# The Lingering Academic Deficits of Low Birth Weight Children

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**ABSTRACT.** ***Objective.*** **To estimate the influence of low birth weight (LBW; ≤2500 g) on academic achievement in reading and mathematics in 12th grade in 2 socioeconomically and racially disparate, geographically defined communities.**

***Methods.*** **Representative samples of LBW and normal birth weight (NBW) children who were born in 1983–1985 and were from the inner city of Detroit and nearby middle class suburbs were assessed longitudinally. Woodcock-Johnson Psycho-Educational Battery–Revised standardized tests of reading and mathematics were used at ages 11 and 17 ($n$ = 773). Multiple regression analysis applying generalized estimating equations was used to assess the independent effects of LBW on test scores.**

***Results.*** **Compared with NBW children, LBW children manifested deficits of 3 to 5 points in age-standardized tests of academic achievement at age 17 that had persisted with little change from age 11. LBW-related deficits were similar in urban and suburban communities and were independent of family factors. At age 17, LBW children were ~50% more likely than NBW children to score below the standardized population mean in both reading and mathematics. The LBW-related deficits in academic achievement in adolescence were largely accounted for by LBW-related deficits in general cognitive abilities, measured by IQ tests at age 6.**

***Conclusions.*** **Interventions to address the lingering effects of LBW on the acquisition of core academic skills during the school years should focus on preschool LBW children in both inner city and suburban communities.** ***Pediatrics*** **2004;114:1035–1040;** ***low birth weight, longitudinal study, academic achievement, urban and suburban communities, epidemiology.***

ABBREVIATIONS. LBW, low birth weight; VLBW, very low birth weight; NBW, normal birth weight; WJ-R, Woodcock-Johnson Psycho-Educational Battery–Revised; GEE, generalized estimating equation; SE, standard error.

Research on the long-term cognitive outcomes of low birth weight (LBW; ≤2500 g) children has focused primarily on very LBW (VLBW), defined as ≤1500 g. This cutoff and lower birth weight cutoffs (eg, 1000 g or even 750 g), used in recent follow-up studies, identify the very small fraction of LBW children who are at the highest risk for severe developmental disabilities.[1–7] Extreme LBW is associated with periventricular hemorrhage and/or infarction, which conveys a high risk of neurologic and cognitive sequelae,[8] as well as a range of other neonatal morbidities that may impair neurodevelopment.[9] However, studies that include heavier LBW children have demonstrated lower scores on cognitive abilities or academic achievement in school-age children throughout the LBW range (≤2500 g), compared with normal birth weight (NBW).[10–16] The biological bases of cognitive deficits in LBW children above the extreme low end of the birth weight distribution are less clear and might include generalized effects of less-than-complete fetal development as a result of either shortened gestation or poor fetal growth or the combination of the two.

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Recent reports on VLBW in early adulthood show lower test scores in reading and mathematics and lower IQ[17–23] and lower educational attainment at age 20.[24] The educational trajectory of LBW children above the VLBW cutoff as they progress from the early school grades to 12th grade is unknown. It is unclear whether deficits observed in LBW children in the early school years persist unchanged or are attenuated or enhanced with time. Furthermore, the impact of social environments on the academic development of LBW children as they mature has not been examined: do LBW children who grow up in middle class suburban communities, in contrast to those who grow up in disadvantaged inner-city environments, overcome their early deficits?

We have previously reported deficits in standardized tests of academic achievement in children in the entire range of LBW at age 11, based on a study conducted in 2 socially disparate communities, one predominantly black, inner city, and the other white, suburban, middle class.[12] In this report, we focus on results from a follow-up assessment of the cohort at age 17. The study design, which compares LBW and NBW children in 2 socially disparate communities, provides an advantage in separating social and biological contributions to outcomes in LBW children (above the VLBW cutoff) that is not often found in previous research. In the absence of severe neurologic complications that would offer a ready explanation for the cognitive deficits of VLBW children, there is a compelling need for a study design (and analytic methods) that can distinguish the influence of LBW from those of social disadvantage and racial minority status. This is so because LBW occurs disproportionately in socially disadvantaged communities, in which children's academic development is adversely influenced by multiple interrelated factors.

