Low Birth Weight, Socioeconomic Status and Childhood Outcomes:

A Fixed-Effects Analysis

Laura McCallister Prichett, MHS, Johns Hopkins Bloomberg School of Public Health

Department of Population and Family Health Sciences

Contact information:
Address: 305 Thornhill Road, Baltimore, MD 21212
Phone/Fax: (410) 435-0194
E-mail: lprichet@jhsph.edu

Nan Marie Astone, PhD, Johns Hopkins Bloomberg School of Public Health

Bernard Guyer, M.D., MPH, Johns Hopkins Bloomberg School of Public Health

Contact information:
Address: 615 North Wolfe Street
Department of Population and Family Health Sciences
Baltimore, MD 21205-2103
Phone: (410) 955-5000
E-mail for Nan Astone: nastone@jhsph.edu
E-mail for Bernard Guyer: bguyer@jhsph.edu

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Abstract

In this paper, we explore the relationships between birth weight and childhood behavior, health and cognitive abilities using a large (N=3428) nationally representative dataset. The focus of the paper is the contrast among estimates of the effect of birth weight in bivariate models of childhood outcomes, multivariate models that control for observed socioeconomic differences, and models that control for unobserved family characteristics that may underlie both birth weight and subsequent outcomes. There is a small, but statistically significant negative relationship between birth weight and various positive childhood outcomes in bivariate and multivariate models, especially among girls. This effect disappears when unobserved characteristics of families are controlled.

There has been increasing interest in long-term effects of perinatal conditions on outcomes in later life and how the interplay between these conditions and a child's home environment affect well-being throughout life. Researchers seeking to address long-term effects of birth weight have been faced with three major issues.

First of all, data on effects of birth weight have only generally been available from small cohort studies, in which infants are followed over time in order to evaluate the impact of perinatal conditions on development (Hardy et al 1979; Werner & Smith 1977). These studies have found links between birth weight status and later health, behavior, and cognitive problems (Breslau et al 1996; Cohen 1995; Eriksson et al 2001; Ford et al 2000; Gadin & Hammarstrom 2000; Ibanez et al 2000; McCormick et al 1996; Moore et al 1999; Rickards et al 1993; Taylor et al 2000). Using small cohort studies to estimate the long term effects of low birth weight can introduce bias, since the samples for such studies are not usually representative of a particular population; certainly they cannot be generalized to the entire U.S. Additionally, using small datasets lessens the power to detect a difference between the groups involved.

Second, a threshold of low birth weight (<2500g) has typically been used to compare outcomes among low birth weight infants versus normal birth weight infants. Barker, however, found a linear relationship between birth weight and risk for adult disease and argues that there may be important differences in outcomes among people across the full birth weight distribution, which are obscured when birth weight is categorized (1999). Barker has suggested the idea of "fetal programming", that poor fetal nutrition and an inhospitable maternal environment can increase a person's risk for many types of disease, including stroke, coronary heart disease, diabetes, and hypertension (1999). If Barker's findings about health outcomes hold true in other domains of outcome, then researchers should use birth weight as a continuous variable because important effects may continue well into the range of normal birth weights.

Third, previous studies have left unanswered questions when it comes to socioeconomic status (SES) as a potential confounder of the relationship between birth weight and childhood and later outcomes. The general finding of studies is that "…favorable social conditions may significantly buffer children from potential functional limitation and disability associated with [low birth weight]" (Hogan and Park 2000 p.434). But the vast majority of these studies have lacked detailed measures of SES. Indeed, even in the presence of high quality SES measures there is still a good chance that unobserved heterogeneity between the families of normal birth weight and low birth weight infants could be responsible for any relationship found between birth weight and negative outcomes.

The availability of a nationally representative dataset incorporating high-quality measures of socioeconomic status, as well as birth weight and developmental outcomes for children allows us to address these three deficiencies in the literature. We use the Panel Study of Income Dynamics Child Development Supplement (PSID-CDS) a large survey of children ages 0-12 nested within the Panel Study of Income Dynamics (PSID to test for linear relationships between birth weight and various childhood outcomes, while controlling for both observed and unobserved indicators of family background, including SES.

Conceptual Framework

Birth weight has been linked to a number of child and adult behavioral, health, and cognitive outcomes. Breslau and colleagues (1996) found a strong association between birth weight and attention deficit hyperactivity disorder (ADHD) in 6 year olds, even after controlling for economic status. Kelly and Nazroo (2001) found a strong association between birth weight and peer problems in girls and hyperactivity in boys. Consideration of the impact of SES often weakens or nullifies findings about the relationships between birth weight and behavior problems (Breslau et al 1996; Kelly & Nazroo 2001; Richards et al 2001).

