Thinness at birth in a northern industrial town


Abstract

Objective—To determine whether babies in an area of Britain with unusually high perinatal mortality have different patterns of fetal growth to those born elsewhere in the country.

Design—Measurement of body size in newborn babies.


Subjects—Subjects comprised 1544 babies born in Burnley, Pendle, and Rossendale Health District, and 1025 babies born in Salisbury Health District.

Main outcome measures—Birthweight, length, head, arm and abdominal circumferences, and placental weight were determined.

Results—Compared with babies born in Salisbury, Burnley babies had lower mean birthweight (difference 116 g, 95% confidence interval (CI) 77, 154), smaller head circumferences (difference 0·3 cm, 95% CI 0·2, 0·4), and were thinner as measured by arm circumference (difference 0·3 cm, 95% CI 0·3, 0·4), abdominal circumference (difference 0·5 cm, 95% CI 0·4, 0·6) and ponderal index (difference 0·8 kg/m², 95% CI 0·6, 1·0). The ratio of placental weight to birthweight was higher in Burnley (difference 0·6%, 95% CI 0·4, 0·9). These differences were found in boys and girls and did not depend on differences in duration of gestation or on the different ethnic mix of the two districts. Mothers in Burnley were younger, shorter in stature, had had more children, were of lower social class, and more of them smoked during pregnancy than mothers in Salisbury. These differences did not explain the greater thinness of their babies.

Conclusions—Babies born in Burnley, an area with high perinatal mortality, are thin. The reason is unknown. Poor maternal nutrition is suspected because Burnley babies have a higher ratio of placental weight to birthweight. The greater thinness at birth of Burnley babies could have long term consequences, including higher rates of cardiovascular disease.

Thickening of the placenta was positively associated with birthweight, perinatal mortality, and the birthweight of babies at birth. Babies born in Burnley had a higher ratio of placental weight to birthweight compared with babies born in Salisbury. The reasons for these differences are unknown, but it is possible that they are related to maternal nutrition or other factors affecting fetal growth.

Methods

All babies born in Burnley General and Odstock (Salisbury) Hospitals between 6 May and 17 December 1991, who were not admitted to the special care baby units, were eligible for inclusion. These hospitals have the only maternity units serving the health districts. Babies admitted to special care baby units were excluded because the detailed measurements might have been detrimental to ill or very small babies. The predetermined time period was calculated to yield a sample of 1500 babies in Burnley and 1000 in Salisbury, where there are fewer births. This gives 95% power to detect a mean difference of 90 g in birthweight, 25 g in placental weight, and 5 mm in crown-heel length between the two districts, using a test at the 5% level of significance.

At birth the baby was weighed to the nearest 5 g using digital scales. The placenta was weighed with one inch of cord attached using digital scales, the clamp being removed at the time of weighing. The scales were checked each week against standard weights: recalibration was not required during the study period.

Mothers were invited to participate in the study in the 24 hours after delivery. Information on their social and demographic characteristics and health during pregnancy was collected by questionnaire and inspection of the hospital notes. Mothers’ height was taken from that measured at booking. Duration of gestation was estimated from the date.
of the last menstrual period combined with ultrasound scanning.

The babies' body size was measured at a median of 16 hours after birth (range 15 minutes to 31 hours). Crown-heel length was measured on a neonatal stadiometer. Head circumference was measured at the maximum occipito-frontal circumference. Mid-arm circumference was measured at a point midway between the acromion and olecranon. Upper abdominal circumference at expiration was measured at a level midway between the xiphisternum and the umbilicus. All measurements were made three times to the nearest millimetre and the mean used in analysis. The circumferences were measured by marking blank tapes. These were read off after all measurements of the baby had been completed.

There were two teams of fieldworkers, comprising three fieldworkers in Burnley and three in Salisbury. Both teams trained together and inter-observer and between team tests of repeatability were performed before the study. The tests were repeated at monthly intervals throughout the study period, using repeated measurements on a set of babies, in a balanced analysis of variance design.

STATISTICAL METHODS

Means and distributions of variables were compared between Burnley and Salisbury using t tests for normally distributed variables, Mann-Whitney U tests for non-normally distributed variables, and χ² tests for categorical variables. The simultaneous effect of variables was analysed using multiple linear regression. Information was incomplete in less than 5% of babies (birthweight eight babies, placental weight 107, crown-heel length 16, head circumference three, arm circumference four, upper abdominal circumference seven, gestation 40). Where information was missing, the baby was excluded from that part of the analysis.

