The association of maternal growth and socio-economic measures with infant birthweight in four ethnic groups

Irvin Emanuel,1,2 Christy Kimpo,1,3 and Victoria Moceri1,4

Accepted 1 June 2004

Background Both maternal socio-economic status (SES) and growth measures are themselves interrelated and are also related to infant birthweight. The objective of this study is to compare the relative importance of such maternal measures as determinants of birthweight of female infants—the prospective mothers of the next generation.

Methods The study base was derived from a population-based multiethnic intergenerational cohort: the Washington State Intergenerational Cohort. Infants of mothers from four ethnic groups were included: non-Hispanic Whites, African Americans, Native Americans, and Hispanics. We generated simple, partial, and multiple correlation coefficients to investigate the association between birthweight and the maternal growth and SES measures.

Results While there were slight differences among the ethnic groups, generally each of three maternal pre-conceptional growth measures—birthweight, stature, and prepregnant weight—was a stronger predictor of female infant birthweight than were each of the five maternal SES factors—age, parity, marital status, educational attainment, and prenatal care onset. After accounting for the proportion of variation in birthweight explained by the maternal growth measures and maternal smoking, the addition of the five SES variables added relatively little to the prediction of infant birthweight. The maximal multiple correlation coefficients ($R^2$) yield values ranging from 9.5% to 12.8%.

Conclusions A mother’s growth before pregnancy is a stronger predictor of infant birthweight than is her current socio-economic circumstance. Since the mother’s growth must have been influenced by the socio-economic circumstances of her family of upbringing, this further highlights the intergenerational contribution on a woman’s reproductive success.

Keywords Growth, birthweight, socio-economic status, intergenerational contribution
weight—with several of the frequently used maternal socio-economic measures, using a population-based multiethnic intergenerational cohort in Washington State.\textsuperscript{18}

While studies have mostly dealt with categories of suboptimal outcome (e.g. LBW, PTB, IUGR), the outcomes of this and a companion study relate to how distributions of female infant birthweight and female stature change from one generation to the next, since characteristically these maternal measures have dose–response associations with pregnancy outcomes of concern. Where dose–response associations exist, the population distribution is a more appropriate descriptor than the prevalence of arbitrarily defined normal/abnormal categories.\textsuperscript{29} Additionally, since birthweight and stature are now known to be associated with some adult chronic diseases,\textsuperscript{30–34} the results of this study have relevance to both reproductive and non-reproductive health problems.

### Methods

#### The data source

The Washington State Intergenerational Study of Birth Outcomes linked vital statistics and statewide hospital discharge data on 46,246 singleton births, 1987–1995, to the birth certificates of their mothers who were born in the state after 1948, when birthweight was on the birth certificate.\textsuperscript{18} We later linked parents and grandparents to the Washington State drivers license database to obtain their self-reported heights. Linkage was accomplished for 72.2\% of mothers and 42.1\% of grandmothers. It was possible to compare the self-reported heights to measured heights of 480 control women of childbearing age from another study. The mean difference, measured to self-reported, was 0.1 in (0.28 cm), with a correlation coefficient of 0.95. It was shown that linkage to the drivers license file increased as educational attainment increased;\textsuperscript{35} thus the mothers in this study tend to be of slightly higher socio-economic circumstances (Table 1).

#### The study base

Because mother's education and prepregnant weight were available on birth certificates only since 1992, this paper is based on live singleton births to singleton mothers occurring in 1992–1995, rather than the entire cohort of births in 1987–1995. Infant deaths are excluded. Because gestational duration was not included on the birth certificates until 1968, there were insufficient numbers of births to include that outcome in our study. We used those births for which all variables have been recorded, which are available in the following proportions of all births in 1992–1995: Whites, 61.5\%; African Americans, 43.7\%; Native Americans, 52.4\%; Hispanics, 56.8\%. Although we found similar results with male and female infants, we restricted our analyses to female infants because they are the prospective mothers of future generations.

