

# The Risk for Impaired Learning-related Abilities in Childhood and Educational Attainment Among Adults Born Near-term

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**Objective** To examine whether near-term births (NTB) and small-for-gestational-age (SGA) infants are at high risk for childhood learning-related problems and poor adult educational attainment, and whether poverty amplifies the adverse effects of NTB and SGA on those outcomes. **Methods** A randomly selected birth cohort ( $n = 1,619$ ) was followed into adulthood. IQ and learning abilities were measured in childhood and educational attainment was measured in adulthood. **Results** NTB ( $n = 226$ ) and SGA ( $n = 154$ ) were associated with lower educational attainment mediated through learning-related abilities at age 7. Childhood poverty moderated the impact of NTB on educational attainment both directly and mediated through lower learning-related abilities. Poverty did not moderate the effect of SGA. **Conclusions** Poorer learning-related outcomes and educational attainment were not limited to children born very (<32 weeks) or extremely (<28 weeks) preterm, especially among those living in poverty. Targeted interventions such as remedial learning during childhood among NTB in poor families may yield higher educational attainment.

**Key words** educational attainment; learning abilities; near-term birth; poverty; small-for-gestational-age.

Children who are preterm, are small for gestational age (SGA), or have low birthweight (LBW), defined as birthweight <2,500 g, often exhibit a wide range of developmental problems (Hack & Fanaroff, 1999; McCormick, 1985; Mutale, Creed, Maresh, & Hunt, 1991). During school-age years, for example, these children were found to have higher incidences of behavior problems (Gray, Indurkha, & McCormick, 2004; Hack, Taylor, Klein, & Eiben, 1994), emotional problems (Cheung, Ma, Machin, & Karberg, 2004), cognitive deficits (Hack et al., 1994; Litt, Taylor, Klein, & Hack, 2005), and learning difficulties (Brooks-Gunn, Gross, Kraemer, Spiker, & Hapiro, 1992; Rickards, Kelly, Doyle, & Callanan, 2001; Saigal, Pinelli, Hoult, Kim, & Boyle, 2003; Saigal, Rosenbaum, Szatmari, & Campbell, 1991; Saigal & Streiner, 1995) compared to controls. However, we still know little about the risks that children born near-term face with regards to their learning-related abilities and educational attainment (near-term birth,

or NTB, is defined as birth of a child between 33 and 37 weeks of gestation).

NTB as a subgroup of preterm birth has recently attracted attention (Barrington & Finer, 1997; Maisels & Newman, 1998; Raju, 2006; Wang, Dorer, Fleming, & Catlin, 2004) partly because of an increase in its prevalence, from 7.3% in 1992 to 16% in 2002, or 71% of all preterm births (<37 weeks; National Center for Health Statistics, 2005). Reasons for this increase include advanced medical interventions in pregnancies (Villar et al., 2004), cesarean delivery and labor induction (Raju, 2006), having children later in life due to lifestyle changes (Mathew & Hamilton, 2002), and an increased rate of multiple births from assisted fertilization (Lee, Cleary-Goldman, & D'Alton, 2006; Russell, Petrini, Damus, Mattison, & Schwartz, 2003). Recent studies have also found an increase in the risk for neonatal and postnatal morbidity and mortality (Kramer et al., 2000; Tomashek et al., 2002) in this

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*Journal of Pediatric Psychology* 34(4) pp. 406–418, 2009

doi:10.1093/jpepsy/jsn092

Advance Access publication September 15, 2008

*Journal of Pediatric Psychology* vol. 34 no. 4 © The Author 2008. Published by Oxford University Press on behalf of the Society of Pediatric Psychology.

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subgroup—risks often neglected, as near-term babies look healthy despite their immaturity (Wang et al., 2004).

NTB babies are usually considered to be at low risk for later neurodevelopmental problems, and so are unlikely to be monitored and followed up (Huddy, Johnson, & Hope, 2001). Though the number of studies evaluating problems beyond early childhood in NTB children is still small, evidence suggest that poor outcomes in infancy and early childhood may not be limited to those born very preterm (<32 weeks) and extremely preterm (<28 weeks), and that NTB should be followed and diligently evaluated and monitored, and regarded as a biological risk (Raju, 2006). This information would have direct bearing on decision making by obstetricians regarding interventions for early delivery.

