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Birth Weight and Early Cognitive Skills: Can Parenting Offset the Link?

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Abstract *Objectives* There is an enduring negative association between low birth weight (<2500 g) and early childhood cognitive skills. This study examines if parenting practices meaningfully contribute to or offset birth weight disparities in cognitive development prior to formal schooling. *Methods* This study uses the ECLS-B, a nationally representative sample of live births in the United States in 2001. Unlike studies focused on one or two measures of parenting and investment, this study considers a wide array parenting measures collected at multiple time points, tracked from before birth across 5 years of development. *Results* Regression results show that nearly 50 % of the low-birth-weight gap in early math and reading ability is associated with family socioeconomic status. Between-family OLS regressions show that parenting practices, including "parental interaction," "cognitive stimulation," and "parent quality", are negatively associated with low birth weight and positively associated with improved cognitive skill among all children. After adjustment for family socioeconomic status, parenting practices did little to offset (by mediation or moderation) remaining birth weight disparities in early cognitive development. *Conclusions* Effective parenting is positively associated with cognitive development, but parenting is not a panacea—the developmental disadvantages associated with poor child health are not linked to parenting practices. We argue that birth weight disparities are rooted in biology and cannot easily be offset by parenting practices.

Keywords Cognitive development · Birth weight · Early childhood · Parenting

Abbreviations

NBW	Normal birth weight
LBW	Low birth weight
VLBW	Very low birth weight
ECLS-B	Early Childhood Longitudinal Study (9 months to kindergarten)
NCES	National Center for Education Statistics
OLS	Ordinary least squares
NCATS	Nursing Child Assessment Teaching Scale
CES-D	Center for Epidemiologic Studies Depression Scale

Significance

What's known on this subject? Low birth weight children perform poorly on tests of cognitive skill across the life course.

What this study adds? It is unclear if parenting behaviors can meaningfully offset the negative relationship between low birth weight and early cognitive development. Using the ECLS-B 2001 data, we find that parenting practices neither mediate nor moderate early childhood birth weight disparities in cognitive development. This runs counter to previous studies suggesting parenting practices can have a profound negative or positive effect on child development net of social status and birth condition.

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Introduction

Low birth weight is a public health problem with social consequences. The low birth weight disadvantage emerges early in the life course, persists into adolescence, and is linked with later-life social and economic standing (Palloni 2006). Compared to NBW children (2500 g or 5.5 lb or more), LBW (<2500 g or 5.5 lb) and VLBW (<1500 g or 3.3 lb) children are developmentally delayed and generally experience a lower quality of life across a variety of social, health, and economic measures (Case et al. 2005; Conley et al. 2003; Palloni 2006). In the United States, the rate of low birth weight has remained large and relatively unchanged, at about 7–8 %, for the past 20 years (Child Trends Databank 2015; Goosby and Cheadle 2009; Hamilton et al. 2015). Understanding the socioeconomic factors associated with LBW and VLBW continues to be an important task of social scientists and public health advocates.

The deleterious effects of poor child health on social inequality have been established, but the pathways connecting poor child health with early cognitive and developmental outcomes remain poorly understood and frequently debated (Conley et al. 2003; Elman et al. 2014; Geronimus 1996; Hack et al. 1995). To be sure, the same factors that increase the risk of LBW—including maternal poverty, neighborhood disadvantaged, and poor maternal health and education—are also strongly correlated with achievement (Blau and Duncan 1967; Conley et al. 2003; Gorman 1999; Morenoff 2003). That family background affects the birth weight-achievement link is not heavily debated. What remains unclear is to what extent parenting behaviors can meaningfully alter the link between poor child health and developmental outcomes independent of family background.

There are two ways parenting could influence birth weight disparities in cognitive development, by *mediation* or *moderation*. First, birth weight disparities in cognitive development could be partially a function of NBW children receiving more and better parenting than their LBW counterparts (mediation). Research investigating whether parents compensate or reinforce health disparities has arrived at mixed conclusions. One study found that that “normal birth weight children are 5–11 % more likely to receive early childhood parental investments than their low-birth-weight *siblings*” (p. 145) (Datar et al. 2010). Two other studies found that parents were unlikely to favor NBW children over their LBW counterparts (Lynch and Brooks 2013; Royer 2009).

Second, it may be that good parenting is especially effective for NBW children, more so than LBW because they are less sensitive to parental investments (moderation). That is, NBW children obtain skills at a faster rate than LBW children when parents engage in high levels of parenting. Evidence for whether or not parenting can meaningfully influence the birth weight gap in cognitive skills is mixed (Currie and Hyson 1999; Tully et al. 2004), with a growing number of scholars questioning the importance of a parenting-health link altogether. The sharpest critiques argue that any mediation or moderation of birth weight disparities in cognitive skills associated with parenting is spurious, merely a reflection of omitted factors correlated with parenting (Conley et al. 2003; Goosby and Cheadle 2009; Hack et al. 1995).

Few studies examine the association between parenting behaviors and birth weight with a rich set of parenting measures using longitudinal data in early childhood. Moreover, studies on birth weight, parenting, and social background are limited by their selective focus; some studies examine parenting and birth weight, other studies examine parenting and cognitive development, but no study has examined birth weight, parenting, and cognitive development as comprehensively as we offer here.

