importance of the mother's life-long nutrition,[5] an emphasis which reflects a long tradition of medical thought.[6]

The association between low birthweight and weight at one year and higher adult disease mortality has been confirmed in subsequent studies for a number of different countries,[7] and other research has indicated a general link at the individual level between childhood socioeconomic conditions and cause-specific adult mortality.[8] Lucas *et al.* have however recently stressed the role of low infant growth in the explanation of higher adult mortality.[9–11]

The present paper examines the evidence on poverty and birthweight and weight at one year in Hertfordshire from 1923 to 1939, a place and period central to the development of the fetal origins hypothesis.

Methods

The primary dataset was derived from the Hertfordshire Health Visitors' Register (HHVR) covering the period 1923–1939. The dataset has been described in detail by Barker *et al.*, and has been used in a series of studies on fetal/infant development and subsequent adult disease mortality.[5] Information on the following variables was extracted from the register: (1) name of child; (2) birth address; (3) birthweight; (4) weight at one year; and (5) mortality in the first year of life. Not all entries in the register contained information on the variables covered by the research. Of the 71 201 total live births (excluding known multiple births), 52 607 (73.9%) had information on birthweight. The percentage of births in the HHVR with information on birthweight was as follows: 1923–1925 66.7%; 1926–1930 76.3%; 1931–1935 72.3%; and 1936–1939 76.3%.

In all, 8948 children were recorded in the register as having died or left in their first year. Of the remaining 62 253 children, 49 459 (79.4%) had a weight at one year recorded and 46 891 (75.3%) had both weight at one year and birthweight registered.

A sub-sample of 13 649 live, full-term births for five towns—Hoddesdon, Berkhampstead, Hertford, Hitchin, and Bishops Stortford—was selected for special analysis. This represented all the children on the registers for these towns for the period 1923–1939, excluding recorded multiple births. Of these children, 10 458 (76.6%) had information on birthweight, 9699 (71.1%) had weight at one year recorded, and 9268 (67.9%) had information on both birthweight and weight at one year.

Detailed examination of the data suggests that birth and infant weights were recorded with a varying degree of accuracy. However, mean values were calculated for all weights, and a simulation study indicated that the rounding of weights did not significantly affect results.

Direct information on father's occupation, family income and housing conditions was not available. Data, however, existed on the rateable value of houses, a numerical measure based on the market value and rent levels of property, indirectly reflecting both family income and housing conditions. Information was collected on rateable values taken from Rating Valuation Registers for the five towns (1923–1939). Rateable values were assigned to the birth addresses listed in the HHVR, enabling a direct link to information on birthweight and weight at one year. Data on rateable value was available for 9357 birth addresses, 68.6% of the total. Birthweight was unrecorded for only 11% of children with birth addresses which had relatively low rateable values (≤£14), but for 16%, 25%, and 38% of children when the corresponding rateable value was £15–£18, £19–£22, and £23+ respectively. Middle class families living in houses with higher rateable values are therefore under-represented in the sample, possibly distorting the findings on rateable value and birthweight.

In total, children for whom information existed in the HHVR and who could be located in rates registers were as follows: information on both birthweight and rateable value 7968 out of a total of 13 649 (58.4%), data on both weight at one year and rateable value 7451 out of total of 13 649 (54.9%).

For both birthweight and weight at one year, z-scores were calculated, the standardization being based on the mean and standard deviation for the data as a whole. This enabled an analysis of the relative gain during the first year of life, studied via the change in birthweight and weight at one-year z scores. Differences in mean birthweight, weight at one year, and relative gain during the first year were tested using ANOVA. In the secular analysis linear trends were tested through the regression of weights on birth year. Similarly, trends in the analysis of poverty and weight were evaluated by allocating numerical values—1, 2, 3, etc—to the rateable value groups, avoiding a few very high rateable values having undue influence.

Results

Secular changes in birthweight and weight at one year in Hertfordshire, 1923–1939

During the period 1923 to 1939 the mean birthweight for live births fell from 7.7 pounds (lbs) in 1923 to 7.4 lbs in 1939 (Figure 1). The trend was approximately linear (deviation from linear trend $P = 0.124$), corresponding to a reduction in mean birthweight of 0.18 lbs per year (95% CI: 0.016, 0.020). This trend however only accounts for 0.5% of the variation in birthweight.

The decline in mean birthweight does not appear to be a function of larger numbers of low birthweight children surviving. Inclusion of the stillbirth rate for each year into the regression model did not moderate the linear trend over time. Nevertheless there were differences in stillbirth rates from year to year and some evidence of a trend [change in the odds ratio (OR) of

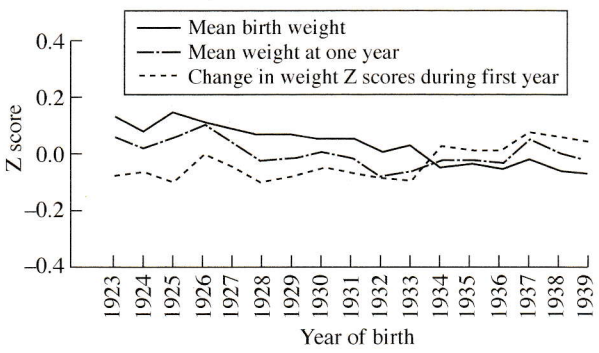

Figure 1 Percentage change in mean birthweight, weight at one year, and relative weight gain during the first year

1.009 per year, 95% CI: 1.000, 1.018]. The percentage of stillbirths as a proportion of all births was as follows: 1922–1925: 2.6%, 1926–1930: 3.0%; 1931–1935: 2.7%; 1936–1939: 3.0%.

