Low Birth Weight and Cognitive Outcomes: Evidence for a Gradient Relationship in an Urban, Poor, African American Birth Cohort

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This study is one of the first to investigate the relationship between low birth weight and cognitive outcomes in an urban, poor, prospectively designed African-American birth cohort. Multivariate analyses of the Pathways to Adulthood study, a subset of the Johns Hopkins Collaborative Perinatal study, compared low birth weight African-American children with normal birth weight African-American children on the Wechsler Intelligence Scale for Children (WISC) at seven years of age. When controlling for various sociodemographic factors, associations were obtained for the very low birth weight group (less than 2000 g) indicating an overall 7 point IQ difference. Milder associations were reported in the moderately low birth weight (MLBW) group (2000 to 2500 g) resulting in a 3 IQ point decrement compared to a normal birth weight reference group. There were no differential effects for gender. Our study revealed a gradient relationship between low birth weight/preterm birth and cognitive ability. Implications for school psychology prevention, assessment, and intervention are discussed.

Keywords: low birth weight, intelligence, African American, Collaborative Perinatal Project, premature birth

Low birth weight (LBW) and prematurity are related phenomena about which more has been written with regard to developmental outcomes than any other set of variables in the prenatal and perinatal literature (Aylward, Pfeiffer, Wright, & Verhulst, 1989; Bhutta, Cleves, Casey, Cradock, & Anand,

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2002; Shenkin, Starr, & Deary, 2004). Researchers have preferred birth weight to premature birth, because birth weight often has been a readily available and accurate measure, although future research studies will benefit from advances in obstetrical technology that provides more precise gestational age measurement. Research investigating the relationship between LBW/preterm birth and cognitive ability has been the subject of great interest. However, this literature base represents only a subset of the extant LBW/preterm birth research. For decades, researchers have investigated issues of etiology and associated economic, social, medical, and psychological correlates of being born too early or with LBW.

It now has been firmly established that children born with very LBW (i.e., <1500 g or 3.5 lbs; VLBW) are at an increased risk for reduced scores on measures of intelligence. Children born with moderately LBW (i.e., 1500 to 2499 g, 3.5 to 5.8 lbs; MLBW) are at risk for similar, albeit less severe, outcomes. However, the research base is far less available within the MLBW category. The vast majority of LBW studies have focused on the VLBW (i.e., <1500 g) or extremely low birth weight (ELBW) (i.e., <1000 g) categories. These birth weight categories encompass only 15% of all LBW births and approximately 1.2% of all births in a given year (World Health Organization, 1980). When MLBW outcome studies are available, they typically are presented as an adjunct to a VLBW study. Furthermore, there is a paucity of LBW outcomes studies stratified by ethnicity, particularly African American. This too represents a significant gap in the research base (Fuller, 2000). By necessity, therefore, our literature review will be broader in scope, encompassing heterogeneous populations.

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ASSOCIATION WITH COGNITIVE OUTCOMES

The LBW-cognitive ability literature is voluminous, ranging from small sample case-control studies to studies utilizing regional and national birth cohorts. In fact, Shenkin et al. (2004) indicated that there are more than 3000 citations with the keywords birth weight and intelligence. Regardless of the type of research design, the accumulated literature indicates a gradient relationship between LBW and intelligence, even when accounting for socioeconomic status. Thus, the cutoff for normal birth weight at 2500 g is somewhat arbitrary because IQ scores tend to increase up until about 4500 g (i.e., 10 lbs), after which point IQ scores tend to decrease. The hypothesis regarding the increasing IQ test scores is that infants who weigh more at birth, after adjusting for parental stature, likely experienced an optimal intrauterine environment that fostered their physical and neurological development. Babies born greater than 4500 g may be born to mothers who experienced gestational diabetes or some other complication of pregnancy that contributed to a less than optimal fetal environment (Ornoy, 2005). Bhutta et al. (2002) reviewed the cognitive outcomes literature on preterm infants published since 1980. Given the parallel relationship between birth weight and preterm birth and the breadth of the Bhutta et al. meta analysis, its conclusions are relevant. The results of their meta-analysis, comprised solely of case control studies, demonstrated the direct proportionality of gestational age with cognitive outcomes. The findings of the Bhutta et al. (2002) meta-analysis further suggested a weighted mean difference of 10.9 points on tests of cognitive ability between infants born preterm even when controlling for sociodemographic factors. Other comparable large-scale LBW studies using regional or national cohorts and sophisticated multivariate techniques have found a similar adverse impact on IQ test scores (Horwood, Mogridge, & Darlow, 1998; Stjernqvist & Svenningsen, 1999; Taylor, Klein, Minich, & Hack, 2000). These studies indicate that VLBW infants (<1500 g) tend to fair worse than their MLBW counterparts.