We use ideal data to examine an extensive set of pre-birth social characteristics and investments and post-birth parenting factors to (1) document the association between birth weight and cognitive development, (2) isolate key parenting behaviors associated with improved cognitive development, and (3) examine how specific parenting behaviors might mediate or moderate the birth weight relationship to cognitive development, independent of family socioeconomic status.

Data and Methods

The *Early Childhood Longitudinal Study-Birth Cohort* (ECLS-B) is a nationally representative sample of 10,700 children born in 2001 (all sample sizes are rounded to the nearest 50th per the data requirements of NCES). The ECLS-B gathers data on parent, child, and home characteristics—ideal for examining factors influencing cognitive and non-cognitive differences at kindergarten entry. We use data from birth certificates and multiple survey waves: (approximately 9 months old), 2 (approximately 24 months of age), 3 (approximately 48 months (4 years) of age) and 4 (entering Kindergarten at age 5). Due to attrition, the final sample is 6100 cases. We make use of OLS regression using Stata 13.1 (StataCorp 2013) and employ Stata’s chained imputation procedure to multiply impute missing values (20 imputed data files, 150 burn-ins). Missing data was low for most measures (1–19 %) with a few exceptions: child’s APGAR score (27 %), information on smoking and drinking during pregnancy

(20 %), and mother's pregnancy weight gain (28 %). Low socioeconomic status and LBW children have higher odds of attrition, indicating our results likely underestimate birth weight disparities in cognitive development. Parenting factors were not associated with attrition.

Measures

Birth Weight Status

Child's birth weight was collected from birth certificate information. Birth weight status was coded as NBW (weighing 2500 g or more at birth), LBW (between 1500 and 2499 g at birth), and VLBW (weighing <1500 g at birth). Given that the relationship between birth weight and cognitive outcomes may be non-linear (Shenkin et al. 2004), we explored other cutoffs and transformations of the birth weight measure. We found no substantive differences in our results (not reported).

Early Cognitive Skill

We use math scores taken at age 5 (Wave 4). The math scale score assesses a child's ability to understand relative size/quantity, match patterns, counting, number recognition, and ordering. The IRT Math scale exhibits both validity and reliability. Individual items display concurrent validity within acceptable standards. There is no evidence of ceiling or floor effects and the IRT score appears to capture a single underlying factor across waves, suggesting a vertical scaling over time (see Najarian et al. 2010). We also examined IRT reading scores during the same wave and found similar patterns, likely due to the high correlation between the two measures (.821). Given a slightly stronger link between math skill and later achievement outcomes (Duncan et al. 2007) we focus on early math scores. Reading results are reported in the Appendix. We should note that we also considered controlling for prior cognitive skills using the *Bayley Mental Assessment* and find much of the birth weight link to cognitive skill occurs in the first 2 years. Results available upon request.

Pre- and Postnatal Factors

We examine a number of pre- and postnatal behaviors potential associated with LBW. We coded the use of *Prenatal Vitamins* administered before and after pregnancy as 0 = no/1 = yes. Frequency of doctor visits (*number of Doctor Visits in 1st Trimester*), a critical period of fetal development and closely associated with later child health (de Bernabé et al. 2004). As participation in Women, Infants, and Children (WIC) Supplemental Nutrition Program might provide nutritional resources that can lead to healthy pregnancies, we include a dichotomous measure of WIC use. In accordance with Federal law and U.S. Department of Agriculture policy, WIC is prohibited from discriminating on the basis of race, color, national origin, sex, age or disability. To account for an impact of daycare on cognitive development, we measures a child's attendance at an early learning centers, nursery schools or preschools on a regular basis at 10 months of age (*daycare*).

Next, we include measures of health behaviors commonly associated with increased risk for LBW including cigarette smoking or drinking while pregnant (Currie 2011; McGovern 2013). The ECLS-B data contains information on smoking (and drinking) from two sources—parent self-reports (Wave 1) and birth certificate information. We considered both sources in preliminary models and found similar results. We ultimately selected birth certificate information for final models as birth certificate information has been shown to be reliable (Ventura et al. 2003). These variables are frequency counts but were dichotomized to 0 = no and 1 = yes given the skewed distribution of responses towards 0.

We also considered the role of maternal age and weight on birth weight (*Mother's Age at Child's Birth*). For weight gain during pregnancy, we use the self-report generated from birth certificate data. To adjust for the BMI of the mother when not pregnant, we also include the *Mother's BMI* as a control (collected at Wave 2).

Parenting Behaviors

We include six factored measures of parenting behaviors. For ease of interpretation, all parenting factors are standardized with a mean of 0 and standard deviation of 1. *Parental Interaction* includes three measures: how often on a weekly basis does a parent or family member (1) read to the child (2) tells stories to the child and (3) sing songs with the child. This scale has a Cronbach's alpha of .61 at time Wave 1 and .59 at Wave 2. We should note that as with other parenting alphas in our study, this is a low score, suggesting a modest correlation across factor indicators (Kline 2015). Despite this, we preserve this factor in the analyses for parsimony and find, regardless of how these groups of variables are combined, there is no discernable impact on our results.

