Birth Weight and Blood Pressure in Childhood
Results From the Health Survey for England

Paola Primatesta, E. Falaschetti, Neil R. Poulter

Abstract—Findings of previous reports relating low birth weight with raised blood pressure in childhood and adolescence have been inconsistent. The present study uses cross-sectional data from a series of nationally representative annual surveys—the Health Survey for England—between 1995 and 2002, totaling a sample of 15,629 children aged 5 to 15. A significant negative relationship between birth weight, in quartiles or dichotomized as low (<2.5 kg) and normal (≥2.5 kg) and systolic blood pressure was apparent. Linear regression analyses confirmed these findings. When current weight was included in the model, the strength of the relationship increased. An interaction term between birth weight and current weight was not significant. A life-course plot for those aged 13 to 15 (n=3900), converting the weight measurements at birth and as a teenager to standard deviation scores to make the regression coefficients comparable, showed the importance of weight gain on blood pressure (1 standard deviation increase in weight from birth to age 13 to 15 was associated with an increase in systolic blood pressure of 0.8 mm Hg). Separating those with low and normal birth weight demonstrated that the increase in weight from birth to adolescence had an effect on blood pressure in both those with low and normal birth weight. Postnatal changes in size have a more important effect on blood pressure in childhood and adolescence than birth weight. Reducing the prevalence of overweight among children may reduce their systolic blood pressure importantly and, particularly among children with lower birth weight, the prevalence of hypertension later in life. (Hypertension. 2005;45:75-79.)

Key Words: blood pressure ■ children

The fetal origins hypothesis suggests that an adverse early life environment has, on average, a lasting effect on health in later life.1 In particular, low birth weight, possibly as a surrogate for poor fetal nutrition, has been shown to have an inverse association with blood pressure and hypertension at various stages in later life. Possible mechanisms include changes in fetal blood flow, resulting in abnormalities of the vasculature or disruption of nephrogenesis.2 Systematic reviews of the literature suggested an inverse association between birth weight and systolic blood pressure of ≈−2 mm Hg/kg.3

However, more recently, questions have been raised regarding various potential biases that may underpin this hypothesis.4 For example, it has been pointed out that a significant inverse association between birth weight and blood pressure later in life is more likely when current weight has been adjusted for.4,5 Given the positive association between current weight and blood pressure,6 and the positive association between birth weight and current weight, the adjustment for current weight may produce a spurious inverse association or exaggerate the strength of an inverse association, if one exists. In addition, a weakening of the association between birth weight and subsequent blood pressure level has been demonstrated once possible confounding factors such as parental blood pressure, maternal smoking, and social circumstances are considered.7

Babies with low birth weight tend to exhibit a more rapid early postnatal growth (“catch-up”) than babies born with normal weight. This clearly creates difficulties associated with separating the effect on blood pressure of fetal development per se from that of later development and environmental influences. Whether the impact of “catch-up” growth on adult blood pressures reinforces the fetal origins hypothesis in relation to blood pressure levels is controversial.5

Systematically collected data from the Health Survey for England8 provided the opportunity to investigate the association between birth weight and blood pressure in childhood and adolescence, the period when this association has been least impressive.3,4

Methods
The Health Survey for England is a cross-sectional study, performed every year in a different sample, representative of the population in England.9 Each year since 1995, the Survey has included a sample of children (age range, 5 to 15 years inclusive). Data are collected at 2 home visits. First is an interviewer’s visit, when a questionnaire is administered to collect information on sociodemographic data, risk...
The increase in systolic blood pressure per 1-kg increase in birth weight was not significant \( (P = 0.18; 95\% \text{ CI}, -0.61, 0.24) \). When other potential confounders were entered in the regression model in addition to age and sex (parental socio-economic status, maternal and paternal systolic blood pressure, maternal and paternal smoking), the differences in systolic blood pressure per 1-kg increase in birth weight remained insignificant \( (0.14; 95\% \text{ CI}, -0.55, 0.28) \). However, when current weight was included with age and sex, or in the full model, the regression coefficients became significant \( (1.07; 95\% \text{ CI}, -1.48, -0.66, \text{ and } -0.98; 95\% \text{ CI}, -1.34, -0.58, \text{ respectively}) \) (Table 2). Maternal and paternal systolic blood pressure and maternal smoking were positively associated with systolic blood pressure in childhood. (Table 2). Interaction terms between birth weight and current weight were included in the model but were not statistically significant (data not shown).