#### The variables

All data except maternal stature were obtained from birth certificates. All maternal variables were linked to their own self-reported heights of 480 control women of childbearing age from another study. The mean difference, measured to self-reported, was 0.1 in (0.28 cm), with a correlation coefficient of 0.95. It was shown that linkage to the drivers license file increased as educational attainment increased;\textsuperscript{35} thus the mothers in this study tend to be of slightly higher socio-economic circumstances (Table 1).

### Table 1: Comparing maternal and infant characteristics of the samples with those excluded because of missing values

#### A. Percentages of dichotomous variables

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mother &lt;20 years</td>
<td>11.74</td>
<td>10.83</td>
<td>25.71</td>
<td>24.84</td>
<td>24.64</td>
<td>24.20</td>
<td>31.20</td>
<td>33.42</td>
</tr>
<tr>
<td>Mother primipara</td>
<td>44.77</td>
<td>40.72+</td>
<td>45.20</td>
<td>39.57*</td>
<td>39.31</td>
<td>34.51*</td>
<td>45.43</td>
<td>47.85</td>
</tr>
<tr>
<td>Mother single</td>
<td>23.75</td>
<td>32.23#</td>
<td>69.35</td>
<td>72.64</td>
<td>62.62</td>
<td>68.45+</td>
<td>48.33</td>
<td>57.44#</td>
</tr>
<tr>
<td>Education &gt;12 years</td>
<td>47.30</td>
<td>44.18*</td>
<td>31.50</td>
<td>32.99</td>
<td>22.62</td>
<td>21.28</td>
<td>23.94</td>
<td>22.69</td>
</tr>
<tr>
<td>Prenatal care &lt;4 months</td>
<td>85.22</td>
<td>77.86#</td>
<td>70.20</td>
<td>63.24+</td>
<td>67.86</td>
<td>60.88+</td>
<td>76.81</td>
<td>67.38#</td>
</tr>
<tr>
<td>Maternal LBWa</td>
<td>4.82</td>
<td>4.61</td>
<td>11.30</td>
<td>9.67</td>
<td>5.94</td>
<td>6.20</td>
<td>6.41</td>
<td>5.68</td>
</tr>
<tr>
<td>Female infant LBW</td>
<td>4.12</td>
<td>5.74*</td>
<td>7.77</td>
<td>13.22#</td>
<td>3.92</td>
<td>6.67*</td>
<td>5.18</td>
<td>6.20</td>
</tr>
</tbody>
</table>

#### B. Means of continuous variables

<table>
<thead>
<tr>
<th></th>
<th>Whites</th>
<th></th>
<th>African Americans</th>
<th></th>
<th>Native Americans</th>
<th></th>
<th>Hispanics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mothers’ birthweight (g)</td>
<td>3315</td>
<td>3318</td>
<td>3010</td>
<td>3139</td>
<td>3295</td>
<td>3307</td>
<td>3286</td>
<td>3288</td>
</tr>
<tr>
<td>Mothers’ stature (in.)</td>
<td>65.09</td>
<td>64.99</td>
<td>64.82</td>
<td>65.11</td>
<td>64.00</td>
<td>63.67*</td>
<td>63.22</td>
<td>63.33</td>
</tr>
<tr>
<td>Prepregnant weight (kg)</td>
<td>66.14</td>
<td>65.26</td>
<td>69.77</td>
<td>69.29</td>
<td>67.53</td>
<td>68.16</td>
<td>66.23</td>
<td>66.00</td>
</tr>
<tr>
<td>Female infant birthweight (g)</td>
<td>3425</td>
<td>3373+</td>
<td>3201</td>
<td>3092#</td>
<td>3343</td>
<td>3331#</td>
<td>3316</td>
<td>3294</td>
</tr>
<tr>
<td>Mothers’ age (years)</td>
<td>26.54</td>
<td>26.82</td>
<td>23.82</td>
<td>24.21</td>
<td>24.12</td>
<td>24.13</td>
<td>22.96</td>
<td>22.71</td>
</tr>
<tr>
<td>Mothers’ education (years)</td>
<td>12.99</td>
<td>12.92</td>
<td>12.10</td>
<td>12.25</td>
<td>11.59</td>
<td>11.44</td>
<td>11.50</td>
<td>11.44</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Low birthweight.