Results

Of 2679 eligible babies, 2612 were included in the study. Twenty two mothers refused to participate and 45 left the hospital before they could be approached. Non-participants tended to be of higher parity than participants. There were no significant differences between participants and non-participants in maternal height, birthweight, placental weight, or duration of gestation. Thirty one babies were excluded from the analysis because they were twins, 11 because they had deformities likely to perturb measurement of their length, and one because sex was not recorded.

Table 1  Size of babies at birth in Burnley and Salisbury

<table>
<thead>
<tr>
<th></th>
<th>Burnley (n=1544)</th>
<th>Salisbury (n=1025)</th>
<th>Difference, Burnley—Salisbury (95% Confidence interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birthweight (g)</td>
<td>3342 (486)</td>
<td>3458 (487)</td>
<td>-116 (-154, -77)</td>
</tr>
<tr>
<td>Crown-heel length (cm)</td>
<td>50.0 (2.1)</td>
<td>50.1 (2.0)</td>
<td>-0.1 (-0.3, 0.04)</td>
</tr>
<tr>
<td>Ponderal index (kg/m²)</td>
<td>26.6 (2.2)</td>
<td>27.4 (2.3)</td>
<td>-0.8 (-1.0, -0.6)</td>
</tr>
<tr>
<td>Head circumference (cm)</td>
<td>34.8 (1.3)</td>
<td>35.1 (1.3)</td>
<td>-0.3 (-0.4, -0.2)</td>
</tr>
<tr>
<td>Arm circumference (cm)</td>
<td>11.1 (0.9)</td>
<td>11.4 (0.9)</td>
<td>-0.3 (-0.4, -0.3)</td>
</tr>
<tr>
<td>Upper abdominal circumference (cm)</td>
<td>33.5 (1.8)</td>
<td>34.0 (1.8)</td>
<td>-0.5 (-0.6, -0.4)</td>
</tr>
<tr>
<td>Placental weight (g)</td>
<td>18.0 (3.1)</td>
<td>17.4 (2.9)</td>
<td>0.6 (0.4, 0.9)</td>
</tr>
<tr>
<td>Placental weight: birthweight ratio (%)</td>
<td>40.1 (1.7)</td>
<td>40.2 (1.4)</td>
<td>-0.1 (-0.3, -0.01)</td>
</tr>
</tbody>
</table>

The results presented are for the remaining 2569 babies, 1305 boys and 1264 girls. Compared with babies in Salisbury, babies in Burnley had lower mean birthweight (table I). They had, however, similar mean length. Thus, they were thinner, as measured by the ponderal index (weight/length²). Burnley babies had smaller mean head, arm, and abdominal circumferences, but similar mean placental weight (table I). Their ratio of placental weight to birthweight was higher. The differences between Burnley and Salisbury were similar for boys and girls. Figures 1 and 2 show that the differences in ponderal index and abdominal circumference were associated with different distributions of the measurements throughout the population, and not only differences at the extremes.

![Figure 1 Distribution of ponderal index (weight/length²) in newborn babies in Burnley and Salisbury](image1)

![Figure 2 Distribution of abdominal circumference in newborn babies in Burnley and Salisbury](image2)

Mean gestation was 0-1 weeks shorter in Burnley (table I). Adjustment for duration of gestation had little effect on the differences in birthweight; ponderal index; head, arm, and abdominal circumference; and ratio of placental weight to birthweight. These remained strongly statistically significant. Table II shows, however, that the differences in ponderal index were largest in babies born before 38 weeks' gestation. There were similar findings for abdominal circumference. The differences were little changed by analysing only those babies who weighed at least 2500 g at birth (n=2486). Babies with a low ponderal index tended to have low abdominal, arm, and head circumference. The correlation
coefficients between ponderal index and these other measurements were 0.48, 0.55, and 0.31.

Replicate measurements on the same babies showed no systematic differences between field-workers in measurements of length and abdominal circumference. Field-workers in Burnley tended to record smaller head and arm circumferences. However, these differences in measurement technique accounted for less than half of the observed difference in means of these two measurements between Burnley and Salisbury.

**Ethnic origin**
Among Burnley babies, those born to Asian mothers had lower birthweight, head and abdominal circumference, and lower placental weight than those born to white mothers. They had similar crown-heel lengths, and therefore had a lower ponderal index. Eighty-six per cent of the mothers in Burnley were white compared with 99% in Salisbury. Thirteen per cent of mothers in Burnley were Asian, mostly from Pakistan. The differences between Burnley and Salisbury persisted, however, if the analysis was confined to babies born to white mothers only (table III).