Although the research base is fairly abundant on the relationship between LBW and global intelligence test scores (e.g., full-scale IQ), the body of knowledge is less available on the relationship between LBW and intelligence test scores at the index and subtest level. An understanding at this level of analysis might determine the existence of particular LBW cognitive profiles and illuminate more specifically cognitive abilities at risk in children with LBW. For instance, studies have reported selective impairments in cognitive abilities such as mental arithmetic, visual-motor skills, spatial abilities, expressive language, and memory (Hack, Breslau, Aram, & Weissman, 1992; Halsey, Collin, & Anderson, 1993; Klein, Hack,

& Breslau, 1989; Teplin, Burchinal, Johnson-Martin, Humphry, & Kraybill, 1991; Vicari, Caravale, Carlesmio, Casadei, & Allemand, 2004). In the few studies that distinguish gender, the cognitive outcomes for males tend to be worse than for females, particularly if the baby was born with VLBW or ELBW (Whitfield, Gruanu, & Holsti, 1997). This line of research substantiates the need for future research that evaluates not only separate male/female outcomes but also controls for gender effects within any gender-combined total analysis. In addition, there is a clear need to investigate LBW outcomes for African American populations. The research that investigates specific African American LBW outcomes is conspicuously absent, despite the twofold increase of prematurity in African American (14%) infants compared to their European American (7%) counterparts (Reichman, 2005; Wen, Smith, Yang, & Walker, 2004). Thus, despite the volumes of available literature on LBW outcomes, there is significant need for studies focused on MLBW outcomes, particularly using longitudinal designs and large samples from regional or national cohorts that include African American samples.

The primary purpose of this study was to report the results of a prospectively designed, African American birth cohort investigating LBW birth in relation to cognitive outcomes at age 7 years. This study's unique features include the use of a prospective design, the capacity to investigate MLBW outcomes, and random sampling of an African American cohort from an impoverished urban region with 50% of the population below the poverty level. It also is able to control for numerous confounding sociodemographic and maternal variables including maternal parity, age, education level, and poverty level. Finally, it provides for separate male/female and combined gender analyses and shows the relationship among cognitive ability, gestational age, and birth weight.

METHOD

Participants

The participants for this study were part of the Pathways to Adulthood study, a randomly selected subsample from the population in the Johns Hopkins Collaborative Perinatal Study (JHCPS), itself a component of the Collaborative Perinatal Project (CPP) of the National Institute of Neurologic and Communicative Disease and Stroke. Please see Hardy et al., 1997, and Hardy & Shapiro, 1999, for further details regarding this study. Despite its age, the CPP still remains an unparalleled longitudinal investigation of prenatal and perinatal factors in relation to later offspring outcomes. At the completion of CPP data compilation, several of the original contributors commented, “it is unlikely that such a study will be undertaken again. . .” (p. viii) due to the significant cost and time commitment required (Sever, Olsen, Hinds, Watson, Perin & Littlefield, 1983). With the possible demise of the *National Children’s Study*, a proposed multiagency longitudinal study that would follow a nationally representative cohort of 100,000 children from conception through age 20, Sever et al.’s statement continues to be supportable.

The cohort mothers who enrolled in the study lived in east Baltimore, mostly within a 10-block radius of the Johns Hopkins University hospital, and attended the Johns Hopkins public obstetric clinic between 1959 and 1965 for their first prenatal visits. Of the original JHCPS, a subsample (n = 2694) of children were selected randomly for follow-up from those whose mothers had started prenatal care after January 1, 1960. Of these children, 2309 children had complete data involving maternal characteristics such as age, parity, poverty level, and educational level, children’s gestational age and birth weight, and complete Wechsler Scales for Children (WISC) IQ results. Of this sample, only African American mothers and their children (n = 1884; 81.6%) were analyzed.

Cohort Characteristics

Table 1 provides obstetric and sociodemographic data on maternal characteristics including age, parity, poverty level, and education level. Perinatal data on cohort children included gestational age and birth weight. Twenty-five percent of cohort mothers were <20 years old when their children were born. Educational attainment among mothers was generally low; only 28.8% of cohort mothers had completed high school.