We examined children's academic test scores at age 17 and estimated the extent to which the academic deficits of LBW children persisted from age 11 to age 17. We examined potential variations in academic achievement of LBW versus NBW children by family factors and between 2 disparate communities. In addition, we examined the extent to which LBW-related deficits in tests of academic achievement at the end of high school can be traced back to deficits in general intelligence at the start of schooling.

## METHODS

### Sample and Data

Data are from a longitudinal study of LBW and NBW children who were assessed at ages 6, 11, and 17 years, with the last assessment conducted in 2000–2002. Complete information on the population, sampling, and assessment results at ages 6 and 11 years is presented elsewhere[12,13,25] and is summarized briefly here. We then describe the third assessment at age 17.

We identified and assessed random samples of 6-year-old children from 2 socioeconomically disparate populations. We targeted the 1983–1985 birth year cohorts of newborns who were 6 to 7 years of age in 1990–1992, the scheduled period of the initial field work. Two major hospitals in southeast Michigan, one in the city of Detroit and the other in a middle-class suburb, were selected. In each hospital, for each year from 1983 through 1985, random samples of LBW and NBW newborns were drawn from hospital discharge records. Children with severe disabilities, identified at birth and at age 6, were excluded, as our goal has been to identify the relatively subtle long-term sequelae of LBW among children who have survived infancy without obvious neurologic damage. Of the 1095 in the target sample, 823 (75%) participated.

The initial samples from the 2 sites differed markedly in racial composition, maternal education, and maternal marital status at the time of the child's birth, whereas differences between LBW and NBW children within each site were small.[10] The urban sample was predominantly black; ~25% of the mothers had not completed high school, and more than one half were single at the time the child was born. In contrast, the suburban sample was predominantly white; only 7% of the mothers failed to complete high school, and ~10% were single. Of the 473 LBW children, 25 (5%) were born weighing 1000 g or less, 51 (11%) weighed 1001 to 1500 g, 93 (20%) weighed 1501 to 2000 g, and 304 (64%) weighed 2001 to 2500 g. The LBW subsets in the 2 population sites were similar to each other in birth weight and Apgar score distribution and in the proportions who were born small for gestational age (<10th percentile).

The second assessment was conducted in 1995–1997, with children in each birth year cohort assessed as they passed their 11th birthday. Of 823 children who were assessed at age 6, 32 (3.9%) had moved out of state by age 11; funding limitations did not permit bringing children in from out of state at this assessment. Of the 791 remaining in the Detroit area, 717 (90.6%) were reassessed at age 11 (87.1% of the initial sample).

In 2000–2002, we assessed the sample a third time, with children in each birth year cohort assessed as they passed their 17th birthday. Of 823 assessed at age 6, 3 (0.4%) were in residential detention/training facilities, 1 (0.1%) was a runaway, 1 (0.1%) was in foster care, and 2 (0.2%) were on parole/probation out of state. Of the 49 children who had moved out of state, 30 returned to Michigan for the age 17 assessment. A total of 713 children were assessed, 86.6% of the initial cohort of 823, including 56 children of the original cohort who were not assessed at age 11. The total number of participants with data on standardized tests of academic achievement at either 11 or 17 years of age was 773, 93.9% of the initial sample of 823. The sample included 46 children from twin pairs, 44 of whom were LBW, 17 urban, and 27 suburban. The Institutional Review Boards of the participating institutions from which the samples were drawn and of Michigan State University, where the analysis of the existing data was conducted, approved the study.