Huddy et al. (2001) reported that approximately one third of children born between 32 and 35 weeks of gestation had difficulties in writing, fine motor skills, and mathematics; about one-fifth had difficulties in reading and fine motor skills; and a quarter received nonteaching assisted help at school. Kirkegaard et al. (2006) evaluated the effects of LBW in a population-based sample of 5,319 children who were born after 33 weeks of gestation. They found that LBW children, after adjusting for gestational age, that is, a crude proxy for SGA, were at a marginally increased risk for reading [odds ratio (OR) = 1.9, 95% confidence interval (CI) = 0.8–4.2] and spelling disabilities (OR = 2.2, 95% CI = 0.96–4.8), and a significantly increased risk for arithmetic disability (OR = 4.5, 95% CI = 1.4–15.0) compared to children with a birthweight (BW) between 3,500 and 3,999 g. Kirkegaard et al. found gestational, age-adjusted BW, which is often used as a crude proxy of intrauterine growth restriction (IUGR), was a risk factor for learning disabilities at age 10. They also found a modest increased risk for spelling disability among NTB relative to those born normal term. However, it is not clear whether NTB who also have psychosocial risks, such as poverty, are at a significant increased risk for learning problems.

Poverty is recognized as a risk factor for childhood cognitive functioning and possibly later educational attainment (Ackerman, Brown, & Izard, 2004; Botting, Powls, Cooke, & Marlow, 1998; Klevanov & Brooks-Gunn, 2006; Shaw, Winslow, Owens, & Hood, 1998). Bradley, Mundfrom Whiteside, Casey, and Barrett (1994) refer to poverty to as double jeopardy since the risks tend to be a cause, or are the consequence of, interrelated biological and psychosocial disadvantages that lead to more serious consequences (Watson, Dirby, Kelleher, & Bradley, 1996). While childhood poverty has been found to be a risk factor for lower cognitive function among school-aged children, it is not known whether poverty is especially deleterious for

those at biological risk such as from preterm birth and SGA. Since poverty brings multifaceted disadvantages, including financial, emotional, psychological, and social disadvantages, which could be more extreme for those with biological risks (even a milder form of the risk such as NTB), it may be a possible amplifier for the risk of learning-related problems in childhood and educational attainment in adulthood. For instance, poverty can certainly limit learning resources and opportunities (Linver, Brooks-Gunn, & Kohen, 2002; Saigal, Hoult, Streiner, Stoskopf, & Rosenbaum, 2000; Watson et al., 1996). Parents who live in poverty may be less likely to provide a stimulating environment, where their offspring could gain hands-on learning experiences as poverty and parental educational level is highly correlated (Brooks-Gunn et al., 1992). Poverty can also create frustration among parents and make it difficult for parents to provide optimal care, bonding, and support to their offspring (McAdoo, 1988; Watson et al., 1996). Further, it can prevent parents from providing an optimal physical environment such as adequate hygiene and safe, uncrowded physical space. It is possible that NTB children have greater need for these resources than non-NTB children.

Furthermore, while it is clear that there are intercorrelations among perinatal risks, childhood poverty, and child cognitive functioning and learning abilities, no prior study has examined these factors simultaneously to understand through what mechanism these risk factors affect educational attainment in adulthood. The delineation of possible interrelationships among those factors, through the examination of the mediating effect of childhood learning-related abilities and the moderating effect of poverty, could help identify who is at increased risk for learning problems and lower educational attainment among NTB children. Doing so will allow us to advance our knowledge on modifiable risk factors.

We hypothesized that (a) NTB and SGA are independently associated with a lower level of educational attainment in adulthood; (b) NTB and SGA may be early determinants of educational attainment in adult life mediated though decreased childhood learning-related abilities (IQ, reading, spelling, and arithmetic); and (c) the adverse effect of NTB and SGA on childhood learning-related abilities and adult educational attainment may be stronger among children who grew up in poverty.