Parental Investments refers to the number of child appropriate and potentially stimulating objects in the home at Wave 2. We include the number of (1) soft toys and role-playing toys; (2) push and pull toys; (3) children's books and (4) children's records, tapes, or CDs, in the home. The economic investments scale has an alpha of .51.

For our measure of *Maternal Warmth*, we utilize a three-item scale of parent–child emotional connectedness. The scale is comprised of three dichotomized variables that indicate whether the mother was observed: (1) speaking spontaneously to the child; (2) responding verbally to the child; and (3) kissing or caressing the child. Cronbach's alpha for the maternal warmth scale is .57 at Wave 1 and .61 at Wave 2.

For *Parenting Quality* we use the composite "Parent Scale Score" compiled by NCES. The scale is developed from the NCATS, an observational coding system for rating caregiver-child interaction patterns that is widely used in clinical practice and research to screen mothers and infants for early intervention programs as well as in maternal and child health research (Summer and Spietz 1994). The NCATS was designed to measure parental responsivity to cues (e.g. pausing as child initiates action), cognitive growth fostering (e.g., type of instructions and modeling), socioemotional growth fostering (e.g., cheerleading), and response to distress (e.g., rearranging toys) (Nord et al. 2005). Parent and child were videotaped and coded across the 50 items when the child was 9 months of age. The scale includes 50 "yes/no" assessments of parenting in the home and has a Cronbach's alpha of .72.

Cognitive Stimulation was assessed when the child was 2 and 4 years of age. This unique measure is based on a task that required parent and child interaction. The assessment of parent–child interaction was developed from the *Three Bags Task*, a semi-structured activity that has been successfully administered in other large studies. Recordings of the parent and child interacting were coded and rated by Westat staff members trained in several global scales of parent–child interaction.

We used three of the parenting global scales (coded from 1 to 7, with 7 representing a high score) that focused on overall emotional supportiveness of the parent in providing cognitive stimulation: parental stimulation of cognitive development, parental sensitivity, and parental positive regard. The scale has a Cronbach's alpha of .84 at Wave 2. Wave 3 measures were slightly modified but similarly focus on parent engagement, emotional supportiveness and cognitive stimulation for an alpha score of .74.

Other Factors

Family *Socioeconomic Status*, a composite scale consisting of total household income, highest level of parental education and occupational prestige, was created by the NCES. The measure is normalized with a mean of zero. *Sibling Size* measures the number of siblings in the household. We also include race and ethnicity due to its link to birth weight and cognitive development (Sparks 2009). The measure for *Race/Ethnicity* is derived from the parent reporting of the child's race and coded as four dummy variables: non-Hispanic White, non-Hispanic Black, Hispanic (any race), Asian, and other racial groups.

We account for *Age of Assessment*, measured in months. Child's sex was coded 1 = female and 0 = male. We account for whether or not the child was a twin (1 = yes, 0 = no). *Gestation Age* is measured in weeks. Family structure was a dichotomous measure coded 1 = child living with both biological parents at 9 months and 0 = otherwise. *Maternal Depression* was constructed from questions using an abbreviated form of the CES-D. Responses to various questions about how the mother reported feeling the past week were factored to create a scale ranging from low to high depression (Cronbach's alpha = .97).

Finally, we included three measures of infant feeding practices. The measure, *Breastfed 6 Months or More*, was collected when the child was 9 months of age. Mothers were asked if they ever breastfed their child and for how many months. In a separate question, they were also asked how many months the child was formula fed. If the child had not been formula fed and was actively being breastfed for longer than 5 months, we considered this evidence that the child was predominantly breastfed for 6 or more months. Mothers who did not predominantly breastfeed for 6 months or more are the referent. We created a dichotomous measure coded 1 if solids were given before 4 months of age, 0 otherwise. For bottle feeding at bedtime, the mother was asked at 9 months if the child was put to bed with a bottle, which we coded as a dichotomous measure (1 = yes, 0 = no).

Results

Table 1 presents summary information for the primary variables included in our analyses. Standardized measures have non-zero means due to sample weights. Comparing Math and Reading IRT mean scores, LBW and VLBW are about 1/5th (−0.23 for math, −0.19 for reading) to a half standard deviation (−0.55 for math, −0.37 for reading) behind NBW children at age 5. There are clear socioeconomic differences in birth weight status (1/4th standard deviation difference between VLBW and NBW (−0.31 + −0.07 = 0.24)).

Table 2 shows that parenting is clearly associated with birth weight. Most importantly, mothers of NBW children, relative to mothers of VLBW children, have higher levels of parenting quality, parental interaction, parental investment, maternal warmth, and cognitive stimulation. Most differences are about 1/5th of a standard deviation (i.e. cognitive simulation (Wave 3) has a value of 0.02 for NBW compared to −0.18 for VLBW).