During 1923–1939 the mean weight at one year varied significantly ($P < 0.001$) from a high of 22.0 lbs in 1926 to a low of 21.5 lbs in 1932. Although in part this variation could be ascribed to a linear trend of –0.015 lbs per year (95% CI: −0.020, −0.011), there was also significant non-linearity to the pattern over time (test for non-linearity $P < 0.001$).

Like weight at one year, the relative change in weight in the first year varied significantly over the time period ($P < 0.001$), but in a complicated way. There was significant linear trend ($P < 0.001$) but a degree of variation within the trend (deviation from linear trend, $P < 0.001$). Nevertheless it is noteworthy that for births during the period 1923–1933, the mean change in z-scores was negative whilst for births during 1934–1939, the mean change in z-scores, was positive. Furthermore there was a linear trend of 0.010 per year (95% CI: 0.008, 0.012) in z-score change. Thus generally there were higher weight gains associated with the latter part of the period studied. (Figure 1).

Poverty and infant mortality, birthweight, and weight gain during the first year of life

Infant mortality is a measure known to be linked to poverty and social class in the first half of the 20th century,[12] and used widely in research on infant development and adult disease mortality.[2–4,13,14] In order to evaluate the effectiveness of rateable value as a measure of poverty, an analysis was carried out of the relationship between rateable value and infant mortality in the five towns. Infant mortality was calculated by expressing the number of infants known to have died in the first year as a proportion of the number of live births. Table 1 summarizes the findings for the five towns on the relationship between rateable value and infant mortality, as well as rateable value and birthweight and relative weight gain in the first year.

Infant mortality was generally lower in the higher rateable value groups. Modelling infant mortality using logistic regression suggests that the trend across rateable value groups is statistically significant. The OR for infant mortality between successive rateable value groups is estimated to be 0.89 (95% CI: 0.82, 0.97), confirming that rateable value is an effective measure of poverty associated with infant mortality.

There was little evidence of a link between rateable value and birthweight (one-way ANOVA, $0.1 > P > 0.05$). This lack of a link might be due to selective recording of birthweights in the different rateable value groups. However, analysis of the infant mortality of children suggests that the trend in infant mortality (OR = 0.78, 95% CI: 0.72, 0.85) was stronger amongst children with recorded birthweights than amongst all children—both with and without recorded birthweight—covered by Table 1. This suggests that any patterns in birthweight with respect to rateable values are not strongly biased by selective recording issues.

There was also no significant association between rateable value and stillbirths, indicating that survival of low birthweight children did not play a role in the relationship between rateable value and birthweight.

In contrast, weight at one year and weight gain in the first year were both significantly associated with rateable value (in both cases one-way ANOVA, $P < 0.001$). Both mean weight at one year and mean weight gain were generally higher in the higher rateable value groups. These findings suggest that poverty (as measured by rateable value) had little or no influence on birthweight, but a significant effect on infant weight gain in Hertfordshire during the period 1923–1939.

Discussion

There was a linear although slight decline in mean birthweight between 1923 and 1939. This was a period when per capita incomes and consumption of food rose significantly in the UK. Consumers' expenditure per head on food at constant prices was as follows: 1920–1924 £22.61; 1925–1929 £24.59; 1930–1934 £26.58; 1935–1938 £27.26.[15] Growing per capita expenditure on food was associated with an increase in most

Table 1 Rateable value, stillbirths, infant mortality, birthweight, and relative weight gain in first year in Hoddesdon, Berkhampstead, Hertford, Hitchin, and Bishops Stortford, 1923_01939 (95% CI)

Rateable value (£)	Stillbirths as a proportion of all births	Infant mortality (per 1000 births)	Birthweight ht (lbs)	Weight at one year	Relative weight gain in first year changes in Z scores
3–6	3.5% (2.2%, 5.1%)	43 (29, 61)	7.5 (7.4, 7.6)	21.1 (20.9, 21.3)	−0.26 (−0.31, −0.17)
7–10	3.0% (2.3%, 3.9%)	42 (34, 52)	7.6 (7.6, 7.6)	21.7 (21.6, 21.8)	−0.10 (−0.12, −0.04)
11–14	2.6% (1.8%, 3.7%)	35 (25, 47)	7.6 (7.5, 7.6)	21.7 (21.6, 21.9)	−0.06 (−0.11, −0.00)
15–18	2.8% (1.6%, 4.5%)	34 (29, 53)	7.6 (7.5, 7.6)	22.1 (21.9, 22.2)	+0.05 (−0.03, +0.13)
19–22	3.6% (1.8%, 6.4%)	24 (10, 48)	7.5 (7.3, 7.6)	21.9 (21.7, 22.2)	+0.13 (−0.01, +0.24)
23+	2.4% (1.2%, 4.2%)	28 (15, 47)	7.5 (7.4, 7.6)	21.9 (21.7, 22.1)	+0.06 (−0.04, +0.16)

nutrients available for consumption.[15] Overall calories available for consumption increased from 3214 in 1920–1924 to 3432 in 1930–1934, although there was a slight decline to 3400 in 1935–1938.[15]

