Stability and Change in Children's Intelligence Quotient Scores: A Comparison of Two Socioeconomically Disparate Communities

Naomi Breslau,1–3 Howard D. Chilcoat,4 Ezra S. Susser,5 Thomas Matte,6 Kung-Yee Liang,7 and Edward L. Peterson1,8

The authors estimated the influence of familial factors and community disadvantage on changes in children's intelligence quotient (IQ) scores from age 6 years to age 11 years. Data were obtained from a longitudinal study of the neuropsychiatric sequelae of low birth weight in two socioeconomically disparate, geographically defined communities in the Detroit, Michigan, metropolitan area. Representative samples of low birth weight and normal birth weight children from the City of Detroit (urban) and nearby middle-class suburbs (suburban) were assessed at age 6 years (in 1990–1992) and age 11 years (in 1995–1997) (n = 717). Children's IQs were measured using the Wechsler Intelligence Scale for Children–Revised. The familial factors considered included maternal IQ, education, and marital status. Multiple regression analysis applying generalized estimating equations was used. The IQs of urban children, regardless of birth weight, declined from age 6 years to age 11 years. The downward shift increased by 50% the proportion of urban children scoring 1 standard deviation below the standardized IQ mean of 100. A negligible change was observed in suburban children. Maternal IQ, education, and marital status and low birth weight predicted IQ at age 6 years but were unrelated to IQ change. Growing up in a racially segregated and disadvantaged community, more than individual and familial factors, may contribute to a decline in IQ score in the early school years. Am J Epidemiol 2001;154:711–17.

Despite controversies about the meaning and nature of general intelligence, few would dispute the claim that scores on standardized intelligence quotient (IQ) tests are strong predictors of important outcomes for members of both majority and minority groups. IQ scores are not immutable; repeated IQ testing during childhood reveals considerable change within individuals (1). However, the causes of IQ change (beyond unreliability) remain unclear. An inverse relation between IQ and age has been reported in groups of children living under various conditions of deprivation (2–5). This evidence, which suggests a decline in IQ with increasing age among socially disadvantaged children, is based on cross-sectional studies of atypical groups conducted several decades ago. Furthermore, familial and community contributions to IQ change were not distinguished in these studies.

We examined the contributions of familial factors and disadvantaged community to IQ change from the beginning of schooling to 5 years later. The data were obtained from a longitudinal study designed to evaluate neuropsychiatric sequelae of low birth weight (≤2,500 g) in two socioeconomically disparate communities, the inner city and middle-class suburbs of a major US metropolitan area (6, 7). Low birth weight has been associated with IQ deficits in that study and in other studies, independent of social disadvantage (6, 8–17). While previous studies have not examined the role of low birth weight in IQ change with increasing age, the data in this study allowed us to estimate and control for the potential effects of low birth weight on IQ change in the general population. Family factors were indexed by maternal IQ, maternal education, and single-parent status, all factors that are related to children's IQ (3). Disadvantaged community was indexed by residence in the inner city in contrast to a middle-class suburb.

MATERIALS AND METHODS

Samples of low birth weight and normal birth weight children were randomly selected from the newborn discharge

child; family characteristics; intelligence; socioeconomic factors
lists of two major hospitals in southeastern Michigan, one in the City of Detroit and the other in a nearby suburb. Subjects were enrolled when they were 6 years of age. We targeted the 1983–1985 cohorts of newborns who reached age 6 in the academic years 1989–1990, 1990–1991, and 1991–1992, the scheduled period of fieldwork. The total number of newborn discharges for the 1983–1985 period was 6,698 in the urban hospital and 16,136 in the suburban hospital. During that period, the Detroit hospital served mostly inner-city residents. The suburban hospital served mostly residents of middle-class suburban communities in the Detroit metropolitan area. In each hospital, for each year from 1983 through 1985, random samples of 130 low birth weight newborns and 93 normal birth weight newborns were drawn. Of the 1,338 sampled children, 196 were known to have moved out of the metropolitan area, to have died, or to be living in foster homes. Forty-seven children identified by medical records as having severe neurologic impairment were excluded, since our goal was to evaluate long-term outcomes in children who had survived to school age without severe impairment. Of the 1,095 children in the target sample, 823 (75 percent) participated in the study; 4 percent could not be located, and the parents of 21 percent refused. Children were evaluated when they were 6 years of age.