Table 1 Sample characteristics by birth weight status (N = 6100), ECLS-B, 2001

Factors	% Missing	Full sample		NBW		LBW		VLBW	
		100 % (n = 6100)		75 % (N = 4600)		15 % (N = 900)		10 % (N = 600)	
				[93 % weighted]		[6 % weighted]		[1 % weighted]	
		Mean	(SE)	Mean	(SE)	Mean	(SE)	Mean	(SE)
Cognitive skill assessments									
Math IRT (Wave 4)	1 %	−0.01	(0.02)	0.01	(0.03)	−0.23	(0.04)	−0.55	(0.04)
Reading IRT (Wave 4)	1 %	−0.05	(0.03)	−0.03	(0.03)	−0.19	(0.05)	−0.37	(0.05)
Child characteristics									
Age of Assessment	0 %	64.77	(0.07)	64.75	(0.08)	64.96	(0.15)	64.84	(0.20)
Female	0 %	0.49	(0.01)	0.48	(0.01)	0.53	(0.02)	0.53	(0.02)
Gestation Age	2 %	38.72	(0.04)	39.03	(0.04)	35.97	(0.16)	29.64	(0.23)
Twin	1 %	0.03	(0.00)	0.02	(0.00)	0.21	(0.01)	0.20	(0.02)
Apgar	27 %	8.93	(0.02)	8.97	(0.02)	8.67	(0.04)	7.72	(0.07)
Family/household factors									
Socio-economic Status	0 %	−0.08	(0.03)	−0.07	(0.03)	−0.28	(0.04)	−0.31	(0.04)
Race/ethnicity									
White	0 %	0.54	(0.02)	0.54	(0.02)	0.45	(0.03)	0.39	(0.03)
Black	0 %	0.14	(0.01)	0.13	(0.01)	0.24	(0.02)	0.31	(0.03)
Hispanic	0 %	0.25	(0.02)	0.26	(0.02)	0.24	(0.02)	0.21	(0.02)
Asian	0 %	0.03	(0.00)	0.03	(0.00)	0.03	(0.00)	0.01	(0.00)
Other	0 %	0.04	(0.00)	0.04	(0.00)	0.04	(0.01)	0.07	(0.01)
Both parents in home	0 %	0.79	(0.01)	0.80	(0.01)	0.73	(0.02)	0.68	(0.03)
Sibling size	0 %	0.99	(0.02)	0.98	(0.02)	1.08	(0.04)	1.06	(0.08)

Sample size rounded to nearest 50th. All measures collected at Wave 1 unless otherwise indicated. Estimates derived from imputed data. Results are weighted

Table 3 presents the relationship between birth weight status and kindergarten-entry math skills (for reading results, see Appendix Tables 5 and 6). Looking across Models, there is a robust association between birth weight and early math skills. For example, in Model 1, VLBW children are more than half a standard deviation lower than NBW children reduction in early math skill at school entry (b = −0.58, $p < .000$). The patterns for LBW are similar but the size of the gap is about half that of VLBW. In Model 2, controls account for about 20 % of the gap for VLBW children (1 − (−0.47/−0.58)) and about 12 % for LBW children (1 − (−0.23/−0.26)). The inclusion of family and household characteristics in Model 3 reduces the overall VLBW/NBW gap in math skill by an additional 25 % (1 − (−0.35/−0.47)) and the LBW/NBW gap by 43 % (1 − (−0.13/−0.23)). Surprisingly, measures of prenatal factors do not impact the VLBW and LBW coefficient estimates in Model 4. Although the pre-natal behaviors are likely associated with low birth weight, few pregnancy related behaviors were associated with birth weight disparities in math skills independent of socioeconomic status.

In Table 4, we examine the relationship between birth weight and cognitive skill adjusting for parenting behaviors and social background. Coefficients in the Full Model show a positive relationship between a number of positive parenting practices and early math skill development among 5 year olds. For example, parenting quality, parental interaction at Wave 2, and cognitive stimulation at Wave 2 and Wave 3 are all positively associated with math skill. Thus, a one unit increase in cognitive stimulation at 24 months, for example, is associated with 0.09 standard deviation increase in early math skill at age 5. However, birth weight gaps are only slightly mediated by parenting practices—parenting factors reduce the VLBW-NBW gap from −.35 to −.31 and the LBW-NBW gap from −.13 to −.12 (compare Table 3, Model 4 with Table 4, Full Model).

The interaction models in Table 4 clearly show that parenting does not alter birth weight disparities in cognitive development independent of family socioeconomic status and control variables. All of the parenting by birth weight interactions are small and statistically insignificant. If the interactions were significant and positive, it would suggest