As mentioned above, David Barker (1999) has linked birth weight to several adult cardiovascular problems. Other research has also found strong associations between birth weight and health outcomes in later life. Eriksson found a strong relationship between low birth weight and coronary heart disease in Helsinki (Eriksson et al 2001). Currie and Hyson (1999) found a significant negative relationship between self-reported health at ages 23 and 33 and low birth weight status. They also found that high SES protected low birth weight women from a negative self-report of health status.

To explore the impact of birth weight on cognition, cohort studies have given groups of infants cognition tests as they progressed through various ages. Common findings have included: reduced IQ scores, learning difficulties, language development difficulties, and memory problems among low birth weight children (Breslau et al 1996; Gyler et al 1993). Many of these studies have demonstrated positive effects of supportive parenting, or of interventions to improve parenting (Brooks-Gunn et al 1992; Cohen 1995; Hogan & Park 2000). Using a nationally representative dataset from Great Britain, Richards founda relationship between low birth weight and reduced cognition scores on tests conducted at ages 8, 11, 15, 26, and 43 (Richards et al 2001). Conley and Bennett (2000) used data from the Panel Study of Income Dynamics (PSID) to find a strong negative association between low birth weight status and high school graduation. Corman and Chaikind (1998) found strong relationships between low birth weight and repeated grades, poor parent-rated school performance, and placement into special education classes. As with behavior and health, socioeconomic status appears to confound the effect of low birth weight on cognition, although this also depends on the measure used and may be confounded by a positive home environment (Werner & Smith 1982).

The two main problems with the majority of studies cited above have been a lack of generalizeability and power and a deficit of SES measures. Cohort studies often to do not include enough observations to detect small effects of birth weight. Additionally, the cohorts involved in these studies are typically not representative of the entire US (or other) population, making generalizations based on the results more difficult. Finally, previous studies in this field have generally not focused on collecting a broad range of high-quality SES measures, which makes controlling for effects of SES difficult.

We hypothesize that low birth weight is associated with problem behaviors, poor health and low cognitive ability. Additionally, we hypothesize that the positive association between low birth weight and these three outcomes remains statistically significant when home environment and SES are controlled. We also hypothesize that the positive association between low birth weight and these three outcomes is significantly stronger among children from low SES homes than for other children of low birth weight status. Finally, we hypothesize that Barker's (1999) idea of birth weight as impacting outcomes along the entire spectrum on birth weight is useful and will apply to the PSID-CDS.

Method

Panel Study of Income Dynamics Child Development Supplement

The Panel Study of Income Dynamics is a longitudinal survey of three sub-samples: 1) a representative sample of U.S. families in 1968; 2) an oversample of poor families in 1968; and 3) a sample of people from those ethnic groups that have immigrated in large numbers to the U.S. since the 1960s (added in 1990). Since the inception of the study, data have been collected every year from sample members on employment, income, wealth, occupation, food expenditures, marriage, and children. As sample members have had children and the children have formed families, those families have then been joined the PSID sample. As couples divorced, sample members were followed and the resulting new families joined the sample. As a result, the 5,000 original families in the 1968 PSID have grown to over 10,000 families.

In 1997, the PSID instituted the Child Development Supplement. Families eligible for inclusion in the supplemental data collection were all those with at least one child under 12. PSID selected up to two children aged twelve and under per family for inclusion in the study. Over 2500 families were eligible for inclusion in the PSID-CDS, and a total of 3,586 children participated, including 1,134 pairs of siblings. The main respondent for the Child Development Supplement was the Primary Caregiver[1] for the child or children in the PSID-CDS. The Primary Caregiver completed a questionnaire and time diary for each child. Only children over age three were personally interviewed. Whenever necessary and possible, self-administered questionnaires were also sent to a child's other caregiver, father outside the home, teacher or childcare provider, and school administrator (Hofferth et al 2000).

In the following section we describe our outcomes in detail; please see Table 1 for a summary of this information.

Behavior Outcome Measures

[1] The Primary Caregiver (PCG) is usually the child's mother. If the mother is not living with the child, the PCG may be the father, or another family member with primary responsibility for caring for the child.