Five years later, in 1995–1997, when the children were 11 years old, we reassessed the sample. Of the total sample, 717 (87.1 percent) completed the second assessment (4 percent had moved out of the geographic area, and the parents of 9 percent refused). The key characteristics of the reassessed sample, including race, maternal education, low birth weight status, and the initial IQ distributions of the children, had changed little (18). Low birth weight children in the urban and suburban samples were similar with respect to neonatal characteristics, including percentage born small for gestational age, number of days spent in the neonatal intensive care unit, percentage with a 5-minute Apgar score ≤5, and distribution across levels of low birth weight.

The urban (City of Detroit) versus suburban classification was based on the family’s address at first assessment. A small minority of families (10 percent) who had resided in the City of Detroit at the time of the first assessment had a suburban address at follow-up, but the time of the change was not ascertained; those families were classified as urban in this analysis. A description of the urban and suburban samples with respect to sociodemographic and neonatal characteristics is presented in table 1. Compared with the suburban sample, the City of Detroit sample had markedly higher percentages of minority children (84.2 percent vs. 5.5 percent), children born to single mothers (58.1 percent vs. 9.7 percent), and mothers with less than a high school education (26.7 percent vs. 6.7 percent). With few exceptions, minority children were Black, reflecting the racial-ethnic composition of the Detroit area. Differences between the low birth weight and normal birth weight subsets within the two communities were small (table 1). Data from the 1990 US Census indicated sharp disparities between the City of Detroit and the remaining metropolitan area in the percentages of non-Whites (78.4 percent vs. 8.4 percent), unemployed persons (19.7 percent vs. 6.0 percent), female heads of households (with no husband present) (56.0 percent vs. 17.2 percent), and families living below the poverty level (40.0 percent vs. 8.6 percent) (19). Thus, the sampling design provided for a comparison of populations with starkly contrasting social conditions.

**IQ measurement**

The Wechsler Intelligence Scale for Children–Revised (WISC-R) (20) was used to measure children’s IQs. The

### TABLE 1. Sociodemographic and neonatal characteristics (%) of urban and suburban children (n = 717) in a study of changes in intelligence quotient (IQ) scores, Detroit, Michigan, metropolitan area, 1990–1992 and 1995–1997

<table>
<thead>
<tr>
<th></th>
<th>Urban community</th>
<th>Suburban community</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total (n = 374)</td>
<td>Low birth weight (n = 231)</td>
</tr>
<tr>
<td>Nonwhite race</td>
<td>84.2</td>
<td>85.7</td>
</tr>
<tr>
<td>Father’s education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than high school</td>
<td>26.7</td>
<td>29.4</td>
</tr>
<tr>
<td>High school</td>
<td>26.5</td>
<td>26.0</td>
</tr>
<tr>
<td>Some college</td>
<td>37.4</td>
<td>36.4</td>
</tr>
<tr>
<td>College</td>
<td>9.4</td>
<td>8.2</td>
</tr>
<tr>
<td>Single mother</td>
<td>58.1</td>
<td>60.0</td>
</tr>
<tr>
<td>Small-for-gestational-age birth</td>
<td>18.3</td>
<td>25.1</td>
</tr>
<tr>
<td>5-minute Apgar score ≤5</td>
<td>1.6</td>
<td>2.6</td>
</tr>
<tr>
<td>Very low birth weight (≤1,500 g)</td>
<td>16.9</td>
<td></td>
</tr>
<tr>
<td>Days in neonatal intensive care unit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>71.4</td>
<td>57.2</td>
</tr>
<tr>
<td>1–7</td>
<td>5.7</td>
<td>5.7</td>
</tr>
<tr>
<td>8–14</td>
<td>3.2</td>
<td>5.2</td>
</tr>
<tr>
<td>≥15</td>
<td>19.7</td>
<td>31.9</td>
</tr>
</tbody>
</table>
WISC-R is age-standardized and has a mean of 100 and a standard deviation of 15 in the general population. Thus, a child whose IQ score remains the same from age 6 years to age 11 years does not show the same performance at both assessments. Instead, the child will exhibit gains in general knowledge, vocabulary, reasoning ability, and other domains. What does not change is the child’s score in comparison with his or her age-mates.

Children were assessed individually under the same standardized laboratory conditions at both ages. Psychometricians were trained to a uniform standard, and all scoring was checked by a second tester. Assessments were conducted blindly with respect to low birth weight status. Psychometricians who conducted the assessment at age 11 were blind to the results obtained at age 6. The correlation between full-scale IQ scores between ages 6 and 11 years was 0.85.