Table 2 Sample characteristics by birth weight status (N = 6100), ECLS-B, 2001

Factors	% missing	Full sample		NBW		LBW		VLBW	
		Mean	(SE)	Mean	(SE)	Mean	(SE)	Mean	(SE)
Prenatal parenting factors									
Prenatal vitamin (before)	0 %	0.36	(0.01)	0.37	(0.01)	0.35	(0.02)	0.31	(0.02)
Prenatal vitamin (after)	0 %	0.89	(0.01)	0.89	(0.01)	0.88	(0.01)	0.88	(0.02)
No. of doctor visits in 1st trimester	0 %	2.46	(0.04)	2.44	(0.04)	2.77	(0.09)	2.90	(0.11)
WIC during pregnancy	0 %	0.42	(0.01)	0.42	(0.02)	0.48	(0.02)	0.43	(0.03)
Smoked during pregnancy	20 %	0.11	(0.01)	0.11	(0.01)	0.19	(0.02)	0.16	(0.01)
Drank during pregnancy	20 %	0.01	(0.00)	0.01	(0.00)	0.01	(0.00)	0.01	(0.00)
Mother's age at child's birth	1 %	27.33	(0.15)	27.37	(0.16)	26.70	(0.34)	27.04	(0.28)
Pregnancy weight gain	28 %	31.29	(0.28)	31.68	(0.29)	27.21	(0.60)	22.81	(0.71)
Mother's BMI (Wave 2)	5 %	24.94	(0.11)	24.97	(0.11)	24.37	(0.23)	25.45	(0.32)
Postnatal parenting factors									
Daycare	0 %	0.09	(0.01)	0.09	(0.01)	0.09	(0.01)	0.09	(0.01)
Parenting quality (alpha .72)	16 %	0.04	(0.02)	0.05	(0.03)	−0.09	(0.04)	−0.17	(0.05)
Parental interaction (alpha = .61)	0 %	0.03	(0.02)	0.03	(0.02)	−0.02	(0.04)	−0.13	(0.06)
Parental interaction (Wave 2, alpha = .59)	0 %	0.00	(0.02)	0.01	(0.02)	−0.05	(0.04)	−0.14	(0.04)
Parental investment (Wave 2, alpha = .51)	0 %	0.03	(0.03)	0.04	(0.03)	−0.10	(0.05)	−0.19	(0.04)
Maternal warmth (alpha = .57)	13 %	0.02	(0.04)	0.03	(0.04)	−0.09	(0.07)	−0.18	(0.08)
Maternal warmth (Wave 2, alpha = .61)	5 %	0.02	(0.03)	0.02	(0.03)	0.03	(0.04)	−0.07	(0.06)
Cognitive stimulation (Wave 2, alpha = .84)	19 %	0.05	(0.03)	0.06	(0.03)	−0.09	(0.05)	−0.28	(0.06)
Cognitive stimulation (Wave 3, alpha = .74)	13 %	0.01	(0.02)	0.02	(0.02)	−0.07	(0.04)	−0.18	(0.05)
Maternal depression (alpha = .97)	7 %	0.00	(0.02)	−0.01	(0.02)	0.01	(0.04)	0.05	(0.05)
WIC	0 %	0.53	(0.02)	0.52	(0.02)	0.63	(0.03)	0.65	(0.02)
Breastfed 6+ months	0 %	0.18	(0.01)	0.19	(0.01)	0.08	(0.01)	0.07	(0.02)
Solid foods before 3 months	0 %	0.23	(0.01)	0.24	(0.01)	0.19	(0.02)	0.13	(0.02)
Put baby to bed with bottle	0 %	0.29	(0.01)	0.29	(0.01)	0.32	(0.02)	0.36	(0.02)

Sample size rounded to nearest 50th. All measures collected at Wave 1 unless otherwise indicated. Estimates derived from imputed data. Results are weighted

parental investments for low birth weight children would improve cognitive skill development in ways that normal birth weight children would not. Overall, we find no discernable evidence that parenting *mediates* or *moderates* the birth weight relationship to cognitive development.

Although parents can improve their VLBW child's cognitive development by engaging in more parental interactions, parental investment, and cognitive stimulation, our evidence suggests that increased parenting cannot mediate the relationship with cognitive skill outcomes or moderate the biological impact of low birth weight. Thus, we find a persistent baseline impact of birth weight that persists above and beyond parenting efforts.

Discussion

Low birth weight, especially VLBW, has a persistent negative association with cognitive development that cannot be easily offset by parenting behaviors after birth (see also Almond and Currie 2011; Goosby and Cheadle 2009). The relationship is partly developmental; LBW babies have higher infant mortality [a 25 % chance of death within the first year (Child Trends Databank 2015)], are more likely to be born with immature lungs, incur birth asphyxiation and periventricular hemorrhage along with other severe medical conditions that impact brain development (Goosby and Cheadle 2009; Hack et al. 1995).

We estimate that 40 % of the VLBW and NBW math skill gap and 50 % of the LBW and NBW math skill gap is attributed to socioeconomic status and related factors—but once set in motion, a nontrivial disparity appears to endure regardless of environmental influences. This clarifies empirical uncertainty as to whether parents mediate or moderate the association of birth weight and child cognitive skill (Currie and Hyson 1999; Tully et al. 2004). Of course, although parenting cannot offset the gap, it can enhance early math development for all children, regardless of birth weight status.

Table 3 OLS modeling the association between birth weight status and kindergarten entry math scores with mediating factors (N = 6100), ECLS-B, 2001