### Assessment of Academic Achievement

The Woodcock-Johnson Psycho-Educational Battery–Revised (WJ-R)[26] was administered at ages 11 and 17. The Word Identification and Word Attack tests of the WJ-R measure basic reading, and the Calculation and Applied Problems tests measure broad math. These composite measures were used in this analysis to measure academic achievement in the 2 core school subjects, namely, reading and arithmetic. The WJ-R tests are age standardized and have a mean of 100 and SD of 15 in the general population. The initial assessment at age 6 did not include tests of academic achievement but included the Wechsler Intelligence Scale for Children–Revised[27] IQ test, which is used in the analysis presented here as a measure of children's early general intelligence. Testers were blind to the LBW status of the children, and at the second and third assessments, they were also blind to the results of the previous assessments.

### Statistical Analysis

We used multiple regression analysis, applying generalized estimating equations (GEE)[28–30] to test and estimate the effects of LBW on academic achievement at ages 11 and 17 years, with family variables and urban versus suburban residence as covariates. GEE offers important advantages over other regression approaches used to measure change over time. It permits simultaneous modeling of the relation of specific factors (eg, LBW) with children's academic achievement at both ages 11 and 17 years. The use of interaction terms allows us to test whether the difference between LBW and NBW in mean test scores was significantly different between ages 17 and 11 years. The coefficient for an interaction between LBW and age (17 vs 11) is equivalent to that produced in a standard regression model in which change in the standardized test scores over time is the response variable and the risk factor (here, LBW vs NBW) is entered as the predictor variable. However, GEE provides information on the relation of LBW with academic achievement at both ages 17 and 11 years, which is not available in a standard regression analysis of score changes. If a significant interaction with age is not detected (and therefore an interaction term is not included in the model), then the coefficient for LBW estimates the relationship of LBW with academic achievement on the basis of the combined data from both assessments, adjusted for other variables in the model (eg, urban vs suburban community). Interactions were tested at $\alpha = .15$. The model in which we tested the interaction between LBW and age is illustrated in the equation $y = \alpha + \beta_1 \text{(LBW)} + \beta_2 \text{(age)} + \beta_3 \text{(LBW} \times \text{age)} + \beta_4 \text{(urban)} + \beta_{5-6} \text{(family factors)}$, where standardized test scores of reading or math at ages 11 and 17 years are the outcomes (y); LBW = 1 if the child is LBW and 0 if NBW; age = 1 for test score at age 17 and 0 at age 11; and urban = 1 if the child's community is urban and 0 if it is suburban. Family factors included maternal education and marital status. Maternal education was divided into 4 levels—less than high school, high school, some college, and college—using 3 binary variables, with college as the reference. Marital status = 1 if mother was single when child was born and 0 if she was married. In additional models, we tested other 2- and 3-way interactions between pairs of risk factors (eg, urban × LBW) and between age and single risk factors (eg, urban × age) and age and pairs of risk factors (eg, LBW × urban × age). The interaction terms given in these illustrations address the research questions concerning potential differences in the development of LBW children in disparate communities. The GEE method estimates regression coefficients and their standard errors, taking into account the correlation between children's test scores across the 2 assessments. This approach yields valid and robust estimates of variances, 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. Another advantage of GEE is that, unlike other statistical approaches to longitudinal data, it does not discard subjects with incomplete responses.[30] The results presented here are based on all of the available data on academic achievement, including cases in which information was obtained at only 1 of the 2 ages in which academic achievement was assessed ($n = 773$). A series of GEE models performed on the subset with complete data from both assessments ($n = 675$) yielded the same results.

## RESULTS

A description of the sample on which the analysis is based ($n = 773$) appears in Table 1 and the means