The poverty index, provided in Table 1, represents the ratio of the family’s annualized income at the cohort child’s birth to the poverty level. For example, if the annualized income of the family equaled $8,000 while the poverty level was $10,064, then the poverty index ($8,000/$10,064) equaled 0.795. A poverty index of 1.0 represents a family living at the poverty level. At birth, approximately 50% of cohort children lived in families at or below the poverty level, and only approximately 10% had an income greater than twice that level. The poverty index statistics was based on United States Department of Agriculture standards for 1960 through 1992, which takes account of family income, size, and inflation rate (Social Security Bulletin, 1993).

Table 1. Cohort Characteristics

	n	Percentage
Child gender		
Male	943	50.05
Female	941	49.95
Total	1,884	100.0
Average WISC scores (total sample)		
Full Scale IQ	91.6	
Verbal IQ	91.5	
Performance IQ	93.3	
Maternal parity		
Primimparous	531	28.2
Multiparious	1,353	71.8
Total	1,884	100.0
Maternal education level		
Less than eighth grade	258	13.7
Eighth grade	250	13.3
Some high school	832	44.2
High school graduate	423	22.4
Some college	109	5.8
Bachelors or higher	12	0.6
Total	1,884	100

	Mean	% 25	% 75	% 90	*SD*
Maternal age	25.3	19.6	30.4	35.7	7.3
Poverty index level	1.15	0.68	1.45	2.05	0.71

Note. WISC = Wechsler Scales for Children.

Materials

All outcome measures were obtained from the Baltimore Pathways to Adulthood study, but were initially part of the JHCPS.

Children were assessed on the WISC (1949). The WISC included four verbal subtests (information, comprehension, vocabulary, and digit span) and three performance subtests (picture arrangement, block design, and coding). Tests results included a verbal IQ index, performance IQ index, and a full-scale IQ index. Standardized scores had a mean of 100 and a standard deviation of 15. Subtest scaled scores had a mean of 10 and a standard deviation of 3.

Data Analyses

Multivariate and univariate analysis of covariance (MANCOVA and ANCOVA, respectively) procedures were used to investigate whether a relationship exists between birth weight and the various cognitive outcomes. Because of the potentially confounding effects of gender, parity, poverty level, educational level, and maternal age, these variables in all analyses were controlled for statistically through the use of covariance procedures. Because maternal educational level and maternal poverty level produced a 0.28 correlation, both variables were incorporated in our statistical models. In addition, Tukey post hoc analyses were used following a significant ANCOVA result. For purposes of our analyses, MLBW was defined as 2000 to 2500 g, whereas VLBW was defined as <2000 g.

RESULTS

WISC

The WISC was analyzed at both the full-scale and verbal/performance index level, as well as at the individual subtest level (see Table 2). A series of ANCOVA models were used to investigate the relationship between birth weight and cognitive ability at the full-scale, verbal, and performance levels. A series of MANCOVA models with follow-up ANCOVAs were used to investigate the relationship between birth weight and the verbal and performance subtests. All analyses were conducted by using a combined total sample as well as with separate male and female subsamples. Because all MANCOVAs and follow-up ANCOVAs for the verbal and performance subtest analyses were significant, Tukey's Honestly Significantly Differences (HSD) post hoc procedures were used to determine which subtests were significantly different. Similarly, ANCOVAs at the full scale and index levels (verbal and performance) were significant (see Table 2), so Tukey's HSD post hoc procedures were used to determine which birth weight categories were significantly different. Table 2 summarizes mean full-scale IQ, verbal IQ, performance IQ, and the verbal and performance subtest standard scores. All means have been adjusted for the covariates (e.g., parity, maternal age, education level, poverty index, and gender). Post hoc (Tukey) analyses revealed a similar trend, regardless of subsample analyzed (total, male only, female only). See the superscript in the title and legend at bottom of table for further clarification of the significant relationships.