## Methods

### *Data Source and Participants*

Data were derived from part of the Johns Hopkins Collaborative Perinatal Study (JHCPS). The JHCPS, part of

the National Collaborative Perinatal Project (NCP), consists of prospective data collected from a random sample of pregnant women who received prenatal care and delivered their babies in the hospital between 1960 and 1964 (Hardy et al., 1997). The NCP utilized collection of data through prospective observation and examination, from pregnancy through the first 8 years of life, attempting to elucidate pathways that adversely influence subsequent child development (Hardy, 2003) during perinatal and early childhood periods. The participation rates varied between 90% during the first years to 88% at ages 7 and 8.

In 1992–1994, the Pathways to Adulthood Study at Johns Hopkins University (PIs: J. Hardy & S. Shapiro) bridged the period from 7–8 to 27–33 years of age. The Pathways study includes 2,694 adult offspring born between 1960 and 1965, randomly selected from among the JHCPS children, who had received the 7-year psychological and/or 8-year language, hearing, and speech assessment (all but a few, <1.0% received both) and their 2,307 mothers (original participants). Fieldwork for the follow-up study (July 1992 through March 1994) provided for the location of subjects and the collection of data from the end of the JHCPS to the date of interview. Mothers and their adult offspring were interviewed separately, after informed consent, by different interviewers. The interviews were, for the most part, conducted face-to-face (70%). When the respondent lived outside the greater Baltimore area or refused a personal interview, the interview was conducted by telephone. A random 10% of all interviews were super-numerated with a brief telephone interview within 10–14 days to maintain the accuracy of data collected. Adult offspring (aged 27–33 years) completed an interview that included a standard questionnaire covering personal characteristics and social and psychological functioning as an adult (Fan & Eaton, 2001; Hardy et al., 1997; Nomura & Chemtob, 2007).

Of the 2,694 offspring eligible for the study, 2,220 (82%) were located and 1,758 completed interviews (71.4% response rate for determining an outcome and 65.3% completing a full interview). Those who were located but did not complete full interviews had mothers with characteristics generally similar to those who were interviewed. Of the 1,758 offspring who completed the adult interviews, 48 had missing information on childhood cognitive and learning performance scores assessed at age 7 and 26 had no information on gestational age at birth. As some children were missing multiple pieces of information, the total was 70 offspring with missing information on either childhood cognitive and learning performance scores or gestational age at birth. Of the remaining 1,688

offspring, 69 (4.2%) whose gestational age was less than 33 weeks were excluded, leaving 1,619 for this study. Analyses of demographic differences between the 1,619 offspring included and the remaining 1,006 offspring, who were eligible for follow-up but excluded, revealed no differences in race (81.7% Blacks vs. 81.6%), maternal parity (3.2 vs. 3.3), maternal monthly income during pregnancy (\$1,028 vs. \$993), and maternal age at birth (25.0 vs. 24.5). However, the included offspring were more likely to be female than the excluded (54.1% vs. 41.3%,  $p < .001$ ).

## Measures

### At Birth

BW was recorded by a nurse observer at delivery. Gestational age was based on mother's self-report on her last menstrual period. SGA was defined as equal to or below the sex- and race-specific 10th percentile in BW for gestational age in the cohort (Clausson, Gardosi, Francis, & Cnattingius, 2001; Goldenberg & Cliver, 1997; Kramer et al., 2001; Robertson, 2003; Wilcox, 1983). The 10th percentile was used as it allows easier comparison of results to other studies and makes no assumptions about the effects of factors such as maternal height, weight, or parity (Hardy et al., 1997).