Because the analysis by quartiles of birth weight included children with “normal” birth weight (defined as a birth weight of at least 2.5 kg)\(^{12}\) in the lowest quartile (\( \leq 3.01 \) kg), we compared systolic blood pressure levels in those with normal birth weight and the 7% of surveyed children who had low birth weight (<2.5 kg). Compared with those with a normal birth weight, children with low birth weight showed an increase in systolic blood pressure of 1.01 mm Hg (95% CI, 0.41, 1.60; \( P < 0.001 \)). Accounting for current weight in the model (in quartiles) increased the predicted effect of low birth weight, showing an increase in systolic blood pressure of 1.87 mm Hg (95% CI, 1.30, 2.44; \( P < 0.001 \)). The increase was also apparent when current weight was treated as a continuous variable (data not shown).

However, in the regression model that included other confounders (socio-economic status, maternal and paternal smoking, maternal and paternal systolic blood pressure), the association between low birth weight and systolic blood pressure was no longer significant (0.21 mm Hg; 95% CI, \(-0.88, 1.26\)) unless current weight was also added to the model, when children with low birth weight showed a significant increase in systolic blood pressure of 1.21 mm Hg (95% CI, 0.19, 2.23).

### Results

Between 1995 and 2002, 22,561 children from the general population were studied in this series of national surveys. The response rates among children varied between 85% (in 1997) and 74% (in 2001) with an average response rate of 78%.\(^{10,11}\) The present study includes 15,629 children aged 5 to 15 (mean age, 9.9 years; 50.2% males), seen once in the course of the survey, who had valid blood pressure, birth weight, and current weight data. Of these, 6,393 had valid data on maternal and paternal weight, blood pressure, smoking status, and socio-economic status. The characteristics of this group did not differ from those of the whole sample.

Table 1 shows the relationship between systolic blood pressure, birth weight, and current weight among children studied. Both birth weight and current weight are expressed in quartiles. Quartiles for current weight are specific for each sample year. In each quartile of current weight, systolic blood pressure increases by decreasing birth weight. The increase is only significant \( (P < 0.001) \) for the third and fourth highest quartiles of current weight. Within quartiles of birth weight, the increase in systolic blood pressure by current weight is significant in all 4 quartiles of birth weight \( (P < 0.001) \). Linear regression was used to investigate the relationship further. Adjusting for age and sex only, the differences in systolic blood pressure per 1 kg of higher birth weight were significant \( (-0.35 \text{ mm Hg}; 95\% \text{ confidence interval [CI]}, -0.61, -0.08; P = 0.01) \) and increased when current weight was added in the model (regression coefficient, \(-1.27; 95\% \text{ CI}, -1.53, -1.02; P < 0.001 \)). The analysis was repeated in the 6,393 children with valid data for the parental characteristics. Adjusting for age and sex only, the difference in systolic blood pressure per 1-kg increase in birth weight was not significant \( (-0.18; 95\% \text{ CI}, -0.61, 0.24) \). When other potential confounders were entered in the regression model in addition to age and sex (parental socio-economic status, maternal and paternal systolic blood pressure, maternal and paternal smoking), the differences in systolic blood pressure per 1-kg increase in birth weight remained insignificant \( (-0.14; 95\% \text{ CI}, -0.55, 0.28) \). However, when current weight was included with age and sex, or in the full model, the regression coefficients became significant \( (-1.07; 95\% \text{ CI}, -1.48, -0.66, \text{ and } -0.98; 95\% \text{ CI}, -1.34, -0.58, \text{ respectively}) \) (Table 2). Maternal and paternal systolic blood pressure and maternal smoking were positively associated with systolic blood pressure in childhood. (Table 2). Interaction terms between birth weight and current weight were included in the model but were not statistically significant (data not shown).

Because the analysis by quartiles of birth weight included children with “normal” birth weight (defined as a birth weight of at least 2.5 kg)\(^{12}\) in the lowest quartile (\( \leq 3.01 \) kg), we compared systolic blood pressure levels in those with normal birth weight and the 7% of surveyed children who had low birth weight (<2.5 kg). Compared with those with a normal birth weight, children with low birth weight showed an increase in systolic blood pressure of 1.01 mm Hg (95% CI, 0.41, 1.60; \( P < 0.001 \)). Accounting for current weight in the model (in quartiles) increased the predicted effect of low birth weight, showing an increase in systolic blood pressure of 1.87 mm Hg (95% CI, 1.30, 2.44; \( P < 0.001 \)). The increase was also apparent when current weight was treated as a continuous variable (data not shown). However, in the regression model that included other confounders (socio-economic status, maternal and paternal smoking, maternal and paternal systolic blood pressure), the association between low birth weight and systolic blood pressure was no longer significant (0.21 mm Hg; 95% CI, \(-0.88, 1.26\)) unless current weight was also added to the model, when children with low birth weight showed a significant increase in systolic blood pressure of 1.21 mm Hg (95% CI, 0.19, 2.23).