An inspection of the means, adjusted for the covariates, clearly shows a trend with respect to full-scale IQ. Children with the lowest birth weights scored the lowest on measures of IQ, followed by MLBW and then normal birth weight. This trend was maintained with respect to separate gender analysis, and there were no gender by birth weight interactions. At both the MLBW and VLBW levels, Tukey post hoc procedures revealed a signifi-

Table 2. Wechsler Scales for Children (WISC) Scores

Birth weight (g)	ANCOVA			MANCOVA w/Follow-up ANCOVA								
				Verbal Subtests				Perf. Subtests				
	FSIQ[a]	VIQ[a]	PIQ[b]	Inf[b]	Co[d]	Voc[c]	DS[c]	PA[e]	BD[f]	Cd[f]	*n*	% Total
<2000												
Total	85.5	85.3	88.3	7.7	7.7	7.4	7.8	7.5	8.3	9.2	85	4.5
Male	84.5	85.3	86.6	7.7	7.9	7.3	7.8	7.4	8.2	8.7	37	2.0
Female	86.2	85.1	89.8	7.6	7.6	7.5	7.8	7.7	8.3	9.6	48	2.5
2000 to 2499												
Total	89.6	89.4	91.8	8.6	7.9	8.2	8.6	8.4	8.4	9.6	183	9.7
Male	90.0	90.6	91.3	8.6	8.3	8.5	8.5	8.6	8.5	9.2	107	5.7
Female	89.4	88.5	92.4	8.5	7.6	7.8	8.7	8.3	8.4	10.1	76	4.0
Total low birth weight											268	14.2
2500–2999												
Total	91.1	91.1	92.7	8.7	8.4	8.5	8.7	8.6	8.6	9.7	576	30.5
Male	90.0	90.4	91.3	8.3	8.5	8.6	8.5	8.6	8.5	9.2	307	16.3
Female	92.2	91.7	94.1	9.0	8.3	8.3	9.0	8.6	8.6	10.2	269	14.2
3000–3999												
Total	92.7	92.5	94.3	9.0	8.6	8.5	9.1	8.7	8.9	9.9	990	52.5
Male	91.9	92.4	92.9	8.9	8.7	8.7	8.9	8.7	8.7	9.5	471	25.0
Female	93.5	92.6	95.8	9.1	8.6	8.3	9.3	8.8	9.0	10.0	519	27.5
>4000												
Total	93.8	93.2	95.5	9.3	8.3	8.2	9.8	8.8	9.3	10.0	50	2.7
Male	93.3	92.5	95.3	8.9	8.3	8.2	9.7	9.0	9.3	9.7	19	1.0
Female	93.6	93.9	94.4	9.6	8.3	8.3	9.9	8.2	9.1	10.2	31	1.6
Total	91.6	91.5	93.3 (unadjusted means)								1,884	100.0
SD	11.5	11.6	12.9 (total sample)									

Note. Level 1 <2000 grams; level 2, 2001–2500; level 3, 2500–3000; level 4, 3000–3999; level 5, >4000. Total Sample ANCOVAs: Full-scale IQ ANCOVA F (4, 1870) = 6.03, p = .0001; Performance IQ ANCOVA F (4, 1870) = 2.95, p = .019; Verbal IQ ANCOVA F (4, 1870) = 11.14, p = .0000; Male Only ANCOVAs: Full-scale IQ ANCOVA F (4, 934) = 5.85, p = .0001; Performance IQ ANCOVA F (4, 934) = 3.37, p = .0095; Verbal IQ ANCOVA F (4, 934) = 5.51, p = .0002; Tukey Post Hoc Analyses (Total, Male, Female): [a] Tukey post hoc analysis = 1 with 2, 3, 4 and 5; 2 with 4. [b] Tukey post hoc analysis = 1 with 2, 3, 4 and 5. [c] Tukey post hoc analysis = 1 with 3, 4 and 5. [d] Tukey post hoc analysis = 1 with 4; 2 with 4. [e] Tukey post hoc analysis = 1 with 3 and 4. [f] Not significant; Female Only ANCOVAs: Full-scale IQ ANCOVA F (4, 932) = 6.48, p = .0000; Performance IQ ANCOVA F (4, 932) = 3.21, p = .0124; Verbal IQ ANCOVA F (4, 932) = 6.69, p = .0000; Verbal Subtests MANCOVAs: Total sample Wilks' λ = 0.8738, F (9, 1874) = 7.14, p = .00000; Male only Wilks' λ = 0.8847, F(8, 934) = 8.63, p = .0000; Female only Wilks' λ = 0.8771, F(8, 932) = 3.88, p = .0000; Performance Subtests MANCOVAs: Total sample Wilks' λ = 0.9131, F(9, 1874) = 6.40, p = .00000; Male only Wilks' λ = 0.9416, F(8, 934) = 2.36, p = .0002; Female only Wilks' λ = 0.9124, F(8, 932) = 3.61, p = .0000; ANCOVA = analysis of covariance; MANCOVA = multiple analyses of covariance; FSIQ = full-scale IQ; VIQ = verbal IQ; PIQ = performance IQ; Inf = Information; Co = Comprehension; Voc = Vocabulary; DS = Digital Span; PA = Picture Arrangement; BD = Block Design; Cd = Coding. Means adjusted for covariates.

