Neighborhood Influences on the Academic Achievement of Extremely Low Birth Weight Children

Laura Andreias,[1] MD, MS, Elaine Borawski,[2] PhD, Mark Schluchter,[2] PhD, H. Gerry Taylor,[1] PhD, Nancy Klein,[1] PhD, and Maureen Hack,[1] MB, ChB

[1]*Department of Pediatrics, Rainbow Babies and Children's Hospital, University Hospitals of Cleveland, Case Medical Center and* [2]*Department of Epidemiology and Biostatistics, Case Western Reserve University*

Objective To examine neighborhood effects on academic achievement of children with extremely low birth weight (ELBW <1000 g) and normal birth weight (NBW) controls. **Methods** The study included 183 8-year-old children with ELBW born during 1992–1995 and 176 sociodemographically similar NBW controls. Academic achievement was measured via The Woodcock–Johnson III Academic Skills Cluster. **Results** Children with ELBW had significantly lower achievement scores (89 ± 16 vs. 97 ± 13). A multilevel estimation of predictors of academic achievement revealed that neighborhood poverty was significantly associated with lower achievement ($\beta = -.17$; 95% CI $-.3$, $-.05$; $p < .01$). Additional correlates included birth weight status, male sex, and parent ratings of attention deficit hyperactivity disorder symptoms. Family characteristics included maternal education and parent protection. **Conclusions** Neighborhood characteristics affect academic achievement of both children with ELBW and NBW controls, over and above individual and family influences. Interventions designed to address family and neighborhood factors may potentially improve these outcomes.

Key words academic functioning; low birth weight; prematurity; neighborhood.

Poor academic achievement has been well documented among children with extremely low birth weight (ELBW <1000 g) and is associated with both biologic and sociodemographic risk factors (Aylward, 2005; Bhutta, Cleves, Casey, Cradock, & Anand, 2002; Hack et al., 1992; Klebanov, Brooks-Gunn, & McCormick, 1994; Taylor, Klein, Drotar, Schluchter, & Hack, 2006). Prediction of achievement skills is particularly critical in this population at high risk for learning problems and may be useful in identifying needs for educational monitoring and in discovering ways to enhance learning outcomes. Most of the research on the effects of sociodemographic factors on academic achievement has focused on the proximal family environment and has rarely considered more distal neighborhood and community factors (Bradley & Corwyn, 2002; Garner & Raudenbush, 1991; McLoyd, 1998). Several researchers have argued that children's individual cognitive and behavioral traits do not fully account for their academic achievement and have strongly advocated for simultaneous consideration of the social environment in which children grow and develop (Aylward, 2002; Raudenbush & Bryk, 2002).

Bronfenbrenner (1979) theorized in the Ecological Systems Theory that child development is influenced by several interactive hierarchical levels of environment. The inner-most level contains the child, and outer-level factors are those that have a direct or indirect influence on development, such as family, school, neighborhood, cultural values, and social contexts. The theory describes neighborhood-level influences as one of the multiple levels of influences on development and justifies the assessment of neighborhood characteristics in predicting academic achievement. Neighborhoods vary in terms of children's learning experiences, as well as in recreational, social, and educational opportunities (Bradley & Corwyn, 2002; Brooks-Gunn, Duncan, & Aber, 1997; Sampson & Morenoff, 2002). Studies indicate that children from poor neighborhoods, when compared with children from

All correspondence concerning this article should be addressed to Dr Laura Andreias, c/o Dr Maureen Hack, Rainbow Babies and Children's Hospital, University Hospitals of Cleveland, Case Medical Center, 11100 Euclid Ave., Cleveland, OH 44106, USA. E-mail: lce5@case.edu

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more affluent neighborhoods, perform less well in school and tend to exhibit lower skill levels and more behavior and health problems even when family characteristics are held constant (Bradley & Corwyn, 2002; Brooks-Gunn et al., 1997).

The family may shelter the child from neighborhood influences on achievement during early childhood but neighborhood effects are likely to become more pronounced with advancing age and greater exposure to schools and peers (Brooks-Gunn et al., 1997). Simultaneous consideration of several sources of variability in achievement is needed to determine the extent to which neighborhood contributes independently to variations in achievement. In most studies, measures of neighborhood effects are based exclusively on aggregate or tract-level census data and are thus likely to underestimate linkages between-neighborhood characteristics and outcomes. Researchers have strongly recommended that measures of neighborhood include both ''objective'' features of the neighborhood and perceived characteristics from the resident's perspective (Brooks-Gunn et al., 1997).