**TABLE 1.** Characteristics of Urban and Suburban Samples at Children's Birth

| | Urban | | | Suburban | | |
|---|---|---|---|---|---|---|
| | Total ($n$ = 394) | LBW ($n$ = 241) | NBW ($n$ = 153) | Total ($n$ = 379) | LBW ($n$ = 201) | NBW ($n$ = 178) |
| | % | % | % | % | % | % |
| Black | 82.5 | 84.6 | 79.1 | 5.5 | 5.0 | 6.2 |
| Male | 44.2 | 42.3 | 47.1 | 52.0 | 50.8 | 53.4 |
| Mother's education | | | | | | |
| Less than high school | 26.1 | 28.6 | 22.2 | 6.9 | 7.0 | 6.7 |
| High school | 26.6 | 26.1 | 27.4 | 27.2 | 27.4 | 27.0 |
| Some college | 37.3 | 36.9 | 37.9 | 37.7 | 37.8 | 37.6 |
| College | 9.9 | 8.3 | 12.4 | 28.2 | 27.9 | 28.6 |
| Single mother | 57.4 | 59.2 | 54.6 | 9.3 | 12.0 | 6.2 |
| Birth weight | | | | | | |
| ≤1000 g | 3.3 | 5.4 | — | 2.9 | 5.5 | — |
| 1001–1500 g | 7.1 | 11.6 | — | 5.3 | 10.0 | — |
| 1501–2000 g | 13.4 | 22.0 | — | 8.7 | 16.4 | — |
| 2001–2500 g | 37.3 | 61.0 | — | 36.2 | 68.2 | — |
| 2501–3000 g | 8.2 | — | 20.9 | 6.9 | — | 14.7 |
| 3001–3500 g | 15.5 | — | 39.9 | 18.8 | — | 40.1 |
| 3501+ g | 15.2 | — | 39.2 | 21.2 | — | 45.2 |
| Apgar | | | | | | |
| 1 min ≤ 5 | 13.3 | 17.5 | 6.6 | 12.3 | 20.5 | 2.9 |
| 5 min ≤ 5 | 2.0 | 2.9 | 0.7 | 1.1 | 2.0 | 0.0 |
| SGA (<10th percentile) | 18.6 | 25.3 | 8.0 | 13.5 | 19.0 | 7.4 |
| In NICU | | | | | | |
| 0 days in NICU | 71.6 | 57.3 | 94.1 | 76.1 | 57.0 | 97.7 |
| ≤2 wk in NICU | 9.0 | 10.9 | 5.9 | 5.8 | 9.5 | 1.7 |
| >2 wk in NICU | 19.4 | 31.8 | 0.0 | 18.1 | 33.5 | 0.6 |
| Maternal age, mean (SD) | 24.5 (5.8) | 24.6 (6.0) | 24.3 (5.3) | 27.7 (4.8) | 27.7 (5.0) | 27.8 (4.5) |

SGA indicates small for gestational age; NICU, neonatal intensive care unit.

(SD) of age-standardized WJ-R reading and mathematics scores at ages 11 and 17 years appear in Table 2. On sociodemographic characteristics, the urban and suburban groups differed widely, whereas LBW and NBW children within each group differed little. Neonatal characteristics (percentages of small for gestation, low Apgar score, distribution of number of days in neonatal intensive care unit, and birth weight levels) were similar in both communities (Table 1). Examination of means of age-standardized academic achievement scores shows the crude test-score differences at ages 11 and 17 years between LBW and NBW children within the urban and suburban communities, against the background of the stark gaps in achievement scores between the 2 communities (Table 2). Twins did not differ from singletons on test scores, controlling for urban versus suburban community ($P$ = .46).

Estimated in multiple logistic regression (controlling for urban vs suburban community, maternal education, and single mother births), LBW children at 17 years of age were significantly more likely to score below the reading and math standardized population mean of 100 than NBW children of the same age: the odds ratio for scoring below average on reading was 1.5 (95% confidence interval: 1.1–2.0) and on mathematics was 1.6 (95% confidence interval: 1.1–2.3).

GEE models failed to detect significant interactions between 1) LBW and age; 2) urban community and age; 3) LBW and urban community; or 4) 3-way interaction of age, LBW, and urban community. Interactions involving maternal education and single mother status also were not significant. Tables 3 and 4 display results from the GEE models used to estimate the effects of LBW on reading and mathematics. For each academic outcome, 2 successive models are presented. Model 1 in each table estimates the effect of LBW on the outcome of interest, controlling for age and the other covariates in the model. In the absence of age interactions, the coefficient of LBW in model 1 estimates the stable effects of LBW, measured at ages 11 and 17. Model 2 in each table introduces the earliest available cognitive measure, that is, general intelligence as measured by standardized IQ tests at 6 years of age. A comparison of the coefficients of LBW in the 2 models shows the extent to which the persisting effects of LBW on academic