\textsuperscript{*} P < 0.05;  \textsuperscript{+} P < 0.01, \# P < 0.001.
Statistical methods

We first confirmed the linearity of associations between infant birthweight and the continuous predictor variables by means of exploratory smoothing splines. We then calculated simple, partial and multiple correlation coefficients to investigate the association of the maternal growth and socio-economic variables with female infant birthweight. A correlation matrix of all predictor variables and female infant birthweight for each ethnic group is available on line as Supplementary Data at IJE online. We generated partial correlation coefficients to estimate the proportion of variance of the dependent variable attributed to a single predictor variable after the variance from all other predictor variables are accounted for. Tests of significance were based on the appropriate partial correlation coefficient t test and corresponding P-value. After this, we generated multiple correlation coefficients (R²) to describe the overall proportion of variation of the dependent variable attributed to all the independent variables included in the equation. We investigated the proportion of variance in birthweight explained by each addition of the growth variables and then the SES variables. The significance of the variable or variables added to the model was determined by the change in the F-test and corresponding P-value. Specifically, we began with mothers’ birthweight, and added, one by one, mothers’ adult stature, then prepregnant weight and, finally, smoking. Smoking is unique, in that it does not explain as much variation of the infant’s birthweight as does mother’s birthweight, stature, prepregnant weight, and pregnancy weight gain were similar in the included and excluded samples. Mean female infant birthweights were slightly higher, and the female infant LBW proportions were slightly lower in the samples included for analysis.

Comparison of simple and partial correlations

Table 2 shows that with one exception (stature of Native Americans), the partial

<table>
<thead>
<tr>
<th></th>
<th>n = 2964</th>
<th>n = 708</th>
<th>n = 893</th>
<th>n = 1061</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Whites</td>
<td>Africans</td>
<td>Native Americans</td>
<td>Hispanics</td>
</tr>
<tr>
<td></td>
<td>r Partial r</td>
<td>r Partial r</td>
<td>r Partial r</td>
<td>r Partial r</td>
</tr>
<tr>
<td>Mother’s birthweight</td>
<td>0.2137#</td>
<td>0.1677#</td>
<td>0.1914#</td>
<td>0.1547#</td>
</tr>
<tr>
<td>Mother’s stature</td>
<td>0.1918#</td>
<td>0.1125#</td>
<td>0.1610#</td>
<td>0.1123#</td>
</tr>
<tr>
<td>Prepregnant weight</td>
<td>0.1975#</td>
<td>0.1407#</td>
<td>0.1740#</td>
<td>0.1204#</td>
</tr>
<tr>
<td>Smoking</td>
<td>0.1956#</td>
<td>0.1640#</td>
<td>0.1615#</td>
<td>0.1488#</td>
</tr>
<tr>
<td>Age</td>
<td>0.0898#</td>
<td>0.0015</td>
<td>0.0031</td>
<td>0.0053</td>
</tr>
<tr>
<td>Parity</td>
<td>0.0704#</td>
<td>0.0626#</td>
<td>0.0426</td>
<td>0.0040</td>
</tr>
<tr>
<td>Marital status</td>
<td>0.1236#</td>
<td>0.0421#</td>
<td>0.0114</td>
<td>0.0142</td>
</tr>
<tr>
<td>Education</td>
<td>0.0896#</td>
<td>0.0025</td>
<td>0.0375</td>
<td>0.0186</td>
</tr>
<tr>
<td>Prenatal care</td>
<td>0.0546#</td>
<td>0.0353</td>
<td>0.1460#</td>
<td>0.1313#</td>
</tr>
</tbody>
</table>

*P < 0.05; † P < 0.01; # P < 0.001.
correlation coefficients of the three maternal growth variables remain statistically significant \( (P < 0.01) \). The simple correlation coefficients of SES factors with infant birthweight were variably statistically significant, and in most cases the partial correlations showed reduced magnitude of the association.