As part of a longitudinal study of school age outcomes of children with ELBW, we previously reported on their functional limitations, special health care needs, and cognitive, academic, and neuropsychological outcomes compared with those of sociodemographically similar normal birth weight (NBW) controls (Hack et al., 2005; Taylor et al., 2006). The objective of the present study was to examine the specific role of the neighborhood on academic achievement by using a multilevel modeling approach that simultaneously accounts for individual, family, and neighborhood characteristics. We hypothesized that children with ELBW who did not have neurologic or sensory impairments would have poorer academic achievement than NBW controls and that this would be influenced by individual, family, and neighborhood effects. Based on Bronfenbrenner's ecological systems theory (Bronfenbrenner, 1979), we further hypothesized that the family environment would exert a greater effect on academic achievement than more distal neighborhood characteristics.

Methods

Study Population

The ELBW population included survivors of a cohort of 344 children with ELBW who were admitted to the Neonatal Intensive Care Unit at Rainbow Babies and Children's Hospital, Cleveland, Ohio, during the years 1992–1995 (Hack et al., 2005). Ten children with major congenital malformations, two with AIDS, and one with tuberous sclerosis were excluded. Of the 331 remaining children, 238 (72%) survived to the age of 8 years of whom 219 (92%) were assessed. Children lost to follow-up did not differ significantly on sociodemographic factors, neighborhood characteristics, birth data, or neonatal complications, from those included in the study. Thirty-six (16%) children who had neurosensory impairments (31 with cerebral palsy, 1 blind, and 4 deaf requiring a hearing aid) were excluded. The study population thus included 183 children with ELBW. They had a mean birth weight of 810 g and a mean gestational age of 26.4 weeks, only 38% were male due to the better survival of females, and 62% were black (Table I). The NBW cohort, born at term gestation, was formed by randomly selecting a child from the same school and of the same race, sex, and age within 3 months of each child with ELBW. In total, 176 NBW children were recruited.

As shown in Table I, birth weight and gestational age differed significantly between groups by the study design. There were no differences with regard to race, gender, or parental level of education, marital status, perception of neighborhood risk, or the selected neighborhood census tract variables, i.e., poverty rate and high school dropouts. As reported previously, children with ELBW had significantly lower academic achievement scores, a lower mean IQ, and higher rates of parent ratings of Attention Deficit Hyperactivity Disorder (ADHD) symptoms, than NBW children (Hack et al., 2005; Taylor et al., 2006). Significantly more ($p < .05$) children with ELBW than NBW controls received intervention services before entering school [83 (45%) vs. 44 (25%)] and were currently receiving special education services [89 (49%) vs. 38 (22%)].

Measures and Procedures

The primary outcome measure was the Academic Skills Cluster of the Woodcock–Johnson Tests of Achievement III which is an aggregate age-standardized composite of the subtests Letter–Word Identification, Math Calculation, and Spelling (Woodcock, McGrew, & Mather, 2001). It uses a standard score scale based on a mean of 100 and standard deviation of 15 and has a median reliability of .95. The Academic Skills Cluster is a summary measure with higher reliability than the subtest scores. All tests were scored according to the child's postnatal age.

Predictor variables considered included the individual, family, and neighborhood factors presented in Table II. These measures were selected based on previous research demonstrating association of those factors with children's academic achievement (Brooks-Gunn et al., 1997; Hack et al., 1992; Taylor et al., 2006). These measures were