The indicator of behavioral problems we use is the Behavior Problems Index (BPI). The BPI was developed by Peterson and Zill (1986) in order to evaluate the degree and incidence of behavior problems in children ages 3-12. It is composed of 30 problem behaviors, and the primary caregiver is asked whether their child exhibits each behavior sometimes, frequently, or never. There are two subscales within the BPI, a measure of aggressive, or externalizing problems and one of internalizing problems such as anxiety/depression (Hofferth et al 2000). Our models use each of the subscales, as well as the combined BPI as an outcome measure.

Health Outcome Measures

The first health indicator we use is a combination of several questionnaire items about specific health problems the child faces ranging from depression to asthma to heart problems from the primary caregiver questionnaire. We add these together to create a scale where a child with no health problems has 0, and a child with all possible health problems has a score of 23.[2] We recognize that using this simple additive scale is somewhat unconventional, but our goal is to use this variable to describe a very general picture of a child's health. Although there is a potential for clustering of conditions, especially among children with disabilities, this variable should still be an effective measure of very general health status.

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[2] Scale of 23 health problems is an additive scale of bivariate measures of whether the child has the following: epilepsy, asthma, diabetes, chronic ear infections, speech impediment, hearing difficulties, difficulty seeing, retardation, emotional problems, anemia, high blood lead count, orthopedic impairment, autism, learning disability, autism, hyperactivity, allergies, breathing problems, tonsillitis, heart problems, digestive disorders, hernia, and ever psychological problems.

Second, we utilize the parental rating of each child's general health from the primary caregiver questionnaire. Parents rate their children's health as excellent, good, fair, or poor. In this case, a rating of "excellent" is given a score of 1, whereas a "poor" rating is scored as 4. Both of these health measures are available for all ages.

Cognition Outcome Measures

The PSID-CDS used the Woodcock-Johnson Revised Tests of Achievement to measure cognitive ability. These tests were administered to children ages 3-12, although two subscales of the tests were only given to those 6 -12. For detailed information on the availability of outcome measures by age group, see Table 1. The two reading-related subscales can be combined to create a Broad Reading score, and the two math-related subscales can be combined to create a Broad Math score. We also use these scores as outcome measures in this analysis.

We also use the Memory for Digit Span test. This test is a subtest of the latest version of the Wechsler Intelligence Scale for Children (WISC-III) and is also used in the National Longitudinal Survey of Youth (NLSY). It is used to assess a child's short-term memory. It is administered to children ages 3-12 and gauges a child's ability to remember sequences of numbers and repeat them. First the child is asked to repeat them in the order given, then in the reverse order. This continues with longer and longer sequences of numbers until the child can no longer repeat the sequence (Hofferth et al 2000).

Birth Weight

The predictor variable of interest is birth weight, which is treated as a continuous variable. Complete birth weight data is available for over 96% of children in the PSID Child Development Supplement.

Socioeconomic Status (SES)

Perhaps the greatest strength of the PSID is the depth and breadth of SES measures available to researchers. For the majority of children in the Child Development Supplement, there is data on their parents' income, assets, education, and occupation, collected prospectively over twenty-five years. The concept of SES itself is multi-dimensional, and researchers have long debated the merits of various SES measures and combinations of measures. After analyzing the usefulness of the various measures of SES available[3], the measure of SES that we generate from the PSID-CDS data is an Occupational Prestige Score (OPS) for the Head of household[4] of each PSID-CDS

[3] In order to determine the most appropriate measure of SES to use in our analyses (given that we had several to choose from) we generated and compared our series of outcome models using Head's OPS, maternal educational attainment, family income during the 5 years surrounding the child's birth, and a factor score created from these three measures. All of the measures demonstrated the same pattern of acting as confounders of the relationship between birth weight and our outcomes. Ultimately, OPS was available for a larger proportion of the observations than any other SES measure (96%) and was consistently strongly correlated with birth weight and our outcomes, so it was chosen to be our SES measure.

[4] The concept of "Head of household" is used throughout the PSID to indicate the family's primary breadwinner. Typically, this will be the father of a PSID-CDS child, but in a single-parent home, it will generally be the child's mother.

family. Hauser (1994) describes OPS as a good indicator of permanent SES. The particular scores used in this analysis come from Nakao & Treas (1992).

Control Variables

In order to capture the effect of a positive home environment, we use the Home Observation for Measurement of the Environment (HOME) scale created by Caldwell and Bradley, which measures the quality of a child's home environment. The environment is evaluated in terms of provision of appropriate cognitive stimulation, degree of maternal warmth shown to the child, and safety and cleanliness of the home (Parcel & Menaghan 1994). We also control for other covariates that may effect given outcome measures, such as the child's age, birth order, race/ethnicity, and family type. Birth order is treated as a binomial variable where a first-born child would have a value of 1 and all others have 0. Family type is treated as a binomial variable with a value of 1 if the child comes from a two-parent home.