	b	Model 1 (95 % CI)	*p*	*b*	Model 2 (95 % CI)	*p*	*b*	Model 3 (95 % CI)	*p*	*b*	Model 4 (95 % CI)	*p*
Birth weight status (reference = NBW)												
VLBW	−0.58	(−0.66 to −0.50)	.000	−0.47	(−0.66 to −0.28)	.000	−0.35	(−0.51 to −0.19)	.000	−0.35	(−0.51 to −0.19)	.000
LBW	−0.26	(−0.34 to −0.18)	.000	−0.23	(−0.33 to −0.14)	.000	−0.13	(−0.22 to −0.04)	.007	−0.13	(−0.22 to −0.03)	.007
Controls												
Age of assessment	0.10	(0.09 to 0.11)	.000	0.10	(0.09 to 0.11)	.000	0.10	(0.09 to 0.11)	.000	0.10	(0.09 to 0.11)	.000
Female				0.08	(0.02 to 0.14)	.008	0.08	(0.02 to 0.13)	.006	0.07	(0.02 to 0.13)	.007
Gestation age				0.01	(−0.01 to 0.02)	.321	0.01	(−0.01 to 0.02)	.443	0.01	(−0.01 to 0.02)	.313
Twin				0.03	(−0.06 to 0.12)	.532	−0.08	(−0.17 to 0.02)	.104	−0.06	(−0.16 to 0.04)	.228
Apgar				0.03	(−0.03 to 0.09)	.320	0.03	(−0.02 to 0.08)	.220	0.03	(−0.02 to 0.08)	.238
Family/household factors												
Socioeconomic status							0.36	(0.32 to 0.39)	.000	0.30	(0.26 to 0.35)	.000
Race/ethnicity												
Black							−0.11	(−0.21 to −0.01)	.027	−0.10	(−0.21 to 0.01)	.065
Hispanic							−0.20	(−0.29 to −0.11)	.000	−0.19	(−0.29 to −0.10)	.000
Asian							0.18	(0.09 to 0.28)	.000	0.16	(0.06 to 0.25)	.002
Other							−0.12	(−0.24 to −0.01)	.039	−0.11	(−0.23 to 0.01)	.067
Both parents in home							0.13	(0.05 to 0.20)	.001	0.09	(0.01 to 0.17)	.022
Sibling size							−0.04	(−0.06 to −0.01)	.009	−0.05	(−0.08 to −0.02)	.002
Prenatal parenting factors												
Prenatal vitamin (before)										−0.02	(−0.09 to 0.05)	.628
Prenatal vitamin (after)										0.05	(0.05 to 0.14)	.341
No. of doctor visits in 1st trimester										0.00	(−0.01 to 0.01)	.970
WIC during pregnancy										−0.09	(−0.15 to −0.02)	.011
Smoked during pregnancy (BC)										−0.05	(−0.16 to 0.07)	.401
Drank during pregnancy (BC)										−0.05	(−0.34 to 0.25)	.748
Mother's age at child's birth										0.01	(0.00 to 0.01)	.003
Pregnancy weight gain (BC)										0.00	(0.00 to 0.00)	.883
Mother's BMI (Wave 2)										−0.01	(−0.01 to 0.00)	.008
Constant	−6.44	(−7.08 to −5.80)	.000	−7.06	(−8.08 to −6.04)	.000	−7.08	(−8.05 to −6.11)	.000	−7.14	(−8.10 to −6.17)	.000

Sample from imputed dataset. Sample is rounded as required for use of NCES restricted data. Data weighted for complex sample design and oversampling. Confidence intervals in parentheses

Table 4 OLS modeling the association between birth weight status and kindergarten entry math scores with mediating factors and interactions (N = 6100), ECLS-B, 2001

	Full model			Interactions: birth weight × parenting factors								
	b	(95 % CI)	*p*	*b*	(95 % CI)	*p*	*b*	(95 % CI)	*p*	*b*	(95 % CI)	*p*
Birth weight status (reference = NBW)												
VLBW	−0.31	(−0.47 to −0.16)	.000	−0.34	(−0.53 to −0.15)	.001						
LBW	−0.12	(−0.21 to −0.03)	.007	−0.16	(−0.28 to −0.04)	.011						
							Interactions by VLBW			Interactions by LBW		
Postnatal parenting factors												
Daycare	0.02	(−0.07 to 0.11)	.631	0.02	(−0.08 to 0.12)	.671	−0.07	(−0.38 to 0.27)	.641	0.00	(−0.23 to 0.23)	.998
Parenting quality	0.04	(0.00 to 0.07)	.045	0.04	(0.00 to 0.07)	.051	−0.04	(−0.13 to 0.05)	.363	−0.02	(−0.10 to 0.06)	.634
Parental interaction	0.03	(0.00 to 0.07)	.084	0.04	(0.00 to 0.08)	.073	0.02	(−0.08 to 0.11)	.746	−0.06	(−0.12 to 0.01)	.104
Parental interaction (Wave 2)	0.04	(0.01 to 0.08)	.006	0.04	(0.00 to 0.07)	.030	0.05	(0.06 to 0.16)	.368	0.09	(0.00 to 0.18)	.063
Parental investment (Wave 2)	0.01	(−0.02 to 0.08)	.386	0.02	(−0.02 to 0.05)	.349	−0.04	(−0.13 to 0.05)	.349	−0.02	(−0.10 to 0.06)	.616
Maternal warmth	−0.02	(−0.05 to 0.02)	.338	−0.02	(−0.06 to 0.02)	.364	0.01	(−0.08 to 0.10)	.806	0.02	(−0.06 to 0.10)	.641
Maternal warmth (Wave 2)	0.01	(−0.03 to 0.05)	.702	0.01	(−0.03 to 0.05)	.627	−0.04	(−0.11 to 0.04)	.313	−0.04	(−0.13 to 0.04)	.318
Cognitive stimulation (Wave 2)	0.09	(0.06 to 0.12)	.000	0.08	(0.05 to 0.12)	.000	0.05	(−0.05 to 0.16)	.310	0.01	(−0.07 to 0.09)	.798
Cognitive stimulation (Wave 3)	0.06	(0.03 to 0.10)	.000	0.06	(0.03 to 0.10)	.000	0.02	(−0.08 to 0.12)	.731	−0.01	(−0.09 to 0.07)	.818
Breastfed 6+ months	−0.01	(−0.08 to 0.06)	.822	−0.01	(−0.08 to 0.06)	.779	−0.03	(−0.38 to 0.32)	.866	0.05	(−0.16 to 0.26)	.641
Solid foods before 3 months	−0.01	(−0.07 to 0.06)	.841	−0.01	(−0.08 to 0.06)	.765	0.03	(−0.18 to 0.25)	.775	0.07	(−0.10 to 0.24)	.434
Put baby to bed with bottle	−0.01	(−0.09 to 0.07)	.770	−0.01	(−0.10 to 0.07)	.716	0.07	(−0.16 to 0.29)	.557	0.03	(−0.14 to 0.20)	.730
Controls		Yes			Yes							
Constant	−7.06	(−8.01 to −6.12)	.000	−7.04	(−8.00 to −6.09)	.000						