Table I. Description of the Study Population

	ELBW ($N = 183$)	NBW ($N = 176$)
Birth data		
Birth weight, mean (*SD*), g	810 ± 124	3300 ± 513****
Gestational age, mean (*SD*), weeks	26.4 ± 2	≥37****
Male sex, *n* (%)	70 (38%)	65 (37%)
Black race, *n* (%)[a]	114 (62%)	118 (67%)
Maternal sociodemographic and neighborhood descriptors[b]		
Age, mean years (*SD*)[c]	38 ± 8	35 ± 8
Education, *n* (%)		
Less than high school	24 (13.1%)	22 (12.5%)
High school/GED	47 (25.7%)	44 (25%)
More than high school[d]	112 (61.2)	110 (62.5)
Unmarried, *n* (%)	95 (52%)	89 (51%)
Perceived neighborhood risk, mean (*SD*)	30 ± 6	30 ± 5
Poverty rate, mean (*SD*)[e]	18% ± 16	20% ± 17
High school dropout rate, mean (*SD*)[e]	10% ± 10	12% ± 10
8-year outcomes		
Academic achievement, mean (*SD*)[f]		
Letter/word identification	90 ± 16	96 ± 14****
Calculation	89 ± 15	98 ± 14****
Spelling	90 ± 16	95 ± 13****
Academic skills cluster	89 ± 16	97 ± 13****
IQ by MPC score, mean (*SD*)[g]	91 ± 15	100 ± 15****
ADHD symptoms, *n* (%)[h]	30 (17%)	9 (5%)***
Parent protection score, mean (*SD*)	30 ± 6	30 ± 5

Note. ELBW, extremely low birth weight; NBW, normal birth weight.
[a]White race includes two Asian ELBW and two Asian NBW children.
[b]Unless otherwise stated, refers to information on the primary caregiver at the time of the study. This was the biologic or adoptive mother for 164 children (90%) in the extremely low birth weight group and 157 children (89%) in the normal birth weight group.
[c]Biological and adoptive mothers only.
[d]Includes more than 1 year of partial college or other training course.
[e]Mean percentage of families below the poverty level and mean percentage of youths not in school and not high school graduates, according to the 2000 Census tract neighborhood in which the families lived.
[f]Denotes academic achievement subtests scores and Academic Skills Cluster score of the Woodcock Johnson Tests of Achievement (Woodcock, McGrew, & Mather, 2001).
[g]Mental Processing Composite score (Kaufman & Applegate, 1988).
[h]Parent ratings of ADHD symptoms—inattentive, hyperactive–impulsive, and combined types (Gadow & Sprafkin, 1997).
***$p < .001$; ****$p < .0001$.

also among those available as part of our larger study of ELBW outcomes by Hack et al. (2005).

The parent version of the Child Symptom Inventory (Gadow & Sprafkin, 1997) rates child behaviors. The scales of interest in this study were those assessing the parent ratings of ADHD symptoms. ADHD was defined as either the Inattentive, Hyperactive–Impulsive, or Combined types according to the DSM IV cutoff scores.

The Parent Protection Scale assesses parenting factors such as supervision, difficulty with separation from the child, discouragement of independent behavior,

Table II. Predictors Considered in the Multilevel Analyses

Individual predictors
Birth weight status: ELBW versus NBW children
Sex: Male versus female
Parent ratings of ADHD symptoms: Present versus absent
Family predictors
Race: Black versus white
Parental level of education: ≤High school level versus >high school
Parental marital status: Married versus unmarried
Perceived Neighborhood Scale: Total score.
Parent Protection Scale: Total score.
Neighborhood predictors
Poverty rate: Percentage of families below the poverty level.
High school dropout rate: Percentage of youth age 16–19 years not in school or lacking high school diploma.

Note. ELBW, extremely low birth weight; NBW, normal birth weight.

and control (Thomasgard, Shonkoff, Metz, & Edelbrock, 1995). It includes 25 items in which parents are asked to rate each statement on a 4-point Likert scale, with higher scores indicating increased parent protection. These are summarized in terms of a total score and subdomain scores (Supervision, Separation, Dependence, and Control). For the purpose of our study, we used the Total Score. The scale has moderate to high internal reliability ($\alpha = .73$) and high retest reliability ($r = .86$, $p = .001$). Internal reliability for our sample was high ($\alpha = .82$).

The Perceived Neighborhood Scale (Martinez, Black, & Starr, 2002), also completed by parents, measures neighborhood dimensions of social embeddedness, sense of community, satisfaction with the neighborhood, and perceived crime. It includes 34 items on a 5-point Likert scale with higher scores indicating poorer neighborhood perception. The scale has high reliability with Cronbach's alpha coefficients above .80 for all dimensions. Internal reliability for our sample was high ($\alpha = .84$). In all analyses, the Perceived Neighborhood Scale was included as a family measure because it was conceptualized as reflecting parental perception rather than as an objective measure of neighborhood quality.