Analytic Plan

In order to evaluate the relationships between each of the outcome measures and birth weight, we use a series of robust multiple regression models run separately for boys and girls. In the first model we regress each outcome on birth weight alone. In the second model, we include the Head's OPS, child's age, birth order, race, HOME score and family type as well as birth weight. Our third model includes an interaction between birth weight and the OPS. In order to correct for correlations between siblings in the regression models (which are traditionally based on the assumption that observations are independent, which is not true in our sample) we use robust regression techniques to generate all of our models.

Sibling Fixed-effects Analysis

To control for family characteristics that might cause both birth weight and outcomes, but which are unobserved and therefore may cause us to observe a spurious relationship between birth weight and the outcomes we conduct a fixed-effects analysis. This model allows us to generate estimates of the effect of birth weight between siblings (i.e. controlling for unobserved family factors) as well as across siblings. One advantage of this model is that it allows us to control for those factors that vary across siblings, such as birth order and gender. Additionally, the method that we use to generate the fixed-effect model allows for the utilization of all observations as opposed to only using siblings sets. This is important for two reasons, first of all, because we retain power by including as many observations as possible when generating our models. Secondly, there is a possibility that families with more than one child may differ in unobserved ways from families that have chosen to have only one child. When families with one and two or more children are all included in the generation of the model, this potential bias is avoided.

Results

Descriptive Characteristics

Table 2 contains key demographic information for the PSID-CDS. In Table 3 we present select outcome variables by birth weight category. The results in Table 3 indicate that there is a positive relationship between birth weight and cognitive test scores.

Table 4 contains key outcome and birth weight information by gender. Birth weight and several outcome measures differ significantly by gender. In particular, we see that boys have poorer (higher) BPI scores than girls, as well as more health problems and higher math scores. Conversely, girls score better on the verbal subtests.

In Table 5 we present the results of three different regression models for each outcome by gender. The first column has the coefficients and p-values of the bivariate analysis for each outcome measure and birth weight (Model 1). The second column has the coefficients and p-values for the full models, controlling for age, birth order, race, family type, HOME score and Head's Occupational Prestige Score (Model 2). Column 3 holds the results of the sibling analyses, using a robust fixed-effects model. In the sibling model, we control for age, birth order, and HOME score.

For boys, we see in Table 5 there is a significant bivariate relationship in the expected direction (negative for behavior and health, positive for cognition) between birth weight and most of our health and cognitive outcomes, but none of our behavioral outcomes. In the full models, however, we see that only the relationships between birth weight and the health outcomes remain significant. In the sibling fixed-effect model, none of the relationships remain significant.

For girls, there is a significant bivariate relationship in the expected direction (negative for behavior and health, positive for cognition) between birth weight and the behavior, health, and cognition variables. In presence of control variables in the full model, the significant relationships between birth weight and the behavior and cognitive outcomes remain, while the significant relationship between birth weight and the health rating by primary caregiver variable disappears. Once again, in the sibling fixed-effect model, none of the previously significant relationships persist. One new relationship is revealed in the fixed-effect model, the relationship between birth weight and the Memory for Digit Span test appears as highly significant in this model.

Our analyses of the potential interaction between birth weight and SES yielded no significant and interesting results. Not only does birth weight not exhibit any negative effects on developmental outcomes in general, but it is also not a risk factor among low SES families.

In Table 6 we present the results of an analysis by gender of birth weight as a categorical variable. Birth weight is divided into four categories, very low birth weight (up to 1500g), low birth weight (1501-2500g), normal birth weight (2501-3500g), and high normal birth weight (3501g and higher). Normal birth weight is used as the reference category. For boys, we see that none of the relationships between birth weight and the outcomes are significant for the very low birth weight group. For the low birth weight group, however, we see significant relationships between birth weight and the Internal and Total BPI scores, both health outcomes, and the Letter-Word and Passage Comprehension cognitive scores. There are significant relationships for the high normal birth weight group for all three behavior outcomes.

Among very low birth weight girls, we see significant relationships between birth weight and the majority of cognitive variables, as well as total BPI and parental health rating. For the low birth weight group, only the number of health problems variable has a significant relationship with birth weight. For the high normal birth weight group, only parental health rating has a significant relationship with birth weight.