### At Age 7 (6 Years 10 Months to 7 Years 3 Months)

Mothers were asked to assess the family's childhood poverty level when children were aged 7. Poverty level is the ratio of the family's annualized income to the poverty level based on the Social Security Bulletin Annual Statistical Supplement and was calculated by the JHCPS researchers, taking into account yearly income, family size, and the inflation rate (Hardy et al., 1997). A poverty index of 1 or more represents a family living below the poverty level. Poverty index was recorded with 0 indicating above and 1 below the poverty line. Cognitive functioning (IQ) and learning performance were also assessed at age 7, by a child psychologist, using the Wechsler Intelligence Scale for Children, Short Form (Wechsler, 1949). Standardized scores had a mean of 100 and a standard deviation of 15. The wide range achievement test measured learning (dis)abilities (reading, arithmetic, and spelling) (Jastak & Jastak, 1965). In view of the narrow age range of the sample at the time of testing, we used the raw scores. Mean (SD) for reading, arithmetic, and spelling was 22.3 (0.10), 19.0 (0.08), and 30.8 (0.20), respectively. Ranges were 0–56, 0–32, and 0–76, respectively.

Data on number of grades repeated, years of education, and degree(s) earned (qualifications) were collected in adulthood [mean age ( $SD$ ) = 31.2 (1.5)] during face-to-face interviews by trained researchers blind to perinatal problems and childhood learning performance. Qualifications were categorized as high-school drop out, high school graduate or general educational diploma, 2-year college degree, 4-year college degree, master's degree, and doctorate.

### **Potential Confounders and Missing Values**

Demographic confounders available for all participants included race and sex of the child. Missing data on IQ, learning ability scores (reading, spelling, and arithmetic), qualifications, and educational attainment are negligible (all < .1%).

This study was ruled exempt by the Institutional Review Board committee because it involved secondary data analysis of de-identified data.

### **Data Analysis**

First, we conducted analysis of variance to examine the relationship of each perinatal outcome group (NTB and SGA) to IQ and learning abilities (reading, arithmetic, and spelling) at age 7. Mean ( $SD$ ) of each outcome variable was compared between participants with or without NTB and SGA. Effect size was calculated based on the Cohen's  $d$  (Cohen, 1988). This was followed by analysis of covariance, with race and sex of the participants as covariates: the adjusted mean ( $SE$ ) of each outcome variable was estimated. To avoid type I errors due to testing each of the four outcomes singly, the level of significant  $p$ -value is set at  $.05/4 = .0125$ , using Holm's (1979) correction. Initial univariate analysis is then followed by structural equation modeling (SEM), which allows simultaneous testing of all the associations among the different measures from different times in the life cycle (perinatal, childhood, and adulthood), which enables assessment of the direct and indirect associations of all predictors (Linver et al., 2002).

The Analysis of Moment Structure program (Arbuckle & Wothke, 1999) allows models to be estimated with missing data using the full information maximum likelihood (FIML) method. It involves the computation of a case-wise likelihood function using all observed variables for a particular case, while including partially complete cases to estimate parameters for the missing data. Monte Carlo studies have shown that the FIML method involves less restrictive assumptions about patterns of missing information, yields unbiased parameter

estimates, increases the efficiency of parameter estimates, and eliminates bias in estimation arising from listwise or pairwise deletion and mean substitution of cases (Arbuckle, 1996; Enders & Bandalos, 2001; McArdle & Hamagami, 1996).

Prior to the analysis, the data set was evaluated for normality by examining the univariate indices of skewness and kurtosis for that of 1.96 or more. Path coefficients (standardized beta weights) can be interpreted in terms of both their significance and their magnitude. Residual variances (i.e., error terms) were allowed to covary for NTB and SGA, as well as IQ and each academic achievement score (reading, spelling, and arithmetic). The overall fit of the hypothesized model was evaluated by various indices: A nonsignificant  $\chi^2$ , normed fit index (NFI) closer to 1.00, comparative fit index (CFI) greater than .95, and root mean square errors of approximation (RMSEA) less than .06 were used to indicate a good fit (Joreskog & Sorbom, 1986; Tucker & Lewis, 1973).

A structural equation model was created to test a hypothesized mechanism (Model 1) to predict adult educational attainment directly from two perinatal risk conditions (NTB and SGA), mediated through childhood learning-related abilities (Model 2) in the total of 1,619 offspring, and then in a multigroup model by poverty status (living below and above the poverty line) at age 7 to test a potential moderating effect. In examining potential moderating effects using multigroup SEM, the models were first tested by imposing constraints in which the paths from each of the indicators were made equal, and then by allowing paths to vary freely one at a time and comparing the differences in  $\chi^2$  value with one degree of difference change.