**TABLE 2.** Mean (SD) of Academic Achievement at Ages 17 and 11

| | Urban | | | Suburban | | |
|---|---|---|---|---|---|---|
| | Total ($n$ = 394) | LBW ($n$ = 241) | NBW ($n$ = 153) | Total ($n$ = 379) | LBW ($n$ = 201) | NBW ($n$ = 178) |
| Academic achievement (age 17) | | | | | | |
| Reading, mean (SD) | 93.6 (17.7) | 92.5 (16.8) | 95.3 (19.0) | 106.2 (15.3) | 104.6 (15.7) | 108.0 (14.7) |
| Mathematics, mean (SD) | 87.3 (13.4) | 85.3 (12.4) | 90.3 (14.3) | 102.7 (17.1) | 100.8 (16.8) | 104.7 (17.2) |
| Academic achievement (age 11) | | | | | | |
| Reading, mean (SD) | 95.3 (18.3) | 94.0 (17.9) | 97.4 (18.8) | 108.5 (15.9) | 106.2 (16.1) | 111.1 (15.2) |
| Mathematics, mean (SD) | 92.1 (16.0) | 89.5 (16.3) | 96.4 (14.7) | 108.7 (17.1) | 105.7 (17.2) | 112.1 (16.5) |

**TABLE 3.** Regression Estimates of Children's Scores on WJ-R Reading Tests at Age 17 From Successive GEE Models, With IQ Score at Age 6 Years Added in Model 2

| | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| | β* | SE | *P* Value | β* | SE | *P* Value |
| LBW vs NBW | −3.34 | 1.14 | .004 | −0.44 | 1.01 | .66 |
| Male | −3.26 | 1.13 | .004 | −2.61 | 0.97 | .01 |
| Age 17 y vs age 11 y | −2.51 | 0.35 | <.0001 | −2.54 | 0.35 | <.0001 |
| Urban community vs suburban | −7.78 | 1.28 | <.0001 | −2.70 | 1.16 | .02 |
| Mother's education† | | | | | | |
| Less than high school | −13.48 | 2.08 | <.0001 | −6.18 | 1.88 | .001 |
| High school | −7.69 | 1.60 | <.0001 | −2.96 | 1.48 | .046 |
| Some college | −4.41 | 1.58 | .005 | −2.37 | 1.39 | .09 |
| Single mother | −5.58 | 1.44 | .0001 | −2.81 | 1.28 | .03 |
| IQ at age 6 | — | — | — | 0.56 | 0.04 | <.0001 |

* Unstandardized partial regression coefficient representing difference in children's WJ-R reading achievement scores associated with the independent variable.
† Reference group: college or above.

**TABLE 4.** Regression Estimates of Children's Scores on WJ-R Mathematics Tests at Age 17 From Successive GEE Models With IQ Score at Age 6 Years Added in Model 2

| | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| | β* | SE | *P* Value | β* | SE | *P* Value |
| LBW vs NBW | −5.07 | 1.05 | <.0001 | −1.62 | 0.79 | .04 |
| Male | −1.27 | 1.04 | .22 | −0.50 | 0.78 | .52 |
| Age 17 y vs age 11 y | −6.10 | 0.36 | <.0001 | −6.13 | 0.36 | <.0001 |
| Urban community vs suburban | −10.31 | 1.19 | <.0001 | −4.23 | 0.97 | <.0001 |
| Mother's education† | | | | | | |
| Less than high school | −14.56 | 1.91 | <.0001 | −5.71 | 1.44 | <.0001 |
| High school | −10.18 | 1.67 | <.0001 | −4.44 | 1.25 | .0004 |
| Some college | −7.08 | 1.58 | <.0001 | −4.59 | 1.18 | <.0001 |
| Single mother | −5.54 | 1.20 | <.0001 | −2.24 | 0.90 | .01 |
| IQ at age 6 | — | — | — | 0.67 | 0.03 | <.0001 |

* Unstandardized partial regression coefficient representing difference in children's WJ-R mathematics achievement scores associated with the independent variable.
† Reference group: college or above.

achievement up to the end of high school are explained by general intelligence scores at the beginning of schooling.