**Statistical analysis**

We used multiple regression analysis, applying generalized estimating equations (GEE) (21–23), to test and estimate the effects of urban versus suburban community, low birth weight, and family factors on IQ at ages 6 and 11 years. The GEE approach offers advantages over other regression approaches used to measure change over time (24, 25). The GEE approach permits simultaneous modeling of the relation of specific risk factors to children’s IQs at both age 6 years and age 11 years. Furthermore, the addition of interaction terms allowed us to examine whether the difference in mean IQ associated with a specific factor—for example, urban versus suburban community—was significantly greater at age 11 years than at age 6 years. The coefficient for an interaction between a risk factor and age is equivalent to that produced in a standard regression model in which change in IQ over time is the response variable and the risk factor is entered as the predictor variable. However, the GEE approach provides information on the relations of risk factors with IQ at each age, which is not available in a standard regression analysis of score change.

The basic model is illustrated in the equation \( Y = \alpha + \beta_1 \) (urban) + \( \beta_2 \) (age) + \( \beta_3 \) (urban \times age) + \( \beta_4 \) (low birth weight) + \( \beta_5 \) (family factors), where standardized IQ scores at ages 6 and 11 years are the child’s outcomes (Y); urban = 1 if the child’s community is urban and 0 if it is suburban; age = 1 for IQ at age 11 and 0 for IQ at age 6; and low birth weight = 1 if the child had a low birth weight and 0 if the child had a normal birth weight. The fifth, sixth, and seventh beta coefficients (\( \beta_5, \gamma \)) are the coefficients of three family factors, maternal IQ, education, and marital status. The coefficient \( \beta_1 \) is the difference between mean IQs at age 6 of urban and suburban children, adjusted for low birth weight and family factors; \( \beta_2 \) is the difference in mean IQ at age 11 versus age 6 for suburban children; and the interaction term, \( \beta_3 \), estimates the extent to which the change in the mean IQ of urban children differs from that of suburban children. Thus, \( \beta_2 + \beta_3 \) is the change in mean IQ among urban children from age 6 to age 11, adjusted for low birth weight and family factors. (In additional models, we evaluated other two- and three-way interactions between pairs of risk factors, e.g., urban community and low birth weight, and between risk factors and age.) The GEE method estimates regression coefficients and their standard errors, taking the correlation between the children’s IQ measures at ages 6 and 11 years into account. This approach yields valid and robust estimates of variance, even when there is a known positive correlation between multiple outcome measures within subjects. The exchangeable correlation option was used as the working correlation in estimation of the GEE models.

**RESULTS**

Mean values and standard deviations for descriptive data, including full-scale, verbal, and performance IQ scores by age, low birth weight versus normal birth weight, and urban versus suburban community, appear in table 2. We focus here on full-scale IQ. Analyses of verbal and performance IQ data yielded similar results (available from the authors). These data suggest a decline in IQ between ages 6 and 11 years in urban children but not in suburban children.

Figure 1 displays the empirical cumulative distributions of IQ scores by age among urban and suburban children, according to birth weight status (normal birth weight vs. low birth weight). The cumulative distribution curves of urban children, both normal birth weight and low birth weight, fall to the left of the curves of suburban children, reflecting the IQ differences between urban and suburban children at both ages. In both birth weight groups, the IQ curves of suburban

---

**TABLE 2.** Mean scores on the Weschler Intelligence Scale for Children–Revised at ages 6 and 11 years, by type of community and birth weight status (n = 717), Detroit, Michigan, metropolitan area, 1990–1992 and 1995–1997

<table>
<thead>
<tr>
<th>Low birth weight (&lt;2,500 g)</th>
<th>Normal birth weight (≥2,500 g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Urban community (n = 231)</td>
</tr>
<tr>
<td></td>
<td>Age 6 years</td>
</tr>
<tr>
<td>Full-scale intelligence quotient (IQ)</td>
<td>93.1 (15.6)</td>
</tr>
<tr>
<td>Performance IQ</td>
<td>92.7 (15.3)</td>
</tr>
<tr>
<td>Verbal IQ</td>
<td>94.7 (15.9)</td>
</tr>
</tbody>
</table>

* Numbers in parentheses, standard deviation.
FIGURE 1. Empirical cumulative distributions of intelligence quotient (IQ) scores at ages 6 and 11 years among urban and suburban children, Detroit, Michigan, metropolitan area, 1990–1992 and 1995–1997. The curves show the percentage of each group falling at or below any given IQ score. Top panel, normal birth weight children; bottom panel, low birth weight children.