Sample from multiple-imputation dataset. Sample is rounded as required for use of NCES restricted data. Data weighted for complex sample design and oversampling. Confidence intervals in parentheses. Controls include measures presented in Table 3

Like any study with survey data, causality is hard to establish. The link between birth weight and cognitive skill development is no different—as it has been recently been contested. Some scholars argue the relationship is trivial, short-term, or spurious (Boardman et al. 2002; Gorman 2002; McGovern 2013; Royer 2009). Although we have identified some of the more important factors that link to VLBW to account for potentially spuriousness, our list is not exhaustive and our longitudinal data only extends to age five. These limitations should be considered when interpreting our results.

Conclusion

It is clear that birth weight influences achievement by shaping emotional and cognitive development during critical child development stages (Duncan et al. 2007) and that these skills matter for later life outcomes (Duncan and Magnuson 2011; Heckman 2008; Merry 2013). We add to this research by identifying large and persistent birth weight disparities in math (and reading) skill from birth to age five.

Our results suggest about half of the VLBW-math score gap is associated with family socioeconomic status. As expected, parenting behaviors measured by parental interaction, cognitive stimulation, and parent quality, are positively associated with improved cognitive scores, regardless of a child's birth weight status, but parenting practices neither mediate nor moderate early childhood birth weight disparities in cognitive development. In short, low birth weight appears to impose a limit to the benefits of effective parenting for cognitive development early in the life course.

Author's Contribution Dr. Lynch initiated the study, developed the first draft of the paper, revised drafts and approved the final manuscript as submitted. Dr. Gibbs developed the literature, added subsequent variables and analyses using statistical techniques, drafted the final manuscript version and approved the final manuscript as submitted.

Compliance with Ethical Standards

Conflict of interest None.

Appendix

See Tables 5 and 6.

Table 5 OLS modeling the association between birth weight status and kindergarten entry reading scores with mediating factors (N = 6100), ECLS-B, 2001

	b	Model 1 (95 % CI)	*p*	*b*	Model 2 (95 % CI)	*p*	*b*	Model 3 (95 % CI)	*p*	*b*	Model 4 (95 % CI)	*p*
Birth weight status (reference=NBW)												
VLBW	−0.34	(−0.42 to −0.27)	.000	−0.23	(−0.40 to −0.07)	.007	−0.15	(−0.29 to −0.01)	.032	−0.15	(−0.29 to −0.01)	.037
LBW	−0.18	(−0.27 to −0.09)	.000	−0.16	(−0.25 to −0.06)	.002	−0.08	(−0.16 to −0.01)	.087	−0.08	(−0.17 to −0.01)	.089
Controls												
Age of assessment	0.11	(0.10 to 0.12)	.000	0.11	(0.10 to 0.12)	.000	0.11	(0.10 to 0.12)	.000	0.11	(0.10 to 0.12)	.000
Female				0.17	(0.10 to 0.12)	.000	0.16	(0.11 to 0.22)	.000	0.16	(0.11 to 0.22)	.000
Gestation age				0.01	(−0.01 to 0.02)	.231	0.01	(−0.01 to 0.02)	.343	0.01	(−0.01 to 0.02)	.247
Twin				0.02	(−0.07 to 0.10)	.724	−0.03	(−0.11 to 0.06)	.553	−0.02	(−0.12 to 0.07)	.604
Apgar				0.03	(−0.04 to 0.09)	.411	0.03	(−0.03 to 0.09)	.306	0.03	(−0.03 to 0.08)	.327
Family/household factors												
Socio-economic status							0.35	(0.31 to 0.38)	.000	0.30	(0.26 to 0.34)	.000
Race/ethnicity												
Black							0.09	(−0.01 to 0.18)	.073	0.09	(−0.01 to 0.20)	.070
Hispanic							−0.09	(−0.17 to 0.00)	.053	−0.08	(−0.17 to 0.01)	.069
Asian							0.36	(0.25 to 0.47)	.000	0.34	(0.22 to 0.45)	.000
Other							−0.05	(−0.18 to 0.07)	.420	−0.04	(−0.17 to 0.09)	.524
Both parents in home							0.16	(0.10 to 0.23)	.000	0.13	(0.06 to 0.20)	.000
Sibling size							−0.08	(−0.10 to −0.05)	.000	−0.09	(−0.12 to −0.06)	.000
Prenatal parenting factors												
Prenatal vitamin (before)										−0.02	(−0.10 to 0.06)	.691
Prenatal vitamin (after)										0.02	(−0.07 to 0.12)	.636
No. of doctor visits in 1st trimester										0.01	(0.00 to 0.03)	.114
WIC during pregnancy										−0.06	(−0.13 to −0.01)	.075
Smoked during pregnancy (BC)										−0.04	(−0.15 to 0.06)	.415
Drank during pregnancy (BC)										−0.12	(−0.50 to 0.25)	.510
Mother's age at child's birth										0.01	(0.00 to 0.02)	.018
Pregnancy weight gain (BC)										0.00	(0.00 to 0.00)	.711
Mother's BMI (Wave 2)										−0.01	(−0.01 to 0.00)	.005
Constant	−6.92	(−7.54 to −6.30)	.000	−7.58	(−8.56 to −6.60)	.000	−7.69	(−8.61 to −6.77)	.000	−7.73	(−8.65 to −6.81)	.000