Discussion

Overall, our study finds small but statistically significant relationships between birth weight and various childhood outcomes, especially among girls in the bivariate analysis. When SES and other relevant variables are controlled for, this relationship still holds. Among girls, our full models indicate that higher birth weight is predictive of fewer behavior problems, fewer health problems, and higher verbal and math scores. Among boys, the relationship holds only for birth weight and reduced numbers of health problems. It is important to note that due to the large number of observations in our sample, we are able to detect very small effects of birth weight, so although we see many significant relationships, the minute regression coefficients tell us that the actual effect of birth weight that we are detecting is minor.

As previously mentioned, a great strength of the PSID-CDS is the availability of high-quality income measures. We have chosen to use occupational prestige of the head of household for purposes of our models. As expected, the inclusion of the OPS in the models eliminates (to an extent) the confounding effects of SES, and several of the significant relationships between birth weight and child outcomes disappear in our full models, especially for the males in our sample (see Table 5). We know, however, that even our high-quality SES measure and other control variables may not wholly capture the effect of poverty or affluence. For this reason, we also conducted a sibling fixed-effects analysis, examining the differences in birth weight and outcomes within families.

The fixed-effects analysis yielded very different results from our full models (see Table 5). This indicates that despite our attempts to include high-quality SES measures in the full models, there is still a great degree of unobserved heterogeneity. This means that our measures are not capturing the full effects of SES or home environment as they confound the relationship between birth weight and our outcomes. In fact, this indicates that birth weight itself does not cause poorer outcomes among low birth weight children, but that unmeasured family factors are really driving good or bad outcomes among children. That said, the strong relationships between birth weight and outcomes in our bivariate models indicate that birth weight may be a useful marker for poorer outcomes within families. From a policy perspective, if a school knows that a child was low birth weight, our results would support focusing efforts on improving outcomes on not only the low birth weight child, but on his or her siblings as well.

In the fixed-effect models, we only see a statistically significant relationship between birth weight and memory for digit span, and this only among girls. This finding may indicate a biological relationship between memory and birth weight that is not related to SES. The fact that this relationship only appears in the sibling model may indicate that the relationship is actually somehow masked by SES or family factors.

SES Interaction

We hypothesized that higher SES is protective of the effects of low birth weight. Our models indicate that this is not the case. One problem may be that our SES measure is not capturing the concepts of poverty or wealth effectively, as this would make us unable to detect interactions.

Birth Weight as a Categorical Variable

Our results validate the use of birth weight as a continuous variable in our models, since the finding appear to be driven not only by very low birth weight observations, but also by the low birth weight, and the high normal birth weight observations. This complements David Barker's previous findings that birth weight is linearly related to adult health outcomes. This finding may provide a basis for future exploration of birth weight and childhood outcomes.

Gender and Birth Weight

Perhaps the most interesting result of our analyses is that birth weight is much more important for predicting outcomes among girls than boys. A recent study by Matte and colleagues found the opposite, that birth weight was important for predicting IQ at age seven among boys, but not girls (2001). One reason for our findings may be that our sample contains girls with a lower average birth weight than boys (3244g versus 3352 g). This may indicate that the sickest girls in our sample have survived, whereas our dataset may not have captured the sickest boys if they died shortly after birth.

Additionally, more of the lowest birth weight boys in our sample are twins. It is possible that these boys' outcomes are better than low birth weight girls, since their weight at birth was a result of their status as a twin. One recent study of low birth weight children found that cognitive ability, growth, and weight gain all exhibited a "catch up" effect in twins, and that many twins who began the study in poor health due to prematurity and/or low birth weight later caught up with their normal birth weight peers

(Falkner & Matheny 1995). The impact of birth weight on twins versus single births is an area for future study. Since a follow-up study to the PSID-CDS is currently underway, it will be interesting to see if the same gender differences found in our study continue to play out as these children enter high school.

Table 1: Age Availability of Outcome Measures and Number of Observations

Subscale	Description	Ages tested	*n*
Behavior Problems Index	BPI internal subscale, external subscale, and total of the two scales	3-12	2591
Additive scale of health problems	Additive scale of 23 potential health problems.*	0-12	3371
Primary Caregiver report	Report of child health by Primary Caregiver. Scores from excellent=1 to poor=4	0-12	3428
Letter-Word Identification	Tests for symbolic learning as well as reading identification skills.	3-12	2126
Passage Comprehension	Measures comprehension and vocabulary skills using multiple-choice and fill-in-the-blank format.	6-12	1890
Broad Reading	Combination of Letter-Word and Passage Comprehension tests.	6-12	1890
Calculation	Measures performance on mathematical calculations and quantitative ability.	6-12	1303
Applied Problems	Measures skill in solving practical problems in mathematics.	6-12	1303
Broad Math	Combination of Calculation and Applied Problems	6-12	1287
Memory for Digit Span	WISC-III subtest, gauges child's ability to remember sequences of numbers.	6-12	1287

* Scale of 23 health problems is an additive scale of bivariate measures of whether the child has the following: epilepsy, asthma, diabetes, chronic ear infections, speech impediment, hearing difficulties, difficulty seeing, retardation, emotional problems, anemia, high blood lead count, orthopedic impairment, autism, learning disability, autism, hyperactivity, allergies, breathing problems, tonsillitis, heart problems, digestive disorders, hernia, and ever psychological problems.