Table 3 displays results from two successive models used to test and estimate the effects of community (urban vs. suburban), low birth weight, and family factors on IQ at ages 6 and 11 years. In model 1, we examined the effects of community and birth weight status. In model 2, we introduced the set of family covariates. In both models, we included only the single interaction that was found to be significant, i.e., the interaction of urban community × age, which indicates that the change in IQ of urban children differs from that of suburban children. Other interactions—e.g., low birth weight × urban community, low birth weight × age, and low birth weight × urban community × age—had coefficients of low magnitude (near zero) that were not statistically significant at \( \alpha = 0.15 \). Results from model 1 show that urban children at age 6 scored 14.0 IQ points lower than suburban children, regardless of birth weight status. Furthermore, from age 6 to age 11, the IQs of urban children, regardless of birth weight status, declined by 5.0 points (–5.19 ± 0.21). A negligible change was detected among suburban children (0.21). From age 6 to age 11, the gap in mean IQ between urban and suburban children widened from 14.0 points to 19.2 points. Low birth weight children, both urban and suburban, scored 5.8 IQ points lower than their normal birth weight counterparts. The size of this difference changed little from age 6 to age 11 in either type of community. This interpretation is based on the failure to detect an urban community × low birth weight interaction or two- and three-way interactions involving low birth weight and age.

Results from model 2 show that the addition of family factors to the GEE model attenuated markedly the observed
urban-suburban difference in children’s IQ at age 6, from 14.0 points to 4.9 points. Thus, the urban-suburban gap in children’s IQ at the beginning of schooling was accounted for in large part by differences in family characteristics. By far, the single most important family factor was maternal IQ: Adding only maternal IQ to model 1 reduced the observed urban-suburban difference in children’s IQ at age 6 from 14.0 points to 5.7 points. In contrast, the decline in IQ at age 11 among urban children calculated in model 1 remained intact. The urban-suburban IQ gap that was not accounted for by family variables increased from 4.9 points at age 6 to 10.1 points at age 11. The results of model 2 also show that maternal IQ was positively related to children’s IQ, as was maternal educational level, and children born to single mothers scored lower than children born to married mothers. However, the interactions of these variables with age were near zero, indicating that they were unrelated to change in children’s IQ.

To illustrate the implications of the IQ decline among urban children from age 6 years to age 11 years, we present in figure 2 the distributions of intraindividual changes in IQ scores in the two types of communities, combining low birth weight children and normal birth weight children. The figure presents a smoothed plot line, using a cubic spline method with continuous second derivatives (26). Although change in IQ score was pervasive in both communities, the net effect was different. The percentages of urban and suburban children whose scores declined by ≥5 points were 51.9 and 31.5, respectively; the percentages whose scores declined by ≥7.5 points were 38.8 and 22.7, respectively; and the percentages whose scores declined by ≥10 points were 30.2 and 14.3, respectively (all comparisons were statistically significant at \( p < 0.0001 \)). Thus, a surplus of 15.9 percent of urban children at age 11 fell behind their own intellectual performance at age 6 by two thirds of a standard deviation, relative to their age reference group at each assessment. A change of 10 WISC-R points falls well above conservative standards for separating change from fluctuation due to measurement error (1).

Additional GEE analyses were conducted in the subset of children who did not change residence between urban and suburban communities (i.e., excluding the 10 percent who changed from an urban address to a suburban address between ages 6 and 11 years). The results of these analyses replicated closely the results shown in table 3. An analysis corresponding to model 1 in table 3 showed that the initial gap in mean IQ score between urban and suburban children in the residentially stable subset widened from 16.4 points to 21.6 points. The urban-suburban IQ gap that was not accounted for by maternal IQ, education, and marital status (corresponding to model 2 in table 3) increased from 7.4 points at age 6 to 12.6 points at age 11. Thus, the increments in the urban-suburban gap from ages 6 to 11 years, as estimated in these analyses, were approximately the same (i.e., 5 IQ points) as those in table 3, which were based on the total sample.
DISCUSSION

Our results suggest that growing up in the inner city might impose disadvantages that lead to a decline in children’s IQ scores from age 6 years to age 11 years. On average, the IQs of urban children declined by more than 5 points. A change of 5 points in an individual child might be judged by some as clinically nonsignificant. Nevertheless, a change of this size in a population’s mean IQ, which reflects a downward shift in the distribution (rather than a change in the shape of the distribution), means that the proportion of children scoring 1 standard deviation or more below the standardized IQ mean of 100 would increase substantially. In this study, the change from age 6 years to age 11 years increased the percentage of urban children scoring less than 85 on the WISC-R from 22.2 to 33.2.