cant full-scale and verbal IQ difference from the normal birth weight comparison (see Table 2). Tukey post hoc analyses further revealed that only the VLBW level was statistically different from the other levels on the performance IQ index. This pattern was consistent across all analyses (total, male only, female only).

Children in the lowest birth weight category had lower IQ levels compared to children in the MLBW category. When compared with the normal birth weight category of 3000 to 3999 g, which comprises the majority of normal birth weight infants, children with VLBW experienced a difference on the WISC full-scale IQ, verbal IQ, and performance IQ indices of 7.2, 7.2, and 6.0, respectively. MLBW infants experienced a difference of 3.1, 3.1, and 2.5, respectively. Furthermore, the infants in the VLBW group full-scale IQ was statistically different from all other birth weight categories analyzed, including the MLBW category.

An ANCOVA, $F(3, 1213) = 2.91$, $p = .03$, investigating birth weight by gestational age by full-scale IQ revealed a linear trend with respect to full-scale IQ, birth weight, and gestational age. These results are presented in Table 3, and the relationship between birth weight and full-scale IQ is depicted in Figure 1. As noted, children with the earliest gestational age and lightest birth weight were found to have the lowest cognitive ability, demonstrating a clear gradient relationship.

WISC Subtest Analyses

To examine birth weight at the subtest level, a series of MANCOVAs (total, male, female) were used to analyze the verbal (information, comprehension, vocabulary, digit span) and performance (picture arrangement, block design, coding) subtests. Since all MANCOVAs were significant, they were followed up with ANCOVAs and then Tukey post hoc analyses. Follow-up ANCOVAs (total sample, male only, female only) for each subtest revealed significant effects for all subtests, with the exception of

Table 3. Full-Scale IQ—Gestational Age by Birth Weight

		Birth weight (g)						
Weeks	*n*	<2000	2000–2499	2500–2999	3000–3999	>4000	Average	*SD*
≤32	56	85.8	86.7	87.3	88.8	n/a	85.4	13.2
33 and 34	58	89.6	90.6	91.2	92.6	n/a	90.6	10.7
35–37	217	89.5	90.5	91.1	92.5	93.9	90.7	11.3
38+	897	90.8	91.8	92.4	93.8	95.3	93.3	11.9
Total	1,228	85.5	90.4	91.7	93.5	95.7	92.3	11.9

Note. Sample size = 1,228, reflecting 659 sample data loss from birth weight total cohort. ANCOVA $F(3, 1213) = 2.91$, $p = .03$.

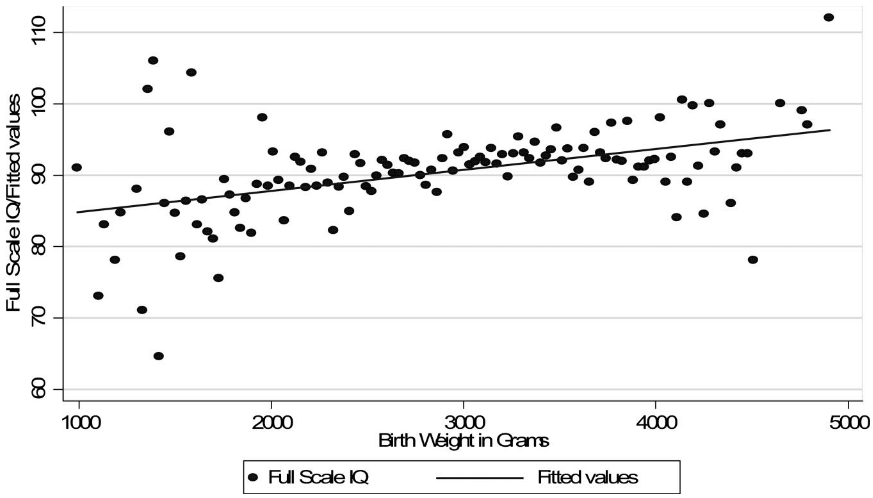

Figure 1. Relationship between birth weight and full-scale IQ.