### Table 1. Systolic Blood Pressure (mm Hg) by Quartiles of Birth Weight and Current Weight

<table>
<thead>
<tr>
<th>Quartiles of Birth Weight, kg</th>
<th>&gt;3.7</th>
<th>3.36–3.70</th>
<th>3.02–3.35</th>
<th>≤3.01</th>
<th>SBP Differences Q4-Q1, mm Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q0 (lowest)</td>
<td>107.5</td>
<td>107.5</td>
<td>107.7</td>
<td>108.2</td>
<td>0.7</td>
</tr>
<tr>
<td>Q1</td>
<td>110.4</td>
<td>111.1</td>
<td>111.8</td>
<td>112.6</td>
<td>2.2*</td>
</tr>
<tr>
<td>Q2</td>
<td>114.2</td>
<td>114.7</td>
<td>115.6</td>
<td>116.6</td>
<td>2.4*</td>
</tr>
<tr>
<td>Q3</td>
<td>6.7*</td>
<td>7.2*</td>
<td>7.9*</td>
<td>8.4*</td>
<td></td>
</tr>
</tbody>
</table>

Q indicates quartile; SBP, systolic blood pressure. *\( P < 0.001 \).
To better describe the combined effects of birth weight and growth up to the teenage years on systolic blood pressure, a separate analysis was performed, as recently recommended, considering only the cohort of 3900 children who were aged 13 to 15 years. The 2 weight measurements (at birth and as a teenager) were converted to z-scores (standard deviation scores) to make the regression coefficients comparable. The regression coefficients of systolic blood pressure on weight z-scores at birth and weight at age 13 to 15 (adjusted by sex) are shown in Figure 1.

The steep slope of the line joining the 2 points indicates the importance of weight gain on systolic blood pressure. Considering that, the equation

$$SBP = a_0 - a_1 \times \text{birthweight} + a_2 \times \text{weight}_{13-15} + \text{error}$$

can be written as

$$SBP = a_0 + a_1 \times (\text{weight}_{13-15} - \text{birthweight}) + (a_2 - a_1) \times \text{weight}_{13-15} + \text{error}$$

the coefficient $a_1$ defines the change in systolic blood pressure corresponding to a unit change in weight standard deviation score from birth to age 13 to 15, adjusted for weight at 13 to 15 years; SBP indicates systolic blood pressure and birthwt indicates birth weight. Because this coefficient is 0.80, 1 standard deviation increase in weight from birth to age 13 to 15 is associated with an increase in systolic blood pressure of 0.8 mm Hg.

Figure 2 shows the life-course plot separately for those with low birth weight (<2.5 kg) and those with normal birth weight (>=2.5 kg). No significant statistical difference is shown between the 2 lines. A negative interaction term between birth weight and weight at age 13 to 15 included in the regression was not significant ($P=0.105$). Hence, the increase in weight from birth to age 13 to 15 has an effect on blood pressure in those with low and normal birth weight.

### Discussion

This sample of children aged 5 to 15 years included in a series of nationally representative surveys between 1995 and 2002 is the largest to investigate the association between birth weight and systolic blood pressure. In this age group, the negative association observed appeared to be significant but relatively weak. As previously reported, the strongly positive and significant association between current weight and systolic blood pressure (Table 1) appeared to enhance the inverse association between birth weight and blood pressure in this study. The inverse impact of decreasing quartiles of birth weight on systolic blood pressure was only significant for those in the top half of current weight distribution, although the effect appeared graded across current weight quartiles.

### Table 2. Multiple Linear Regression Coefficients and 95% CI Showing Differences in SBP (mm Hg) by Risk Factors When Adjusting for All Confounders, Excluding and Including Current Weight

<table>
<thead>
<tr>
<th>Risk Factors</th>
<th>Excluding Current Weight, mm Hg (95% CI)</th>
<th>Including Current Weight, mm Hg (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birthweight, kg</td>
<td>-0.14 (-0.55, 0.28)</td>
<td>-0.98 (-1.38, -0.58)</td>
</tr>
<tr>
<td>Current weight</td>
<td>—</td>
<td>0.32 (0.29, 0.34)</td>
</tr>
<tr>
<td>Age, y</td>
<td>1.48 (1.40, 1.55)</td>
<td>1.55 (0.02, 0.29)</td>
</tr>
<tr>
<td>Sex, male vs female</td>
<td>0.11 (-0.35, 0.56)</td>
<td>0.29 (-0.19, 0.72)</td>
</tr>
<tr>
<td>Social class, manual vs nonmanual</td>
<td>-0.02 (-0.55, 0.50)</td>
<td>0.23 (-0.22, 0.69)</td>
</tr>
<tr>
<td>Maternal SBP, 1 mm Hg increment</td>
<td>0.13 (0.11, 0.14)</td>
<td>0.11 (0.09, 0.13)</td>
</tr>
<tr>
<td>Paternal SBP, 1 mm Hg increment</td>
<td>0.09 (0.07, 0.11)</td>
<td>0.08 (0.07, 0.10)</td>
</tr>
<tr>
<td>Maternal smoking, current vs never</td>
<td>1.13 (0.51, 1.74)</td>
<td>0.68 (0.09, 1.27)</td>
</tr>
<tr>
<td>Paternal smoking, current vs never</td>
<td>-0.53 (-1.14, 0.07)</td>
<td>-0.10 (-0.64, 0.44)</td>
</tr>
</tbody>
</table>