With respect to reading (Table 3), results of model 1 show that, controlling for gender, age, urban community, maternal education, and single mother birth, LBW children, on the average, scored 3.34 points lower than NBW children ($P = .004$). This adjusted estimate is lower than the unadjusted estimate of −4.92 (SE = 1.28), calculated in a GEE model that did not include the covariates. From the failure to detect interactions, it can be inferred that the observed deficit in reading associated with LBW was stable over time, uniform across urban and suburban communities, family factors, and child's gender. All of these variables had significant effects on children's reading scores, and urban community, low maternal education, and single mother status were associated with considerably greater deficits in children's reading scores than the deficit associated with LBW. Nonetheless, a significant effect of LBW independent of these factors was detected.

The introduction of children's IQ scores at age 6 in model 2 of Table 3 virtually obliterated the deficits associated with LBW in reading achievement that persisted up to age 17 (the coefficient of LBW was reduced from −3.34 to −0.44). In other words, IQ deficits associated with LBW at the beginning of schooling[10] accounted almost in full for the deficits in reading achievement associated with LBW measured 5 and 11 years later, at ages 11 and 17 years. In contrast, adverse family factors and urban community remained influential for reading achievement up to age 17, independent of early IQ, as can be seen in model 2. The most important factor associated with lower reading achievement at the end of high school was low maternal education, especially a mother's failure to complete high school. This influence on reading achievement at ages 11 and 17 was independent of children's IQ at the beginning of schooling.

Results from parallel analyses of standardized mathematics scores are displayed in Table 4. Model 1 in Table 4 yielded similar results to those for reading, with the exception of the male disadvantage, which was observed for reading but not for mathematics. Controlling for other variables in the model, LBW children scored 5.07 points lower than NBW children ($P < .0001$). This estimate is lower than the unadjusted estimate of −7.02 (SE = 1.24), calculated in a GEE model that did not include the covariates. The LBW-related deficit is larger in mathematics than in reading. Model 2 in Table 4 shows a small (although significant) residual effect of LBW in math achievement that is not accounted for by LBW-related IQ deficits at the beginning of schooling. With respect to family factors and urban versus suburban community, results were similar to those observed for reading.

In additional GEE models, we estimated the relation of level of LBW with reading and mathematics scores, adjusted for gender, family variables, and urban community. LBW children were divided into VLBW (≤1500 g; $n$ = 76), intermediate LBW (1501–2000 g; $n$ = 93), and high LBW (2001–2500 g; $n$ = 304). For reading achievement, no gradient was observed, with LBW children in all 3 levels scoring below NBW children (−2.98, SE = 2.41 in VLBW; −6.67, SE = 1.92 in intermediate LBW; and −2.44, SE = 1.21 in the highest LBW level). In contrast, for mathematics achievement, a gradient was observed, with VLBW children showing the greatest deficit (−8.71, SE = 2.25), LBW children in the intermediate level showing a somewhat smaller deficit (−7.04, SE = 1.82), and LBW children in the highest level showing the smallest deficit (−3.58, SE = 1.12), relative to NBW children. The deficits in math in all 3 levels of LBW (vs NBW) are significant at .001.

## DISCUSSION

The key findings of this study can be summarized as follow: 1) LBW children, both inner city and suburban, showed moderate deficits in academic achievement at ages 11 and 17, 2) the LBW-related deficits in adolescence were almost entirely accounted for by LBW-related deficits in general intelligence at 6 years of age, 3) a larger gap in academic achievement (than the gap associated with LBW) was observed between the two socioeconomically and racially disparate communities, and 4) deficits attributable to disadvantaged community and family adversity increased during the first 5 years of schooling and persisted with no additional change thereafter.