Sample from multiple-imputation dataset. Sample is rounded as required for use of NCES restricted data. Data weighted for complex sample design and oversampling. Confidence intervals in parentheses

Table 6 OLS modeling the association between birth weight status and kindergarten entry reading scores with mediating factors and interactions (N = 6100), ECLS-B, 2001

	Full model			Interactions: birth weight × parenting factors								
	b	(95 % CI)	*p*	*b*	(95 % CI)	*p*	*b*	(95 % CI)	*p*	*b*	(95 % CI)	*p*
Birth weight status (reference = NBW)												
VLBW	−0.13	(−0.27 to 0.01)	.067	−0.13	(−0.30 to −0.04)	.130						
LBW	−0.07	(−0.17 to 0.02)	.105	−0.08	(−0.20 to −0.05)	.239						
							Interactions by VLBW			Interactions by LBW		
Postnatal parenting factors												
Daycare	0.03	(−0.06 to 0.11)	.555	0.03	(−0.06 to 0.13)	.454	−0.13	(−0.40 to 0.15)	.362	−0.16	(−0.39 to 0.07)	.179
Parenting quality	0.05	(0.01 to 0.08)	.007	0.05	(0.02 to 0.09)	.007	−0.06	(−0.15 to 0.03)	.183	−0.05	(−0.13 to 0.03)	.253
Parental interaction	0.01	(−0.02 to 0.05)	.413	0.02	(−0.02 to 0.09)	.344	0.03	(−0.05 to 0.11)	.485	−0.07	(−0.14 to 0.00)	.055
Parental interaction (Wave 2)	0.05	(0.02 to 0.09)	.003	0.05	(0.01 to 0.09)	.007	0.00	(−0.09 to 0.09)	.980	0.05	(−0.03 to 0.13)	.222
Parental investment (Wave 2)	−0.01	(−0.04 to 0.03)	.724	−0.01	(−0.04 to 0.03)	.697	0.02	(−0.08 to 0.13)	.670	0.02	(−0.05 to 0.09)	.565
Maternal Warmth	0.01	(−0.02 to 0.04)	.541	0.01	(−0.03 to 0.05)	.564	−0.03	(−0.12 to 0.05)	.445	0.00	(−0.07 to 0.08)	.906
Maternal Warmth (Wave 2)	−0.02	(−0.06 to 0.02)	.261	−0.02	(−0.06 to 0.02)	.267	0.03	(−0.03 to 0.10)	.331	0.01	(−0.07 to 0.10)	.758
Cognitive stimulation (Wave 2)	0.05	(0.01 to 0.08)	.010	0.05	(0.01 to 0.08)	.013	0.07	(−0.03 to 0.17)	.179	−0.02	(−0.10 to 0.06)	.637
Cognitive stimulation (Wave 3)	0.05	(0.02 to 0.09)	.002	0.05	(0.01 to 0.08)	.009	0.02	(−0.06 to 0.09)	.636	0.08	(0.00 to 0.16)	.047
Breastfed 6+ months	0.01	(−0.06 to 0.09)	.710	0.01	(−0.07 to 0.10)	.740	−0.02	(−0.39 to 0.36)	.928	0.08	(−0.16 to 0.31)	.519
Solid foods before 3 months	0.00	(−0.07 to 0.06)	.935	0.00	(−0.07 to 0.07)	.988	−0.01	(−0.20 to 0.17)	.871	−0.04	(−0.21 to 0.13)	.639
Put baby to bed with bottle	−0.01	(−0.08 to 0.07)	.862	−0.01	(−0.09 to 0.07)	.821	0.05	(−0.16 to 0.26)	.639	0.03	(−0.13 to 0.20)	.705
Controls		Yes			Yes							
Constant	−7.64	(−8.55 to −6.74)	.000	−7.639	(−8.59 to −6.72)	.00						

Sample from multiple-imputation dataset. Sample is rounded as required for use of NCES restricted data. Data weighted for complex sample design and oversampling. Confidence intervals in parentheses. Controls includes measures presented in Appendix Table 5

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