block design and coding. Block design and coding were found to be nonsignificant. In all other subtests, except comprehension, Tukey post hoc analyses revealed that the lowest birth weight group (<2000 g) was significantly different from the remaining levels of birth weight. On the comprehension subtest, the MLBW level (2000 to 2500 g) also was significantly different from children with normal birth weight (i.e., birth weights of 3000 to 3999 g). As noted in Table 2, this pattern of Tukey post hoc significant results was consistent across all the total sample analysis and the separate male/female analysis.

DISCUSSION

Our investigation of an urban, poor African American cohort produced findings consistent with the extant LBW literature base. Children born with VLBW (<2000 g) experienced more depressed cognitive ability scores compared with children in the MLBW group (2000 to 2500 g). There were no differential effects with respect to gender. More specifically, the results of our study revealed an approximate seven-point difference between VLBW and normal birth weight and a three-point difference with MLBW. These IQ differences are consistent but slightly lower than those reported in the birth weight literature. For instance, a quality systematic birth weight review indicated a 10-point IQ difference between the lightest and heaviest groups, which attenuated, but remained statistically significant, when the confounding variables were controlled for in the analyses (Shenkin et al., 2004).

There are a number of possible explanations for this difference. First, our VLBW category contains children who were born with birth weights of 1501 to 1999 g. In other studies, this range would be categorized as MLBW, with VLBW being reserved for infants <1500 *g*. Thus, the inclusion of these heavier (e.g., 1500 to 1999 g) infants could have skewed upward the average cognitive ability results within this group. A second explanation also is possible. Because of sampling limitations, we did not exclude from our analysis those infants born with intrauterine growth restriction (i.e., small for gestational age infants). These infants tend to experience some of the more deleterious neurocognitive outcomes and are sometimes excluded from LBW studies and studied separately (Hack, 1998). Third, in the late 1950s and early 1960s, the field of neonatology was less sophisticated than it is today. As a result, some of the more medically fragile infants would not have survived, whereas others that did survive might face increased disabilities because of improper or nonexistent medical intervention. Thus, it is possible that our study includes fewer of the more medically fragile infants and a higher percentage of surviving infants who experienced greater cognitive morbidity. Fourth, our sample is homongenous, comprised of an urban, poor, African American cohort. Perhaps LBW/preterm birth has a differential effect with respect to ethnicity and poverty? This question deserves further study. To our knowledge, our study represents one of the first to investigate this topic using an African American birth cohort. Finally, instead of case-control analyses, we used multivariate analyses, which allows for a more precise statistical control of confounding variables. This too might have accounted for some of the difference in results.

The results of our study in relation to intelligence test scores suggest that MLBW infants may escape some of the more deleterious effects faced by their VLBW counterparts. Although statistically significant differences of approximately three IQ points have been found in the children in the MLBW group, these results are perhaps less meaningful from a clinical standpoint. Finally, the results of our study suggest a linear trend and quite possibly a phenomenon akin to a dose-response relationship with respect to LBW. On measures of IQ, VLBW children performed more poorly than MLBW infants, who in turn performed worse than their normal birth weight peers. This would point to the need for additional studies that investigate whether heavier birth weight infants, when controlling for gestational age and size of parents, might produce higher IQ outcomes. It also suggests that the normal birth weight cutpoint of 2500 g is somewhat arbitrary.

The results of our study did not furnish evidence for a LBW cognitive profile through an investigation of WISC subtests. In fact, the results of our study produced a finding that is somewhat inconsistent with the literature. Two subtests that are often purported to measure perceptual-motor ability—block design and coding—were nonsignificant. The literature has reported a fairly strong relationship between birth weight and visual-motor skills and spatial abilities (Davis, Burns, Wilkerson, & Steichen, 2005; Halsey et al., 1993; Ornstein, Ohlsson, Edmonds, & Asztalos, 1991). Another interesting result was that performance on the verbally laden verbal index was more adversely impacted than performance on the nonverbal performance scales. Again, this is inconsistent with other studies that report greater deficits in nonlanguage-based skills (Davis et al., 2005). Overall, the results of our findings do not suggest a specific and distinct cognitive profile. Instead, the results suggest a more global impact on cognitive ability. In fact, our findings are consistent with the literature that eschews subtest profile analysis in favor of analysis at broader index levels because of a lack of consistent evidence that points to a distinct subtest profile among populations with and without disabilities (Watkins, Glutting, & Youngstrom, 2005).