Deficits in academic achievement associated with LBW measured at age 17 were little changed since age 11, when academic achievement was first measured in this cohort. The average deficit in reading achievement was small, just above one fifth of SD. The deficit in mathematics was larger, approximately one third of SD. We also found that LBW children at age 17 were ~50% more likely to score below the standardized population average of 100 in both reading and mathematics, compared with NBW children who had similar family characteristics and resided in the same community. Moreover, with respect to mathematics, we found a gradient relationship across levels of LBW, with those born at ≤1500 g showing the greatest deficits, although even LBW children >2000 g at birth showed significant deficits, on average. The closer link of LBW with mathematics than with reading has been previously reported for younger children.[14,15,31] Consistent with this general finding, we previously reported a greater relative risk of learning disabilities in math than in reading in LBW boys.[13]

Differences between LBW and NBW children in core school subjects (reading and mathematics) were of the same magnitude in the urban and suburban groups. The uniform LBW-related deficits were independent of the wide gaps in these test scores between the 2 communities, the urban composed primarily of disadvantaged minority members and the suburban almost entirely white middle class. Furthermore, there were no detectable changes in the effects of LBW on academic achievement over time in either community. As they matured, LBW children neither improved in the suburban community nor fell further behind in the urban community, relative to NBW children in their respective communities.

We found that the deficits associated with LBW in reading and mathematics at ages 11 and 17 could be traced back to LBW-related deficits in general cognitive abilities, as measured by standardized IQ tests at the start of schooling.[10] In other words, early LBW-related deficits in general intelligence, detected before differences in children's learning during their formal education exerted their influence, forecasted the reading gap and most of the gap in mathematics between LBW and NBW children near the end of high school.

In contrast, low maternal education, single mother status, and urban residence were found to continue to influence academic test scores, independent of children's general intelligence at the start of schooling. We have previously reported that family variables and urban versus suburban community influenced IQ at age 6 in both LBW and NBW children.[10] The results of this study extend those findings in that they show that, apart from their effect on IQ at school entry, adverse family and community environments continue to influence children's acquisition of reading and math skills after school entry. For example, children whose mother did not complete high school scored more than one third of SD in reading and mathematics below children whose mother completed college, independent of the children's IQ at school entry. These later influences on the acquisition of core academic skills seem to have occurred chiefly in the first 5 years of schooling, that is, up to age 11, with little additional detectable increments between ages 11 and 17. This interpretation is based on the finding of no significant interactions between child's age (between ages 11 and 17) and urban versus suburban community, maternal education, or single mother status on either reading or mathematics, as explicated above. A similar pattern of results has been reported by Phillips et al[32] in regard to the racial gap in academic achievement, based on longitudinal data from US samples. Analysis of those data revealed increased racial gaps in tests of academic achievement from the 1st to the 12th grade, with most of the increase occurring before high school.

These findings suggest that preschool interventions that are directed to the goal of redressing the disparities associated with social disadvantage are unlikely, on their own, to prevent the deficits in core academic skills that occur after school entry. In contrast, the development of interventions to prevent the lingering effects of LBW on academic achievement at the end of high school should be targeted primarily to enhancing general intelligence at the preschool years.

In this study, we evaluated the effects of LBW on academic achievement independent of the effects of social environments. Our key strategy was to compare LBW with NBW children in 2 socially disparate communities. We also took into account the influence of family factors that play a major part in the academic development of children. The results show that the effects of LBW, even in privileged middle-class suburban communities, persist throughout high school and thus may influence ultimate levels of educational attainment and subsequent occupational and economic status. It should be noted, additionally, that LBW births occur disproportionately more often in urban socially disadvantaged ethnic groups, in which children's cognitive development is adversely influenced by multiple interrelated factors. Thus, apart from the persistent modest effects of LBW per se on their cognitive development, a considerable proportion of LBW children also are subject to the cumulative adverse effects of social and family disadvantages experienced by all children, LBW and NBW, in disadvantaged communities.

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