**Multiple correlation analysis**

Table 3 presents the various multiple correlation models for each ethnic group. Mother’s birthweight by itself explains the largest amount of variation in infant’s birthweight of all the variables \((3.66–4.99\%)\). As each growth variable is sequentially added, there is an increase in the \( R^2 \) values. All of the growth variables together explain \( 6.16–9.74\% \) of the variation in infant’s birthweight. After all the maternal growth variables are included, the addition of maternal smoking also substantially increases the \( R^2 \) values, except in the Hispanics where smoking adds a negligible amount. After the three maternal growth variables and smoking are included, the addition of all the socio-economic variables together minimally increases the multiple \( R^2 \) values. Generally, the association of the maternal growth and SES variables is comparable in relative strength across the four ethnic groups, except for stature in the Native American group and smoking in the Hispanic group.

**Discussion**

We compared the predictive strength for female infant birthweight of several maternal growth and socio-economic variables. Each of the preconceptional maternal growth variables—birthweight, stature, pre-pregnant weight—individually was a stronger predictor of birthweight than each of the five SES factors: maternal age, parity, marital status, educational attainment, and month of onset of prenatal care. The simple, partial and multiple correlation analyses demonstrated the overriding importance of maternal growth variables in explaining the variation in infant birthweight. There were similar results for all four ethnic groups. In the Whites and African Americans, maternal smoking independently explained more of the variation in birthweight than all the sociodemographic variables taken together. The reasons for the different associations of smoking for the Hispanics are not clear, but may relate to incomplete reporting of smoking.

The similar findings of the associations with the maternal growth measures in all ethnic groups is a confirmation of the results and we speculate that similar patterns of associations will be found in the general population and in other ethnic groups. However, we found no association between maternal stature and infant’s birthweight in Native Americans; the reasons for this are unclear.

Most studies of mothers’ stature and/or birthweight related to their pregnancy outcomes have been concerned with the risk for suboptimal pregnancy outcome, such as LBW, PTB, and IUGR in the current generation.\(^9,11,13,14,18–20,38\) However, all reported associations of these maternal growth variables with pregnancy outcomes have a dose–response pattern, and distributions of continuous variables generally describe populations more adequately than dichotomizing them into arbitrary abnormal/normal categories.\(^29\) Therefore, to investigate the associations with infant birthweight, we used linear correlation analysis, rather than logistic regression analyses, because the former refer to the distributions of birthweight. Thus, the main objective was to describe important segments of the intergenerational growth process by comparing maternal growth variables with maternal sociodemographic variables as predictors of the distribution of infant birthweight. We were interested in birthweight of female infants as the primary outcome. Female infants are the prospective mothers of the next generation. Maternal birth size and adult stature are stronger determinants of the prenatal growth of the next generation than are such paternal factors,\(^15,16,20\) while each parent makes about an equal contribution to postnatal growth. Thus there is justification for devoting more study specifically to the growth of females. Such studies will provide further insights into what may occur in future generations, and may allow more objective evaluations of current health care practices and socio-economic forces in shaping the future. Therefore a better understanding of factors which influence maternal growth allows further insights into future trends.

The increasing evidence that birth size is related to child-

<table>
<thead>
<tr>
<th></th>
<th>Whites</th>
<th>African Americans</th>
<th>Native Americans</th>
<th>Hispanics</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>2964</td>
<td>708</td>
<td>893</td>
<td>1061</td>
</tr>
<tr>
<td>Maternal birthweight</td>
<td>0.0457</td>
<td>0.0366</td>
<td>0.0387</td>
<td>0.0499</td>
</tr>
<tr>
<td>+ Mother’s stature</td>
<td>0.0667</td>
<td>0.0492</td>
<td>0.0416</td>
<td>0.0755</td>
</tr>
<tr>
<td>R(^2) increase</td>
<td>0.0210</td>
<td>0.0126</td>
<td>0.0029</td>
<td>0.0256</td>
</tr>
<tr>
<td>+ Prepregnant weight</td>
<td>0.0863</td>
<td>0.0654</td>
<td>0.0616</td>
<td>0.0974</td>
</tr>
<tr>
<td>R(^2) increase</td>
<td>0.0196</td>
<td>0.0162</td>
<td>0.0200</td>
<td>0.0219</td>
</tr>
<tr>
<td>+ Smoking</td>
<td>0.1186</td>
<td>0.0891</td>
<td>0.0774</td>
<td>0.0979</td>
</tr>
<tr>
<td>R(^2) increase</td>
<td>0.0323</td>
<td>0.0237</td>
<td>0.0158</td>
<td>0.0005 n.s.</td>
</tr>
<tr>
<td>+ All SES factors</td>
<td>0.1282</td>
<td>0.0986</td>
<td>0.0953</td>
<td>0.1105</td>
</tr>
<tr>
<td>R(^2) increase</td>
<td>0.0096</td>
<td>0.0095</td>
<td>0.0179</td>
<td>0.0126</td>
</tr>
<tr>
<td>All SES factors alone</td>
<td>0.0197</td>
<td>0.0151</td>
<td>0.0262</td>
<td>0.0194</td>
</tr>
<tr>
<td>All SES factors + smoking</td>
<td>0.0462</td>
<td>0.0345</td>
<td>0.0390</td>
<td>0.0191</td>
</tr>
</tbody>
</table>