Table 2: Characteristics of the PSID Child Development Supplement

Number of children	3,586
Number of households	2,394
Birth weight distribution: <1500	1.4%
1500-2499	8.2%
2500-3499	53.8%
3500+	36.7%
Ages: <3 infants & toddlers	23.4%
3-4 preschoolers	16.8%
5-9 school age	36.9%
10-12 preteens	22.9%
Race: White	47.8%
Black	40.4%
Hispanic	7.3%
Other	5.6%
Median Parental Income	$33,225
Average education of family head	12.6 years

Table 3: Selected Outcome Variables and Birth Weight

Outcome Variable	**Birth Weight Category**		
	<1500g	**1500-2500g**	**2501g+**
Number of observations	47	280	3101
Behavior: BPI External Scale	25.83	23.57	23.22
BPI Internal	18.03	16.64	16.19
BPI Total	44.55	41.16	40.34
Health: # of Problems	1.50	1.18	.84
Cognition: Letter-Word Score	103.94	101.74	102.61
Passage Comprehension	97.00	102.75	103.45
Broad Reading Score	98.33	103.99	103.90
Calculation	95.58	99.49	100.79
Applied Problems	100.41	103.57	104.76
Broad Math Score	94.92	102.99	103.84

Table 4: Means and Standard Deviations for Birth Weight and Outcomes in Full Analytical Set of PSID-CDS Observations by Gender

Predictor	**Male (n=1743)**	**Female (n=1685)**
Birth weight (grams)	**3352 (671)**	**3244 (617)**
Outcome		
Behavior		
Behavior Problems Index (BPI)	**41.0 (8.8)**	**39.9 (8.3)**
Internal Subscore	**16.4 (4.8)**	**16.0 (4.0)**
External Subscore	**23.8 (5.9)**	**22.7 (5.7)**
Health		
Number of health problems	**.94 (1.1)**	**.69 (1.0)**
Health Rating by Primary Caregiver (1=excellent, 2=very good, 3=good, 4=fair, 5=poor)	1.7 (.8)	1.7 (.8)
Cognition		
Letter-Word Score	92.9 (32.0)	92.5 (35.3)
Passage Comprehension Score	**101.0 (18.1)**	**103.3 (18.4)**
Broad Reading Score	**71.1 (47.8)**	**77.9 (47.3)**
Calculation	101.0 (17.9)	101.2 (17.6)
Applied Problems	**107.1 (20.0)**	**104.8 (19.9)**
Broad Math Score	104.6 (19.9)	103.7 (18.1)
Memory for Digit Span	13.0 (4.0)	13.3 (4.0)

Bold indicates statistically significant difference at the $p<.1$ level.

Table 5: Significant Regression Coefficients for Birth Weight in Bivariate, Full, and Sibling Analyses by Gender

Outcome	**Regression Coefficient (signif. at p<.1 level)**					
	Males			**Females**		
	Bivariate	**Full***	**Sibling****	**Bivariate**	**Full***	**Sibling****
Behavior Problems Index (BPI)	NS	NS	NS	-.0008 *P=.039*	-.0008 *P=.055*	NS
Internal Subscore	NS	NS	NS	NS	NS	NS
External Subscore	NS	NS	NS	-.0005 *P=.034*	-.0006 *P=.045*	NS
Number of health problems	NS	-.0001 *P=.016*	NS	-.0001 *P=.010*	-.0002 *P<.0001*	NS
Health Rating by Primary Caregiver (1=excellent, 2=very good, 3=good, 4=fair, 5=poor)	-.0001 *P<.0001*	-.00006 *P=.077*	NS	-.0001 *P<.0001*	NS	NS
Letter-Word Score	.0054 *P<.0001*	NS	NS	NS	NS	NS
Passage Comprehension Score	.0021 *P=.016*	NS	NS	.0033 *P=.001*	.0019 *P=.058*	NS
Broad Reading Score	.0067 *P=.004*	NS	NS	.0047 *P=.070*	.0034 *P=.051*	NS
Calculation	NS	NS	NS	.0040 *P<.0001*	.0022 *P=.056*	NS
Applied Problems	.0028 *P=.020*	NS	NS	.0034 *P=.008*	NS	NS
Broad Math Score	.0021 *P=.084*	NS	NS	.0045 *P<.0001*	.0022 *P=.061*	NS
Memory for Digit Span	NS	NS	NS	NS	NS	.0021 *P=.008*