Neighborhood variables were extracted from the U.S. Bureau of the Census—*2000 Census Summary File 3*, at the census tract level. Census variables represent aggregate variables that are linked through geographic identifiers to individual level data. We considered four neighborhood characteristics: the poverty rate (i.e., percent of families living below the poverty level), the percent of female-headed households, the percent of males not in the labor force, and the percent of high-school dropouts (a measure of neighborhood educational attainment).

Pearson product–moment correlation coefficients between the poverty rate, percent of female-headed households, and percent of males not in labor force were very high ($r = .84$ and $r = .74$, respectively). However, the correlation coefficient between the poverty rate and the high-school dropout rate was relatively low ($r = .39$). The latter two factors were thus selected to represent the neighborhood characteristics, diminishing the potential for multicollinearity.

The children were tested during a half-day session which included tests of cognitive, academic, and neuropsychological skills (Taylor et al., 2006). Parent questionnaires were administered to the primary caregiver, usually the mother, while the child was being tested. Child examiners were blinded as to the birth weight category of the child. Maternal race was considered as a sociodemographic construct and was self-identified by the parent from the list of racial/ethnic categories used for Federal reporting. The study protocol was approved by the Institutional Review Board of University Hospitals of Cleveland and written consent was obtained from parents.

Data Analyses

Statistical analyses included *t*-test comparisons for continuous measures, chi-square analyses for categorical measures, Pearson correlations, and multi-level regression analyses using linear mixed-effects models with census tract as a random effect. All continuous covariates were centered at the grand mean to parameterize the models so that the results would be easily interpretable. In addition, birth weight status was controlled in all models. All analyses were conducted using SAS/STAT Software (Version 9.1.3).

Multilevel analyses were estimated using SAS Proc Mixed for mixed effects modeling using the maximum likelihood estimation and Satterthwaite's degrees of freedom approximation (Littell, Milliken, Stroup, & Wolfinger, 1996). Because clustering of individuals within census tracts violates the assumption of independence amongst observations in traditional ordinary least-squares regression, the fitted models included a random effect for census tract, thus controlling for within-census tract correlation of observations. The appropriateness of the multilevel approach was assessed in two steps: firstly by testing the significance of the between-census tract variance, and secondly by estimating the intraclass correlation coefficient derived as the ratio of the between-census tract variance divided by the sum of the between- and within-census tract variances. To compare the goodness-of-fit of various models, we used the Akaike Information Criterion (AIC) in which smaller values indicate better fit (Akaike, 1974).

Aiming to provide more efficient estimates at all levels, our data analyses were structured so that they paralleled the theoretical concept that neighborhood characteristics influence families and children.

Results

Univariate Correlates of Academic Achievement

Individual, family, and neighborhood correlates of academic achievement were examined separately for children with ELBW and for NBW controls. Within the ELBW group, the mean Academic Skills Cluster differed significantly by gender (male vs. female 85.1 ± 16 vs. 91.1 ± 16), presence or absence of ADHD symptoms (82.7 ± 21 vs. 90.1 ± 15), race (black vs. white, 85.8 ± 16 vs. 93.8 ± 17), maternal level of education ($\leq$high school vs. $>$high school 80.4 ± 16 vs. 94.1 ± 14), and marital status (unmarried vs. married 85 ± 15 vs. 92.1 ± 18), all $p < .01$. Pearson correlations with the Academic Skills Cluster were $r = -.32$ for the Parent Protection Scale, $-.14$ for the Perceived Neighborhood Scale, $-.32$ for the poverty rate, and $-.24$ for the percent of high-school dropouts (all $p < .05$).

The mean Academic Skills Cluster for the NBW group did not differ significantly by gender (males vs. females 94.3 ± 14 vs. 97.8 ± 12). However, there were significant differences according to the presence or absence of ADHD symptoms (77.8 ± 15 vs. 97.5 ± 12), race (black vs. white 94.3 ± 12 vs. 101.1 ± 14), maternal marital status (unmarried vs. married 92.8 ± 14 vs. 100.3 ± 11), and maternal level of education ($\leq$high school 90.2 ± 13 vs. $>$high school 100.3 ± 11), all $p < .01$. Pearson correlations with the Academic Skills Cluster were $r = -.22$ for the Parent Protection Scale, $-.34$ for the Perceived Neighborhood Scale, $-.42$ for the poverty rate, and $-.23$ for the percent of high-school dropouts (all $p < .01$).