**MATERNAL HEIGHT, AGE, AND PARITY**
The babies of taller mothers were larger in all measurements. Mothers in Burnley were on average 2.9 cm shorter than mothers in Salisbury. The differences in size at birth between the districts were seen at all maternal ages.

Babies of older mothers, those more than 30 years, were on average 157 g (95% CI 110, 204) heavier than babies born to mothers aged less than 25 years. Mothers in Burnley were on average 1.8 years younger than those in Salisbury. A large proportion of mothers under the age of 25 years—45% in Burnley compared to 26% in Salisbury. Differences in size at birth between Burnley and Salisbury, however, were seen at all maternal ages.

Firstborn babies were on average 103 g (95% CI 65, 141) lighter than laterborn babies. Parity was higher in Burnley, where 11% of mothers were having their fourth or later baby, compared with 6% in Salisbury. Differences in size at birth between Burnley and Salisbury were seen, however, at each level of parity.

**SOCIAL CLASS**
Babies of mothers in social classes I and II were on average 78 g (95% CI 21, 136) heavier than babies of mothers in social classes IV and V. Thirty per cent of Burnley mothers were in social class IV or V compared to 20% of Salisbury mothers. Differences in size at birth between Burnley and Salisbury, however, were seen in each social class and were of similar magnitude.

**MATERNAL SMOKING**
Babies of mothers who smoked during pregnancy were on average 252 g (95% CI 212, 292) lighter than the babies of non-smoking mothers. Thirty-six per cent of mothers smoked during their pregnancy in Burnley compared with 24% in Salisbury. We classified maternal smoking during pregnancy as “non-smoker”, “light” (1–9 cigarettes per day) or “heavy” (10 cigarettes per day). Table IV shows that the differences in size at birth between the two places were seen in the babies of both non-smoking and smoking mothers.

**MULTIPLE REGRESSION**
We carried out multiple regression analyses to allow for the inter-relationships of maternal factors which were associated with size at birth. Each birth measurement was regressed onto maternal height, age, parity, social class, and smoking habit, and their interactions. The additional effect of place, that is the difference

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**Table II Ponderal index at birth in Burnley and Salisbury according to duration of gestation**

<table>
<thead>
<tr>
<th>Gestation (completed weeks)</th>
<th>Burnley (n=1327)</th>
<th>Salisbury (n=1013)</th>
<th>Difference, Burnley—Salisbury (95% confidence interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤37</td>
<td>25.7 (n=138)</td>
<td>27.4 (n=63)</td>
<td>-1.7 (p&lt;0.0001) (-1.0, 0.5)</td>
</tr>
<tr>
<td>38-39</td>
<td>26.6 (n=504)</td>
<td>27.3 (n=314)</td>
<td>-0.7 (-0.0, 0.5)</td>
</tr>
<tr>
<td>40-41</td>
<td>27.1 (n=698)</td>
<td>27.4 (n=568)</td>
<td>0.0 (0.0, 0.5)</td>
</tr>
<tr>
<td>&gt;41</td>
<td>27.6 (n=157)</td>
<td>27.6 (n=67)</td>
<td>0.0 (0.0, 0.5)</td>
</tr>
</tbody>
</table>

**Table III Size of babies at birth in Burnley and Salisbury: white mothers only**

<table>
<thead>
<tr>
<th>Mean SD</th>
<th>Burnley (n=1327)</th>
<th>Salisbury (n=1013)</th>
<th>Difference, Burnley—Salisbury (95% confidence interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birthweight (g)</td>
<td>3357 (479)</td>
<td>3459 (489)</td>
<td>-103 (-142, -63)</td>
</tr>
<tr>
<td>Crown-heel length (cm)</td>
<td>50.6 (21.0)</td>
<td>50.1 (20.0)</td>
<td>0.5 (-0.3, 0.1)</td>
</tr>
<tr>
<td>Ponderal index (kg/m³)</td>
<td>26.7 (21.2)</td>
<td>27.4 (23.2)</td>
<td>-0.7 (-0.9, -0.5)</td>
</tr>
<tr>
<td>Head circumference (cm)</td>
<td>34.9 (13.3)</td>
<td>35.1 (13.3)</td>
<td>-0.2 (-0.3, -0.1)</td>
</tr>
<tr>
<td>Arm circumference (cm)</td>
<td>11.1 (0.9)</td>
<td>11.4 (0.9)</td>
<td>-0.3 (-0.4, -0.2)</td>
</tr>
<tr>
<td>Upper abdominal circumference (cm)</td>
<td>33.5 (1.8)</td>
<td>34.0 (1.8)</td>
<td>-0.5 (-0.6, -0.3)</td>
</tr>
<tr>
<td>Placental weight (g)</td>
<td>605 (122)</td>
<td>601 (126)</td>
<td>0.6 (-0.1, 1.5)</td>
</tr>
<tr>
<td>Placental weight: birthweight ratio (%)</td>
<td>18.1 (3.1)</td>
<td>17.4 (2.9)</td>
<td>0.7 (0.5, 1.0)</td>
</tr>
<tr>
<td>Gestation (completed weeks)</td>
<td>40.1 (1.7)</td>
<td>40.2 (1.4)</td>
<td>-0.1 (-0.2, 0.0)</td>
</tr>
</tbody>
</table>