Limitations

The findings of our study ought to be viewed in light of the following limitations. First, we did not exclude LBW for gestational age children from our analysis, because this exclusion would have severely constrained the sample available for analysis. Second, we were unable to control for additional factors that have been linked to LBW, such as maternal smoking, substance use, maternal pregnancy weight gain, and maternal infection (Chomitz, Cheung, & Lieberman, 1995; Dombrowski, Martin, & Huttunen, 2005; Martin, Dombrowski, Mullis, Wisenbaker, & Huttunen, 2006). Third, advances in neonatal and obstetric technology now have the capacity to save medically fragile LBW children or palliate the ill effects of LBW, which could not occur during the late 1950s and early 1960s. These infants tend to experience the most adverse neurocognitive outcomes. Finally, the original WISC has been criticized as culturally biased. This would constrain to some degree the generality of our findings. However, we used only the African American cohort in our analysis. Despite these limitations, our investigation of an urban, poor African American cohort produced findings consistent with the extant literature and represents one of the few times that a homogeneous, prospectively designed study has been conducted on this population.

Mechanisms of Perturbation and Periods of Vulnerability

Increasing research suggests that the outcomes associated with LBW/ preterm birth have a neurodevelopmental origin. Both human and experimental animal research indicates that being born too early can contribute to abnormal neuronal development and reduced brain volumes (Bhutta & Anand, 2001; Peterson et al., 2000). For instance, Bhutta and Anand (2001) report smaller volumes of the sensorimotor cortex and the surrounding cortex, corpus callosum, amygdala, hippocampus, and basal ganglia in preterm children. In addition, neuroimaging and ultrasound studies have shown that premature neonates, particularly those born before 33 weeks' gestation, are prone to germinal matrix and intraventricular hemorrhage, hydrocephalus, and infarction of the periventricular region and cerebral cortex (Paneth, Rudelli, Kazam, & Monte, 1994). The vast majority of brain-imaging studies has focused on children born very early and with VLBW or ELBW. Thus, the putative cause of adverse developmental sequelae in MLBW children (typically >33 weeks' gestation) has not been a frequent topic of investigation. Thus, there is significant need not only for additional developmental outcomes studies with MLBW children, but also for brain imaging studies that could lead to a better understanding of the etiology of the adverse developmental outcomes. Although an exploration of the etiology of MLBW is not the focus of this study, our discussion of the mechanisms of perturbation underscores a more general need for additional MLBW research that focuses on not only outcomes, but also the neurodevelopmental basis for such outcomes.

Implications for Prevention, Assessment, and Intervention

The long-term developmental outcomes associated with LBW/preterm birth represent a public health crisis that deserves greater attention from the school psychology profession. One study revealed that the economic costs of LBW exceed that of AIDS, and rivals that of alcoholism (Lewit, Baker, Corman & Shiono, 1995). Within the African American community, this crisis is even more considerable because African American infants experience a twofold increase in preterm births. School psychologists are in a position to increase awareness not only of outcomes, but also prevention, assessment, and intervention.

Prevention

It has been well established in the literature of the need for prenatal medical monitoring, cessation of smoking, and avoidance of teenage pregnancy (Aylward et al., 1989; Bhutta et al., 2002). Some of the more common, as well as preventable, factors that have been associated with

LBW include access to prenatal medical care that includes monthly obstetric visits, access to information about healthy prenatal development such as appropriate weight gain (i.e., avoid too little or too much), teenage pregnancy, alcohol or drug use, and the importance of smoking cessation (Valero de Bernabe et al., 2004). On this last point, research indicates that cigarette smoking accounts for as much as 20% to 30% of LBW and premature births (Chomitz et al., 1995). Research also indicates that as many as 30% of women in this country continue to smoke during pregnancy (Magee, Hattis, & Kivel, 2004). Thus, smoking cessation for women in their reproductive period represents one of the most important prevention activities that can be undertaken.