*Figure 1.* Life-course plot for systolic blood pressure (SBP) on weight at birth and at 13 to 15 years. The plot shows regression coefficients of SBP on weight z-score (sex-adjusted) at the 2 ages. Values are regression coefficients (95% CI).

*Figure 2.* Life-course plot for SBP on weight at birth and at 13 to 15 years, separately for those with a <2.5 kg (dotted line) and >=2.5 kg birth weight (continuous line). The plot shows regression coefficients of SBP on weight z-score (sex-adjusted) at the 2 ages. Values are regression coefficients (95% CI).
In addition, the age- and sex-adjusted regression of birth weight on systolic blood pressure was increased when current weight was considered, as were differences in systolic blood pressure between children with low and normal birth weights.

A significant inverse relationship between birth weight and blood pressure has been reported in several studies, with the results from systematic reviews of the literature indicating a decrease in systolic blood pressure of $\approx 2$ mm Hg for each 1-kg increase in birth weight. Some studies show that a statistically significant relation only exists when current weight and body mass index are adjusted for. When accounting for the effect of publication bias in addition to the effect of adjusting for current weight, an update of the aforementioned meta-analysis estimated that the effect of birth weight on systolic blood pressure was reduced to a 0.4-mm Hg decrease for 1-kg increase in birth weight. A criticism made of many published studies has been the failure to further adjust for potential confounders. In our study, when other variables such as maternal smoking (associated with lower birth weight), maternal blood pressure (positively associated with both low birth weight and higher blood pressure in children), and paternal blood pressures were considered, the relationship between birth weight and childhood systolic blood pressures was weak and nonsignificant, whereas when current weight was included in the model, the strength of the inverse relationship increased, becoming significant.

In this age group, the relationship between systolic blood pressure and birth weight should be best-considered in the context of the current weight. Current weight adjusted for birth weight is a measure of change in weight or growth. By using $z$-scores in a life-course plot, the regression coefficients between systolic blood pressures and weight at birth and as teenagers were made comparable. The life-course plot confirmed that change in weight between birth and age 13 to 15 years was a more important determinant of systolic blood pressure than birth weight. An interaction term between birth weight and current weight in the model was not significant, again suggesting that body size at birth does not act in a major way to modify the effect of current size on blood pressure. Babies who are smaller at birth tend to grow more rapidly (ie, exhibit catch-up growth) than babies with normal birth weight. Several reports suggest that it is this rapid early postnatal growth that contributes to raised body mass index and higher blood pressures later in life. These data were supported by data from one study that showed that lower nutrient intakes and consequent slower growth rates in infancy might have more favorable health outcomes in later life. Unfortunately, the Health Survey for England database does not include data on weight other than at birth and at the time of survey, and consequently the effect of early postnatal growth cannot be evaluated. Nevertheless, the data shown in Table 1 and Figures 1 and 2, together with the lack of significance of the interaction term, suggest that birth weight is relevant to blood pressure in childhood and adolescence but less relevant than postnatal growth, as reflected by current weight at that age. In our study, the information on birth weight was collected from the parents. A good correlation of ($\approx 0.7$) has been reported between birth weight measured through birth records and that assessed through parental report or self-report.

Although these data suggest that children aged 5 to 15 who are in the heaviest quartile of current weight and lowest quartile of birth weight tend to have the highest systolic blood pressures (9 mm Hg higher than those in the opposite situation; Table 1), we have shown that for children up to age 15, the association between current weight and systolic blood pressure is more important than birth weight.

**Perspectives**

This report confirms and extends the findings of several previous studies among children, showing a weak inverse relationship between birth weight and systolic blood pressure. In this age group, current body weight appears to be a stronger determinant of current blood pressure than birth weight. Implementation of a public health policy that reduces the prevalence of overweight in children between ages 5 and 15, such that no child exceeded the median level observed in this data set, would be expected to produce a mean systolic blood pressure level of $\approx 109$ mm Hg, whereas a policy designed to prevent birth weights falling below the median level encountered in these survey data would be expected to produce a mean systolic blood pressure level of $\approx 111$ mm Hg. These levels constitute falls of 3 and 1 mm Hg, respectively, compared with the mean levels actually observed. Such reductions either separately or ideally together would be potentially important and beneficial at the population level.

**Acknowledgments**

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**References**

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