**Table IV Differences in size of babies at birth, according to maternal smoking during pregnancy**

<table>
<thead>
<tr>
<th>Mother’s smoking habit during pregnancy</th>
<th>0 cigarettes per day</th>
<th>1-9 cigarettes per day</th>
<th>10 cigarettes per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birthweight (g)</td>
<td>-79 (-125, -33)</td>
<td>-140 (-247, -33)</td>
<td>-97 (-191, -2)</td>
</tr>
<tr>
<td>Crown-heel length (cm)</td>
<td>-0.03 (-0.2, 0.2)</td>
<td>-0.3 (-0.7, 0.2)</td>
<td>-0.1 (-0.5, 0.3)</td>
</tr>
<tr>
<td>Ponderal index (kg/m³)</td>
<td>-0.7 (-0.9, -0.5)</td>
<td>-0.8 (-1.3, -0.3)</td>
<td>-0.6 (-1.0, -0.2)</td>
</tr>
<tr>
<td>Head circumference (cm)</td>
<td>-0.2 (-0.3, -0.1)</td>
<td>-0.4 (-0.7, -0.1)</td>
<td>-0.4 (-0.6, -0.1)</td>
</tr>
<tr>
<td>Arm circumference (cm)</td>
<td>-0.3 (-0.3, -0.2)</td>
<td>-0.4 (-0.6, -0.2)</td>
<td>-0.3 (-0.5, -0.1)</td>
</tr>
<tr>
<td>Upper abdominal circumference (cm)</td>
<td>-0.4 (-0.6, -0.2)</td>
<td>-0.5 (-0.9, -0.1)</td>
<td>-0.5 (-0.9, -0.2)</td>
</tr>
<tr>
<td>Placental weight (g)</td>
<td>0 (-12, 12)</td>
<td>2 (-27, 30)</td>
<td>-3 (-31, 26)</td>
</tr>
<tr>
<td>Placental weight: birthweight ratio (%)</td>
<td>0.4 (0.2, 0.6)</td>
<td>0.8 (0.1, 1.5)</td>
<td>0.6 (-0.1, 1.5)</td>
</tr>
<tr>
<td>Gestation (completed weeks)</td>
<td>-0.1 (-0.3, 0.1)</td>
<td>-0.2 (-0.6, 0.2)</td>
<td>-0.2 (-0.6, 0.1)</td>
</tr>
</tbody>
</table>
between Burnley and Salisbury after allowing for differences in maternal characteristics, is shown in table V. Babies were significantly thinner, measured by ponderal index and arm and abdominal circumferences, in Burnley, and had higher placental weight to birthweight ratios after allowing for the differences in mothers. The differences in birthweight and head circumference were diminished and no longer statistically significant. This depended on the inclusion of maternal height in the regression model.

Table V: Differences in size of babies at birth, allowing for maternal height, age, parity, social class, and smoking

<table>
<thead>
<tr>
<th></th>
<th>Difference, Burnley–Salisbury (95% confidence interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birthweight (g)</td>
<td>-34 (-71, 2)</td>
</tr>
<tr>
<td>Ponderal index (kg/m²)</td>
<td>-0.6 (-0.8, -0.5)</td>
</tr>
<tr>
<td>Head circumference (cm)</td>
<td>-0.1 (-0.2, 0.0)</td>
</tr>
<tr>
<td>Arm circumference (cm)</td>
<td>-0.2 (-0.3, -0.1)</td>
</tr>
<tr>
<td>Abdominal circumference (cm)</td>
<td>-0.2 (-0.4, -0.1)</td>
</tr>
<tr>
<td>Placental weight: birthweight ratio (%)</td>
<td>0.4 (0.1, 0.6)</td>
</tr>
</tbody>
</table>

Discussion

We have compared the distributions of size at birth in two districts in England. One, Burnley, has for many years had one of the highest perinatal mortality rates in the country. The other, Salisbury, has rates around the national average. We found that babies born in Burnley were thinner at birth, as measured by ponderal index, arm and abdominal circumferences and had smaller head circumferences (table I). These differences were not the result of differences between the districts in the duration of gestation. Thus, they reflect different patterns of fetal growth.