All \( P \)-values \(< 0.001\), except +: \( P < 0.01\), and n.s.: not significant.
same time as the evidence that adult stature was related to adult chronic diseases, and earlier than the evidence that birthweight was related to several adult chronic diseases. However, consideration of the importance of mothers’ growth to future reproductive success, affecting primarily young women and children, has been eclipsed by the fervour of the consideration of prenatal growth to several adult chronic diseases, affecting primarily older men and women. In any event, the results of this study relate to other health problems besides pregnancy outcome. But the importance of maternal growth underlies any consideration of the association of growth to other health problems, since maternal growth is a more important determinant of prenatal growth than is paternal growth.

Studies of the association of prenatal growth to adult chronic diseases have been criticized because sometimes there is no adjustment for socio-economic factors because of lack of data. Our results show that after maternal growth measures are accounted for, the addition of socio-economic factors adds relatively little to explain the variation in birth size. Of course, there are other SES factors unavailable to this study that might alter such a conclusion. Nevertheless, the existing evidence suggests that previous maternal growth is more important for future growth than are existing socio-economic conditions. This is supported by previous studies in which the association of maternal birthweight to several pregnancy outcomes is little affected by adjustment for SES factors. Some studies show that associations of prenatal and postnatal growth with some adult chronic diseases also are little changed by adjusting for SES factors. This suggests that the value of studying such health problems in available historical convenience samples with little socio-economic data will be increased.

By gleaning from several hundred articles, Kramer identified a number of determinants of intrauterine growth which he considered to be important: maternal birthweight, stature, prepregnant weight, cigarette smoking, and parity, all of which had direct effects, while indirect effect were ascribed to maternal education and age, and possibly marital status. To our knowledge, this is the first study that includes all of these factors in the same mother/infant pairs, and our results generally support Kramer’s interpretation.

However, these factors have been insufficient to explain outcome differences between poor and well-off mothers and, in particular, differences between African Americans and other ethnic groups. The repeated demonstration of associations between maternal birthweight and adult stature with infant outcome, together with the association of maternal grandmother’s stature with grandchild’s prenatal growth strongly indicates that this intergenerational growth process needs to be further explored. Unfortunately, data on these important maternal growth variables with sufficient size samples rarely exist. The development of the Washington State Intergenerational Cohort has provided sufficient data for some such purposes. So far, studies of this cohort have found associations between mother’s birthweight and the following perinatal problems: LBW and PTB gestational diabetes mellitus, respiratory distress syndrome, and the risk for cesarean section.

The weaker association of sociodemographic risk factors for birthweight in African Americans, in both the correlation and multiple correlation analyses, is consistent with the usual finding in such studies. In particular, low-risk African American mothers compared with high-risk mothers derive less relative benefit in terms of pregnancy outcome than their White counterparts. This suggests that African Americans are exposed to more deleterious environmental conditions, some of which we speculate are intergenerational, which may be partly responsible for the downward displacement of the maternal birthweight distribution compared with other ethnic groups.