The influence of urban versus suburban residence on IQ change contrasts with other important predictors of children’s IQ, namely low birth weight, maternal IQ, maternal education, and single mother status. Low birth weight was associated with an IQ deficit of approximately one third of a standard deviation in both disadvantaged inner-city children and middle-class suburban children, a deficit that was detected at age 6 and remained unchanged at age 11. Low birth weight children neither fell further behind nor caught up with their normal birth weight age-mates in either community. Familial determinants of IQ, i.e., maternal IQ, education, and marital status, exerted stable and uniform influences on children’s IQ scores across age and in both communities; none were associated with IQ change. Furthermore, the initial IQ gap of 14 points (at age 6) between urban and suburban children was narrowed to 4.9 points when family factors, primarily maternal IQ, were controlled. In other words, urban-suburban disparities in family environment and perhaps genetics (to the extent that genetic factors are reflected in maternal IQ) explained two thirds of the urban-suburban IQ gap at age 6. However, these factors did not account for any part of the IQ decline (by 5 points, on average) among urban children from age 6 to age 11.

Recent reviews of studies conducted from the early decades of the 20th century through recent years suggest an influence of socioenvironmental factors on IQ (2–5, 27–31). An inverse relation between IQ and age has been reported among children living under various conditions of deprivation, such as impoverishment, racial discrimination, and erratic school attendance (2–5, 32). The evidence comes primarily from cross-sectional studies rather than from longitudinal studies that follow the same individuals over time. An analysis of longitudinal data from US samples (33) revealed an increased racial gap in academic achievement from the first grade to the 12th grade. IQ change was not measured in that study.

The 1996 report of a task force established by the American Psychological Association summarized the evidence on factors involved in IQ variability (31). The report concluded that IQ is the “joint product of genetic and environmental variables” and that an important environmental variable with a clear-cut influence on IQ is schooling. Schools not only transmit information but also develop intellectual skills and attitudes that influence IQ scores. The evidence for an effect of schooling on IQ scores takes several forms, as summarized in the report (31). It includes data showing that same-age children who have been in school longer have higher IQ scores and that IQ scores tend to drop over summer vacation, especially among lower-class children whose summer activities do not resemble the school curriculum.

Distinguishing between family factors and community factors allowed us to estimate their separate contributions to children’s IQs over time. However, we recognize that from an intergenerational perspective, these indicators are not completely separable. For example, although maternal IQ might be viewed as a measure of heritability of IQ, differences in maternal IQ reflect in part the cumulative legacy of growing up in socioeconomically disparate communities, as suggested by the results of this study.

Our sample of urban children reflected the racial composition of the inner city, which is predominantly Black, in sharp contrast to the predominantly White suburban sample. Consequently, we could not distinguish the effects of race from the effects of growing up in the inner city on the decline in IQ. However, whether one focuses on the children’s race or on their inner-city residence, the results suggest that the disadvantages under which the urban children grew older contributed to their failure to progress at a normative pace. Our findings do not rule out a potential role for unmeasured aspects of the family environment, such as child-rearing practices, in the IQ declines of urban children. However, they do underscore the need to examine the influence of extrafamilial factors, including community economic resources and the organization and quality of schools, regarding which there are stark inequalities between inner cities and middle-class suburbs.

More direct evidence for a causal role of extrafamilial factors in the observed IQ change might come from information on length of residence in the inner city. A finding that children who spent more of their lives in the inner city showed a larger decline in IQ would strengthen the argument supporting the disadvantaged-community hypothesis. Additionally, data on children’s school or classroom characteristics (e.g., time spent on an academic curriculum) and community economic resources would allow inquiry into potential mechanisms. Future assessments of the children in this study will include measurement of these variables. While the results of our analysis, which controlled for maternal IQ (the strongest predictor of children’s IQ scores), suggest a role for growing up in a racially segregated, disadvantaged community, information on length of residence and school characteristics might permit a clearer interpretation of the findings.

ACKNOWLEDGMENTS

This study was supported by grant MH-44586 from the National Institute of Mental Health, Bethesda, Maryland (Dr. Naomi Breslau).

The authors thank Dr. Meredith Phillips for helpful comments on an earlier version of this article.

Am J Epidemiol Vol. 154, No. 8, 2001
REFERENCES