Multilevel Predictors of Academic Achievement

Individual, family, and neighborhood risk factors considered in the multilevel analyses are described in Table II. As a first step in the analyses, birth weight status was included to provide an appropriate baseline model for comparison without individual, family, or neighborhood predictors (Model 0). As a second step, we assessed the influence of individual factors (Model A). The next step aimed to differentiate individual effects from family effects while controlling for confounding (Model B). The final analysis tested the hypothesis of neighborhood effects on academic achievement over and above the individual and family factors (Model C). Models A–C were also evaluated in terms of the percent reduction in within- and between-tract variance they achieved relative to Model 0. As discussed by Singer (1998) and Snijders and Bosker (1994), these can be interpreted as percentages of the explainable between- and within-tract variance that can be explained by the fitted model. Interactions of birth weight status with individual, family, or neighborhood factors were examined to determine if the effects of these factors varied by birth weight status. The results of the multilevel analyses are presented in Table III and further described below.

Null Model (Model 0)

The null model estimated the variance between census tracts compared to the variance within census tracts providing a baseline against which to compare the more complex models. The observed between-tract variance was significantly nonzero ($p = .0011$) and the intraclass correlation was .26, supporting the appropriateness of a multilevel approach. The AIC was 2952.9.

Individual Predictors Analysis (Model A)

Birth weight status, male sex, and the presence of ADHD symptoms were significant risk factors for poor academic achievement. Model A explained an additional 7.7% of the between- and 7.5% of the within-tract variance in Model 0.

Individual and Family Predictors Analysis (Model B)

The individual (birth weight status, sex, and presence of ADHD symptoms) and family risk factors (race, maternal education, and parent protection) continued to predict academic achievement. This model accounted for 48.5% of the between-tract variance and 22.2% of the within-tract variance. By adding family factors to the individual level

Table III. Multilevel Predictors of Academic Achievement

	Model 0	Model A	Model B	Model C
Intercept, β [95% CI]	97.1 [94.7, 99.3]***	99.4 [96.8, 101.8]***	104.9 [97.9, 111.9]***	100.1 [92.3, 107.8]***
Fixed effects				
Individual characteristics				
Birth weight status[a]	−7.6 [−10.5, −4.7]***	−6.4 [−9.3, −3.5]***	−5.9 [−8.5, −3.3]***	−6.4 [−8.9, −3.8]***
Male sex		−5.0 [−8.1, −1.9]**	−4.6 [−7.4, −1.9]**	−4.3 [−7.0, −1.6]**
ADHD symptoms[b]		−9.7 [−14.3, −4.9]***	−7.2 [−11.6, −2.9]**	−6.9 [−11.2, −2.7]**
Family characteristics[c]				
Education[d]			−8.3 [−11.1, −5.5]***	−7.6 [−10.5, −4.8]***
Black race[e]			−3.9 [−7.2, −0.7]*	−2.2 [−5.7, 1.2]
Unmarried			−2.1 [−5.1, 0.9]	−1.0 [−4.0, 2.0]
Parental protection			−0.4 [−0.6, −0.1]**	−0.3 [−0.6, −0.1]**
Neighborhood perception			−0.01 [−0.1, 0.1]	0.04 [−0.1, 0.1]
Neighborhood characteristics				
Poverty rate[f]				−0.2 [−0.3, −0.05]**
High school dropouts[f]				−0.1 [−0.2, 0.2]
Random effects				
Between-tract variability	58.4 [33.6, 125.3]***	53.9 [31.3, 114.0]***	30.1 [15.3, 84.3]**	30.5 [15.7, 82.0]**
Within-tract variability	163.5 [132.6, 206.7]***	151.3 [122.9, 190.8]***	127.2 [103.9, 159.3]***	123.5 [100.9, 154.7]***
Variance explained[g]				
Between-tract variability	0	7.7%	48.5%	47.8%
Within-tract variability	0	7.5%	22.2%	24.5%
AIC	2952.9	2904.6	2810.2	2806.1
Model comparison[g]		48.3	142.7	146.8