Thirteen per cent of mothers in Burnley were born outside Britain, mostly in Pakistan, and more of the Burnley mothers were of low socioeconomic status and smoked during pregnancy. Their average height was 2.9 cm shorter, they were 1.8 years younger, and more were multiparous. These differences between the districts in the characteristics of the mothers did not, however, explain the differences in thinness, but accounted for much of the difference in head circumference (table V).

Our study populations included all hospital deliveries in the two health districts during a predetermined time period. The only babies excluded were the small number born outside hospital, and those who were admitted to the special care baby units. The clinical indications for admission to these units were similar in the two districts and almost all of the admitted babies weighed less than 2500 g. The differences in mean birth measurements between Burnley and Salisbury were little changed by analysing only babies weighing at least 2500 g. These differences reflect the distributions of birth measurements throughout the two populations and are not the result of an excess of very small, thin babies in Burnley (fig 1 and 2). The high perinatal mortality in Burnley may therefore result from influences which impair fetal growth throughout its whole range.

If a fetus is deprived of nutrients or oxygen in the last trimester, when the head and body have almost reached full size, it will waste. At birth it will have low weight in relation to lengths, a disturbance which has been termed “subacute fetal distress”. The nutrient and oxygen supply to the fetus is a major influence on fetal growth. In addition, the mother actively constrains growth, as is shown by the strong relation between birthweight and mother’s height. Babies in Burnley were thinner after allowing for maternal height, whereas the smaller head circumference was mostly dependent on the mother’s shorter stature. In looking for the causes of thinness it is therefore necessary to focus on influences which determine fetal growth other than physiological constraint by the mother.

Babies with a low ponderal index, born at term, have been labelled as having fetal undernutrition. The low average arm and abdominal circumferences of babies in Burnley are further evidence of undernutrition. Maternal influences associated with reduction in weight but preservation of length include energy restriction and low weight gain in pregnancy. Babies born after the “Dutch hunger winter” in 1944–5 had a disproportionate reduction of birthweight in relation to length.

The babies in Burnley also had a higher ratio of placental weight to birthweight. Disproportionate placental size is thought to be an adaptation to maternal undernutrition. It occurs in babies whose mothers were anemic during pregnancy. It can be produced in sheep by reducing the calorie intake of ewes in early pregnancy. The thinness of babies in Burnley may result in impaired neonatal metabolism: such babies may, for example, suffer from neonatal hypoglycaemia. Babies who are thin at birth may also have impaired metabolism in later life. Recent follow up studies of men and women born in Preston and Sheffield have shown that those who were thin at birth have, as adults, increased death rates from cardiovascular disease and high rates of syndrome X, the coexistence of hypertension, impaired glucose tolerance, and abnormal lipids. These associations are thought to reflect programming, whereby influences which impair fetal growth have permanent effects on the structure and function of particular organs and tissues.

Burnley has high death rates from circulatory disease—the standardised mortality ratio during 1991 was 116 compared with 90 in Salisbury. The thinness of babies in Burnley now suggests that these high death rates from circulatory disease may persist. This would be consistent with long term forecasts of national and regional trends in cardiovascular mortality in England and Wales which suggest that the differences in cardiovascular mortality between the north and south of the country will increase.

We conclude that in a district of England with high perinatal mortality there is evidence of widespread subacute fetal distress which results in thinner babies. This poorer growth late in pregnancy is seen throughout the population and is related to influences other than maternal height, age, parity, social class and smoking. We suggest that they may result from imbalances in maternal nutrition. The nature of these is unknown and further studies are needed.

We are grateful to the staff of the maternity departments of Burnley General Hospital and Odstock Hospital Salisbury for their cooperation, and to the obstetricians for permission to recruit their patients. We also thank Mr Paul Winter and Mr Graham Wield for assistance.
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Rossendale, and Salisbury District Health Authorities.

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