How people grow is a very complex, poorly understood biosocial process. While growth at various stages is certainly influenced by socio-economic factors, the results of this process—the growth measures themselves—need to be studied. Both mother’s birthweight and her stature are determinants of infant outcome. These maternal growth measures are in turn partly determined by the socio-economic circumstances of the mother’s family of upbringing. For instance, studies in Aberdeen and of the 1958 British Birth Cohort showed that maternal stature was related to the occupational class of both the mother’s father and the mother’s husband. Further, there was a variable pattern of maternal stature related to the mother’s upward and downward marital mobility. Thus we may speculate that in terms of some infant outcomes the socio-economic circumstances of the mother’s family of upbringing may be as important or even more important than the mother’s SES circumstances at the time of her pregnancies. To investigate this possibility would require a linked database of at least four generations with the requisite data. In any event, this study highlights the need to study maternal growth per se in order to better define the importance of socio-economic factors in human reproduction.

The final R² values which include all of the variables vary between 0.0953 and 0.1282 leaving most of the variation yet to be explained. Clearly there are other factors which need to be further elucidated, which may include nutrition, infection, toxins, stress, suboptimal physiological processes, physical environment, and genetic factors.

We speculate that any future health issue which is related to birth size may also be related to postnatal growth and adult stature, and vice versa, with variability in the relative importance of each. Our findings that maternal prenatal and postnatal growth measures are related to infant outcome offer further justification for the need for a life course as well as an intergenerational approach to epidemiology.

**Strengths and weaknesses**

The major and perhaps unique strength of this study is the comparison of the association with female infant birthweight of maternal growth variables and maternal socio-demographic variables, not only in one ethnic group, but in four ethnic groups. The outcome of interest is not low birthweight, but birthweight of female infants, the prospective mothers of the next generation. Similar results were seen when infants of both genders were included in the analyses (data not shown).

While our database was population-based, because of absence of variables from vital statistics records for some years, and missing data points for some mother/infant pairs, subsamples of the four ethnic groups constitute the study base. These study samples are of slightly lower socio-demographic risk compared with those births that were excluded from analysis, so we make the usual caveat that our results may not apply to the general...
population. But the consistency of our findings in each ethnic group makes the pattern of our results plausible and likely to be similar in the general population.

Summary
1. We found that each of three preconceptional maternal growth variables—mother’s birthweight, adult height, and prepregnant weight—usually explains more variation in infant birthweight than did each of several socio-economic variables—mother’s age, parity, marital status, month of onset of prenatal care, and educational attainment. Almost identical results were seen in four ethnic groups: non-Hispanic Whites, African Americans, Native Americans, and Hispanics.
2. Because birthweight and adult stature have been found to be factors in several adult chronic diseases, as well as female reproductive problems, the results of this study have implications for both reproductive and non-reproductive health problems irrespective of gender.
3. The associations reported here account for less than 15% of the variance of birthweight, which highlights the need to study other possible factors in suboptimal pregnancy outcome, including infection, toxins, nutrition, suboptimal physiologic processes, physical environment, stress, and genetic contribution.
4. Others have found that the socio-economic circumstances of the mothers’ family of upbringing are important to the growth of the mother, and thus our results also indicate their importance to the prenatal growth of her infants.
5. Further insights into causes of some suboptimal birth outcomes will come from further elucidation of this intergenerational growth process.

Acknowledgements
This study was supported in part by Grant MCI-5–30837 from the Maternal and Child Health Bureau (Title V, Social Security Act). Health Resources and Services Administration, U.S. Department of Health and Human Services. The authors thank the following for their suggestions: Mary Lou Thompson, Ph.D., Michelle Williams, Sc.D., and Gene P Sackett, Ph.D., all of the University of Washington.

KEY MESSAGES
- A mother’s growth before pregnancy better predicts infant birthweight than does her socio-economic circumstances during her pregnancy.
- Since the mother’s prepregnancy growth probably was influenced by the socio-economic circumstances of her family of upbringing, this highlights the intergenerational contribution to a woman’s reproductive success.

References
37 StataCorp. STATA Statistical Software: Release 6.0. College Station, TX: Stata Corporation 1999.