Note. CI, confidence interval.
[a]ELBW versus NBW.
[b]Refers to parent ratings of ADHD symptoms—inattentive, hyperactive–impulsive, and combined types (Gadow & Sprafkin, 1997).
[c]Unless otherwise stated, refers to the primary caregiver, which was the biologic or adoptive mother for 164 children [90%] in the extremely low birth weight group and 157 children [89%] in the normal birth weight group.
[d]Primary caregiver education of high school or less.
[e]White race includes two Asian ELBW and two Asian NBW children.
[f]According to 2000 US Census.
[g]Relative to Model 0.
$*p < 0.05$; $**p < 0.01$; $***p < 0.001$.

model (Model A), an additional 14.7% of the within-tract variance and 40.8% of the between-tract variance were explained. Model B showed a considerable improvement in the model fit compared to Model A [AIC change (A – B) = 94.4].

Individual, Family, and Neighborhood Predictors Analysis (Model C)

The individual characteristics continued to be significant risk factors for poor academic achievement. Moreover, the family characteristics including parental education, increased parent protection, and neighborhood characteristics including poverty rate were significantly associated with lower academic achievement. The effect of race on academic achievement was not significant. The explained variance changed only slightly in this model but the model fit improved after adding neighborhood characteristics to the model [AIC change (B – C) = 4.1]. A likelihood ratio test indicated that the final model, with census tract as a random effect, fit significantly better compared to an ordinary least-squares model with only within-tract variability ($p = .0052$).

An additional individual/neighborhood combined model was estimated to determine the exact magnitude of the neighborhood factors on academic achievement unmediated by family factors (data not shown). By adding neighborhood factors to the individual level model, the fit improved as judged by a 38-point reduction of the AIC; however, there was less than fit improvement in the model comparing individual and family characteristics (AIC reduction 94.4). These findings support the hypothesis that the family environment displays a greater influence on school-age academic achievement than neighborhood characteristics.

Interactions with the birth weight status were not significant. Model comparisons showed a significant improvement in the model fit for all models when compared to Model 0 as well as for the combined models (Models B and C), when compared to Model A. For all estimated models, hypothesis tests for random effects indicated statistically significant random variation in academic achievement across census tracts.

Discussion

In this study of 8-year-old children with ELBW and NBW controls, we used a conceptual model based on Bronfenbrenner's framework which explained variation in children's achievement scores. Specifically multiple predictors at the individual, family, and neighborhood levels were independently related to a composite measure of academic skills. The results provide evidence that for both ELBW and NBW populations neighborhood characteristics have direct effects on academic achievement over and above the effects of individual and family variables. As hypothesized, the neighborhood effect as measured by the poverty rate had a significant negative impact on academic achievement. For each unit increase in the poverty rate, there was a 0.2-point reduction in the academic achievement score. Each step in the analyses, which entailed first adding family and then neighborhood factors to the individual model, provided an improvement in the fit of the model and resulted in an increase in explained variance. Individual- and family-level coefficients were stable with and without neighborhood variables indicating that the neighborhood effects were not redundant with any of the individual or family characteristics but contributed independently to the variance in academic achievement. In addition, interactions with the birth weight status were not significant indicating that family and neighborhood influences on academic achievement were similar regardless of the birth weight status.

In early childhood, the neighborhood influences children's development primarily by its effects on parents. With increasing age, as children spend less time at home and more time at school and with peers, the quality of interactions outside of home becomes increasingly important. We found that at the age of 8 years, the family influences on academic achievement were greater than neighborhood influences; however, with increasing age, the neighborhood factors may play an increasingly prominent role. Although larger effects on academic achievement were observed for family attributes, the magnitude of neighborhood effects observed in this study is surprising given the likelihood that parents of school-age children may regulate their children's direct exposure to the neighborhood environment. The observed negative effect of the neighborhood may be due to intrinsic mechanisms such as lack of educational resources (e.g., parks, libraries, children's programs), lack of social networks, negative peer influence, low parental expectations, low emphasis on school and work skills, and lack of adult monitoring (Brooks-Gunn et al., 1997; Sampson & Morenoff, 2002). The fact that both family- and neighborhood-level factors had strong effects on academic achievement, even after controlling for birth weight status, further suggests that our results have relevance for both ELBW and NBW populations. For example, the positive effect of higher maternal education and the detrimental effects of disadvantageous neighborhoods were observed for the total sample regardless of birth weight status.