* model includes: age, birth order, race, family type, HOME score, and Head's Occupational Prestige score

** model includes: age, birth order, and HOME score

Table 6: Significant Regression Coefficients (P<.10), Confidence Intervals. and P Values for Birth Weight Categories for Males and Females.

	Males*			Females*		
Birth Weight Category**	VLBW (Up to 1500g)	LBW (1501-2500g)	HNBW (3501 plus)	VLBW (Up to 1500g)	LBW (1501-2500g)	HNBW (3501 plus)
N=	23	149	540	24	131	717
Behavior Problems Index (BPI)	NS	1.80 -.228, 3.83 *P=.082*	1.24 .127, 2.36 *P=.029*	4.58 -.335, 9.49 *P=.068*	NS	NS
Internal Subscore	NS	1.01 -.052, 2.08 *P=.062*	.494 -.093, 1.08 *P=.099*	NS	NS	NS
External Subscore		NS	.931 .182, 1.68 *P=.015*	NS	NS	NS
Number of health problems	NS	.289 .036, .542 *P=.025*	NS	NS	.376 .167, .585 *P<.0001*	NS
Health Rating by Primary Caregiver	NS	.177 .006, .347 *P=.042*	NS	.720 .288, 1.15 *P=.001*	NS	.087 -.007, .182 *P=.071*
Letter-Word Score	NS	-7.13 -13.6, -.617 *P=.032*	NS	NS	NS	NS
Passage Comprehension Score	NS	-4.96 -9.68, -.242 *P=.039*	NS	-11.5 -21.9, -1.15 *P=.029*	NS	NS
Broad Reading Score	NS	NS	NS	-18.2 -36.3, -.055 *P=.049*	NS	NS
Calculation	NS	NS	NS	-12.1 -26.1, 1.85 *P=.089*	NS	.NS
Applied Problems	NS	NS	NS	NS	NS	NS
Broad Math Score	NS	NS	NS	-13.3 -27.2, .468 *P=.058*	NS	NS
Memory for Digit Span	NS	NS	NS	-2.56 -5.53, .408 *P=.091*	NS	NS

* model includes: age, birth order, race, family type, HOME score, and Head's Occupational Prestige score

** reference category is "normal birth weight", or 2501g-3500g

References

Barker, D. J. (1999). The long-term outcome of retarded fetal growth. *Schweiz.Med.Wochenschr., 129,* 189-196.

Breslau, N., Brown, G. G., DelDotto, J. E., Kumar, S., Ezhuthachan, S., Andreski, P. et al. (1996). Psychiatric sequelae of low birth weight at 6 years of age. *J.Abnorm.Child Psychol., 24,* 385-400.

Breslau, N., Chilcoat, H., DelDotto, J., Andreski, P., & Brown, G. (1996). Low birth weight and neurocognitive status at six years of age. *Biol.Psychiatry, 40,* 389-397.

Brooks-Gunn, J., Gross, R. T., Kraemer, H. C., Spiker, D., & Shapiro, S. (1992). Enhancing the cognitive outcomes of low birth weight, premature infants: for whom is the intervention most effective? *Pediatrics, 89,* 1209-1215.

Cohen, S. E. (1995). Biosocial factors in early infancy as predictors of competence in adolescents who were born prematurely. *J.Dev.Behav.Pediatr., 16,* 36-41.

Conley, D. & Bennett, N. G. (2000). Is biology destiny? Birth weight and life chances. *American Sociological Review, 65,* 458-467.

Corman, H. & Chaikind, S. (1998). The Effect of Low Birthweight on the School Performance and behavior of School-Aged Children. *Economics of Education Review, 17,* 307-316.

Currie, J. & Hyson, R. (1999). *Is the Impact of Health Shocks Cushioned by Socioeconomic Status? The Case of Low Birthweight*. Cambridge, Massachusetts: National Bureau of Economic Research.

Eriksson, J. G., Forsen, T., Tuomilehto, J., Osmond, C., & Barker, D. J. (2001). Early growth and coronary heart disease in later life: longitudinal study. *BMJ, 322,* 949-953.