There are no direct figures on per capita consumption of food available for Hertfordshire during the pre World War II period, but there is evidence of increasing prosperity which was reflected in the changing class structure of the county: the proportion of professional, commercial, or administrative occupations increased from 22% of the total in 1921 to 26% in 1931, and 31% in 1951.[16–18]

The decline in birthweight between 1923 and 1939 may have been partly due to an increasing proportion of women who smoked during pregnancy, although the data is too piecemeal to allow precise calculations. However, total annual consumption of tobacco increased in the UK amongst women from 0.8 thousand tons in 1923 to 9.5 thousand tons in 1939, and subsequently to 23.5 tons in 1946, when about 41% of all women smoked.[19] There was little or no relationship between social class and smoking amongst women in 1946,[19] suggesting that smoking was not a factor in the relationship between poverty and birth and infant weight in the pre World War II period. Other demographic factors, such as changes in parity may also have played a part in the reduction of birth weight during this period.[20] Data are not currently available to clarify these issues, and these are topics to be explored in future research.

Studies carried out in England during the first half of the 20th century found no significant association between poverty and birthweight, but a strong association between family income and infant growth in the first year of life.[21,22] One of the most detailed of these studies was that carried out in Birmingham by Pooler,[23] a study not widely reported in the literature. The findings are summarized in Table 2.

There was little association between family income and weight at 3 weeks, but a progressive increase in the differences in infant weight between the income groups during the first year. By the age of one year there was a difference of 1 lb 10 oz in the average weight of children in the highest and lowest income groups. Assuming a standard deviation of 11/2 lbs for birthweights and 3 lbs for weights at one year, this indicates that income had little or no influence on birthweight but a strong impact on weight gain during the first year of life. The findings on poverty and weight in the first year of life in Birmingham are mirrored in the findings of the present study, with little or no association between rateable value and birthweight but a link between rateable value and weight gain in the first year of life.

In England social class and family income are known to have generally affected patterns of food consumption in this period. In 1936/37 families in the top 5% income group spent an average of about 17 shillings per head on food, compared with 6 shillings per head spent by the bottom 15%.[15] It was estimated that none of the top 5% were below the British Medical Association (BMA) food expenditure minimum, compared with 48% in the bottom 15% group.[15]

Poverty appears to have had little or no effect on birthweight in Hertfordshire during the period 1923–1939. As shown in the BMA study, social class and poverty affected women's life-long nutrition.[15] Although there is no statistical evidence available on the relationship between poverty and nutrition in the county during this period, there is documentary evidence that poverty had a significant effect on the nutrition of Hertfordshire women both during childhood and early adulthood in the pre World War II period.[24–26]

Birthweight is influenced by a wide range of environmental and biological factors, such as maternal age, height and weight, parity, as well as a parental propensity to diseases such as diabetes and coronary heart disease.[7, 27–29] Intergenerational associations have been shown with parental birthweight being associated with offsprings' birthweight.[30] Many of the studies have assumed that birthweight is largely shaped by patterns of maternal nutrition. However the exact influence of the long-term nutrition of mothers on the birthweight of their children is yet to be determined.[5,28,30–32]

Conclusion

Average birthweight appears to have declined in pre World War II Hertfordshire despite an apparent increase in per capita consumption of food and an increase in weight gain during the first year of life. In the first half of the 20th century, there was also little association between poverty and birthweight, but a significant link between poverty, weight at 1 year and infant weight gain. This suggests that poverty-related differences in nutrition played a more significant role in post-natal than pre-natal development.

Given the established links between birthweight and weight at one year and mortality from heart disease, strokes, and stomach cancer, further clarification of the relative roles of

Table 2 Average weight of infants by family income group, Birmingham, 1908–1913

	No. of families	Average income (shillings & pence)	Average weight of infants (lbs and oz)				
			Age 3 weeks	Age 13 weeks	Age 26 weeks	Age 39 weeks	Age 52 weeks
A1 (lower income families)	641	1.7	8.1	10.9	12.1	15.12	17.1
A2 (medium income families)	431	2.11	8.3	10.10	13.14	15.13	17.8
B (higher income families)	493	4.11	8.0	11.2	14.5	16.11	18.11

biological, demographic, and environmental factors in birthweight and infant weight gain are important for an understanding of adult disease mortality. By unravelling the childhood determinants of adult disease in such detail, future research should help to clarify appropriate preventative health policies.

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