Our results support the findings of previous research with regard to individual and family determinants of academic achievement of children with ELBW at school age (Hack et al., 1992; Klebanov et al., 1994; Taylor et al., 2006) and extend those findings by demonstrating the impact of both the distal (e.g., neighborhood) and proximal contexts (e.g., individual and family) on academic achievement within a multilevel model. Specifically, we found that being born ELBW, male sex, and the presence of ADHD symptoms are risk factors for poor academic achievement even after controlling for neighborhood and family risk factors. Also in line with previous research, caregiver level of education had a strong positive association with academic achievement (Bradley & Corwyn, 2002; Klebanov et al., 1994). Children whose mothers had more than high school education scored almost 8 points higher in achievement tests than those whose mothers had a high school level of education or less. One of the mechanisms through which maternal education might operate is parental involvement since educated parents are more likely to attend school programs and extracurricular activities than noneducated parents (Kohl, Lengua, & McMahon, 2000). The parents' education may however also reflect genetic influences.

Our results indicate that increased parental protection had a negative effect on academic achievement, even after controlling for family sociodemographic characteristics. Increased parental protection may give children little or no latitude in making decisions and may thus impede their development and academic achievement (Thomasgard et al., 1995). An alternative explanation is that children with academic and health problems elicited increased parental protection (Thomasgard et al., 1995). In our recent study on parental protection of this cohort which included the neurologically abnormal subset of children, we found that child neurologic abnormality was one of the major determinants of increased parental protection (Wightman et al., 2007). Increased parental protection is also more common in low-income families and poor neighborhoods and may represent an adaptive response to dangers posed by such neighborhoods (McLoyd, 1998). However, our results indicate a significant effect of parent protection regardless of neighborhood determinants. We found no relationship between race and academic achievement indicating that the reported racial gap in academic achievement may be explained primarily in terms of the socioeconomic factors associated with race, such as poverty and community neighborhood effects including poor schools (Lee, 2002; McLoyd, 1998). Caregiver marital status was also not associated with academic achievement. Previous studies demonstrating this association failed to control for many family risk factors included in our analyses, and hence the relation to martial status may reflect confounds with other factors (Brooks-Gunn et al., 1997).

The strengths of this study include our use of multilevel analyses. Previous estimation of neighborhood effects on academic achievement has to a large extent been based on ordinary least-squares regression models (OLS) (Diez-Roux, 2000; Raudenbush & Bryk, 2002). A multilevel approach not only evaluates the incremental contributions of various levels of context but also accounts for the fact that individuals may be clustered within neighborhoods that have particular characteristics. Additionally, most previous research on neighborhood effects has been limited by the exclusive use of census-based measures and has not included neighborhood risk as perceived by residents themselves. The outcome measure we used, the Woodcock–Johnson Tests of Achievement (Woodcock et al., 2001) is normed on a diverse population and regarded as unbiased with regard to race, gender, and socioeconomic factors. Furthermore, the study sample included children born after 1990, a period of increased survival and morbidity among preterm children.

Limitations include the fact that we lacked a comprehensive measure of parenting and that the magnitude of the neighborhood effects may reflect the influence of other individual and family factors not included in the study. In additional analyses to investigate potential mediating effects, neighborhood coefficients remained stable, supporting the existence of direct neighborhood effects on achievement unmediated by family characteristics. Potentially important factors, such as quality of schools, friendship networks, or nonparental adult monitoring, were not considered in the study. Furthermore, our study population represents an urban tertiary perinatal center which includes more persons of lower social class and minority race than the general US population and may thus not be applicable to other populations in the United States.

In conclusion, the results of this study stress the importance of neighborhood factors on children with ELBW and NBW control's academic achievement, especially in poor urban minority communities. The findings also demonstrate the importance of considering school and other community-level supports and barriers on achievement in seeking ways to enhance educational outcome in children at biologic risk for learning problems and in the general population. Understanding the effects of the distal social environment on academic development of preterm children is critical to developing appropriate response strategies and improving the options available to families and schools. By rising the possibility that interventions structured to address family and neighborhood contexts may be more effective than those focusing only on individual factors such as birth weight status of the child, these findings have implications for changes in public policy.

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