However, it also is somewhat naïve and perhaps unrealistic to expect that a woman within a particular impoverished milieu will be able to unilaterally make particular lifestyle changes or gain access to appropriate prenatal care without the support of social and psychoeducational programs. Many women who smoke during pregnancy, eat poorly, engage in substance use, or lack access to prenatal care also live in impoverished neighborhoods surrounded by violence and a lack of social support (Fuller, 2000). Thus, women from disadvantaged locales tend to experience some of the greatest risk factors for the LBW/preterm births. It is within a school psychologist's purview to facilitate greater community awareness of the need for medical/prenatal care, lifestyles changes, and how to access important social programs. At a broader policy level, school psychologists with the assistance of American Psychological Association Division 16 and the National Association of School Psychologists should consider joining forces with other professional groups such as the American Academy of Pediatrics to raise awareness among policymakers and legislatures about the ill effects of LBW/preterm birth and the subsequent need for prevention activities as part of a comprehensive system of health.

Assessment

We contend that children born prematurely and with LBW should be identified for early assessment. Several states have infant mental health assessment and intervention services. Although some school psychologists have training in infant mental health, many do not. Thus, there are infant mental health specialists with evidence-based programs for children ages birth to three who are available for consultation or collaboration (see http://www.zerotothree.org/imh/training.html for further details). Furthermore, some states (e.g., New Jersey) send out notification to parents and early intervention specialists for the purpose of making a home visit to evaluate infants born prematurely. Unless there are obvious developmental delays, this evaluation might occur anytime after the child's age-adjusted 6-month birthday. The evaluation should be multifaceted and might include a speech-language pathologist, a physical therapist, an occupational therapist, and a school psychologist. If the child is assessed at an age greater than 1 year, an individual with specialized expertise in behavioral and emotional functioning should participate. In fact, school psychologists, with their expertise in assessment, would be valued members of such an assessment team.

From another angle, school psychologists conducting evaluations of school-aged children should focus more explicitly on collecting prenatal and perinatal history. This information should include questions on birth weight, gestational age, length of stay in a neonatal intensive care unit (NICU), need for respiratory therapy, and other intrusive medical procedures or complications. This information may be informative in creating a clearer understanding of why a child might be having a particular academic or behavioral struggle. It also may serve to increase empathy for a particular child's plight. In addition, the field requires the development of additional universal screening instruments incorporating prenatal and perinatal questions that can be administered in a cost-effective manner to LBW children at school entry. This type of assessment may serve to identify students in need of more targeted intervention.

Intervention

Children born too early or with LBW require monitoring for their need for early intervention. This is the case even for children who do not display any obvious signs of adverse impact at birth. Although many children born with LBW escape adverse effects, many others face subtle developmental outcomes that may lie dormant until later in development, such as school entry, when the tasks become more complex. Therefore, we recommend that LBW children be assessed to determine need for intervention. Early intervention projects for LBW and premature infants such as the Infant Health and Development program (Infant Health & Development Program, 1990; Gross, Spiker, & Haynes, 1997) show promise for improving the development of LBW/premature children. This program consisted of home visits (birth to 3 years), parent group meetings, and child development service centers (age 1 to 3 years). At post intervention, moderate gains were noted at age 3. In a follow-up of these children at age 8, attenuation of the initial large gains was noted, but modest intervention related gains (WISC–III full-scale IQ = 4.4; Woodcock Johnson Tests of

Achievement, Third Edition [WJ-III] Math = 4.8) persisted in the MLBW group (birth weight >2000 g) (McCarton et al., 1997). Furthermore, other agencies, such as McGill University's Health Centre, have initiated NICU follow-up clinics where premature infants are monitored well beyond their stay in the NICU for neurodevelopmental and health complications (http://www.muhc.ca/media/ensemble/2005may/neonatal/). As with the Infant Health and Development program, the McGill approach has provided preliminary evidence for developmental improvement. In both programs, children were provided with early intervention cognitive, language, and motor activities to enhance their performance in these areas, and both programs reported initial postintervention positive results.

In summary, there is need for concerted effort to prevent LBW/preterm birth. There also is additional need to intervene in the lives of premature and LBW infants. This need is even more urgent in urban, poor African American populations (Fuller, 2000). School psychologists with their specialized understanding of early childhood development could be at the locus of this effort by facilitating greater prevention, assessment, and intervention activities for LBW/preterm birth infants. This may be done directly or indirectly via consultation, collaboration, or advocacy. Whichever route is chosen, school psychologists should become more fully involved with children who were born too early or with LBW. Although many LBW/preterm birth infants escape the deleterious effects, others will be significant consumers of psychological and educational services in the schools.

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