Falkner, F. & Matheny, A. P. (1995). The long-term development of twins: Anthropometric factors and cognition. In L.G.Keith, E. Papiernik, & D. M. Keith (Eds.), *Multiple Pregnancy: Epidemiology, Gestation, and Perinatal Outcome* (pp. 613-624). London: Parthenon.

Ford, G. W., Doyle, L. W., Davis, N. M., & Callanan, C. (2000). Very low birth weight and growth into adolescence. *Arch.Pediatr.Adolesc.Med., 154,* 778-784.

Gadin, K. G. & Hammarstrom, A. (2000). School-related health--a cross-sectional study among young boys and girls. *Int.J.Health Serv., 30,* 797-820.

Gyler, L., Dudley, M., Blinkhorn, S., & Barnett, B. (1993). The relationship between psychosocial factors and developmental outcome for very low and extremely low birthweight infants: a review. *Aust.N.Z.J.Psychiatry, 27,* 62-73.

Hardy, J. B., Drage, J. S., & Jackson, E. C. (1979). *The First Year of Life*. Baltimore: Johns Hopkins University Press.

Hofferth, S. L. (1998). *Healthy Environments, Healthy Children: Children in Families* University of Michigan.

Hofferth, S. L., Davis-Kean, P. E., Davis, J., & Finklestein, J. (2000). The PSID Child Development Supplement 1997 User Guide. Survey Research Center, Institute for Social Research, University of Michigan [On-line]. Available: http://www.isr.umich.edu/src/child-development/usergd.html

Hogan, D. P. & Park, J. M. (2000). Family factors and social support in the developmental outcomes of very low-birth weight children. *Clin.Perinatol., 27,* 433-459.

Ibanez, L., Ferrer, A., Marcos, M. V., Hierro, F. R., & de Zegher, F. (2000). Early puberty: rapid progression and reduced final height in girls with low birth weight. *Pediatrics, 106,* E72.

Kelly, Y. J., Nazroo, J. Y., McMunn, A., Boreham, R., & Marmot, M. (2001). Birthweight and behavioural problems in children: a modifiable effect? *Int.J.Epidemiol., 30,* 88-94.

Matte, T. D., Bresnahan, M., Begg, M. D., & Susser, E. (2001). Influence of variation in birth weight within normal range and within sibships on IQ at age 7 years: cohort study. *BMJ, 323,* 310-314.

Mayer, S. E. (1997). *What Money Can't Buy: Family Income and Children's Life Chances*. Cambridge, Massachusetts: Harvard University Press.

McCormick, M. C., Workman-Daniels, K., & Brooks-Gunn, J. (1996). The behavioral and emotional well-being of school-age children with different birth weights. *Pediatrics, 97,* 18-25.

Moore, V. M., Cockington, R. A., Ryan, P., & Robinson, J. S. (1999). The relationship between birth weight and blood pressure amplifies from childhood to adulthood. *J.Hypertens., 17,* 883-888.

Nakao, K. & Treas, J. (1992). *The 1989 Socioeconomic Index of Occupations: Construction from the 1989 Occupational Prestige Scores* (Rep. No. 74). Chicago: University of Chicago National Opinion Research Center.

Parcel, T. L. & Menaghan, E. G. (1994). *Parents' Jobs and Children's Lives*. New York: Walter de Gruyter.

Peterson, J. L. & Zill, N. (1986). Marital disruption, parent-child relationships, and behavior problems in children. *Journal of Marriage and the Family, 48,* 295-307.

Richards, M., Hardy, R., Kuh, D., & Wadsworth, M. E. (2001). Birth weight and cognitive function in the British 1946 birth cohort: longitudinal population based study. *BMJ, 322,* 199-203.

Rickards, A. L., Kitchen, W. H., Doyle, L. W., Ford, G. W., Kelly, E. A., & Callanan, C. (1993). Cognition, school performance, and behavior in very low birth weight and normal birth weight children at 8 years of age: a longitudinal study. *J.Dev.Behav.Pediatr., 14,* 363-368.

Taylor, H. G., Klein, N., & Hack, M. (2000). School-age consequences of birth weight less than 750 g: a review and update. *Dev.Neuropsychol., 17,* 289-321.

Werner, E. E. & Smith, R. S. (1977). *Kauai's Children Come of Age*. Honolulu: The University Press of Hawaii.

Werner, E. E. & Smith, R. S. (1982). *Vulnerable but Invincible: A Longitudinal Study of Resilient Children and Youth*. New York: McGraw Hill.