## **Results**

### **Sociodemographic Status, Perinatal Problems, and Educational Attainment**

Detailed characteristics of the participants are shown in Table I. The majority were Black, and 55% were female. At the time of the birth of their child, mothers were relatively young (mean age 24.9), had lower education (14% had less than primary school education), and had multiple children ( $M = 3.2$ ). Approximately one-third lived below the poverty line when the participant was at age 7. In adulthood, approximately one-fifth of the cohort had not completed high school, while one-eighth had some college education. Relative to their mothers, participants had more education ( $M = 12.3$  years). Mean ( $SD$ ) individual annual income in adulthood was \$16,694 ( $SD = \$14,580$ ).

**Table 1.** Demographic and Perinatal Characteristic of Mothers and Offspring ( $n = 1,619$ )

Characteristics	<i>N</i>	%
G2 Gender		
Male	734	45.3
Female	885	54.7
G2 Race		
White	304	18.8
Black	1,312	81.0
Others	3	2
Parity, mean (SD), range	2.2 (1.3), 0–13	
Primipara	496	30.6
1	278	17.2
2	227	14.0
3	194	12.0
4	151	9.3
5+	263	16.3
Missing	10	.6
Maternal age at the birth of G2, mean (SD), range	24.9 (7.1), 12.2–47.1	
<15	58	3.6
15–19	403	24.9
20–24	476	29.4
25–29	296	18.3
30–34	215	13.3
35+	171	10.6
Maternal education		
<8th grade	226	14.2
8th grade	224	14.1
Some high school	692	43.6
High school graduate	337	21.2
Some college	96	6.1
Bachelors or higher	11	.7
Poverty level at delivery		
Below	698	50.2
Above	812	43.1
Missing	109	6.7
Poverty level when child was 7		
Below	496	30.6
Above	1,123	69.4
Birth-term		
Near-term	226	14.0
Full-term	1,393	86.0
Size at birth		
Small for gestational age	154	10.1
Not small for gestational age	1,465	89.9

Note. *N* may vary due to missing value.

### ***IQ and Learning Abilities at Age 7 as a Function of Perinatal Problems (NTB and SGA): Univariate Analysis***

First we tested Hypothesis 1 by examining the association of each perinatal problem with IQ and

learning abilities (reading, spelling, and arithmetic) singly (Table II). Offspring with NTB relative to full-term birth had a significantly lower mean IQ (88.9 vs. 93.5), as well as reading (28.8 vs. 31.8), spelling (21.0 vs. 22.8), and arithmetic (17.7 vs. 19.5) scores. Similarly, offspring with SGA, relative to non-SGA, had a significantly lower mean IQ (89.2 vs. 93.45), as well as reading (29.1 vs. 31.8), spelling (21.1 vs. 22.8), and arithmetic (17.7 vs. 19.5) scores. Although significant, the effect of NTB was small for IQ (Cohen's  $d = .40$ ), reading ( $d = .31$ ), and spelling ( $d = .35$ ), and moderate for arithmetic scores ( $d = .48$ ). Similarly, the effect size of SGA was small for IQ ( $d = .40$ ), reading ( $d = .31$ ), and spelling ( $d = .37$ ) and moderate for arithmetic scores ( $d = .53$ ). Adjustment of the race and gender of the child and mother's marital status changed mean scores minimally, as presented in the second row in Table II for each cell.

### ***Description of Structural Equation Models and Model Fit (Model 1 and Model 2)***

Our use of SEM allowed for a complete and simultaneous test of all the associations between perinatal problems (NTB and SGA), learning-related abilities (IQ, reading, spelling, and arithmetic scores) at age 7, and educational attainment in adulthood (qualifications and years of education). Cronbach's alpha for the four observed variables for learning-related abilities and for the two variables observed for educational attainment showed good internal consistency ( $\alpha = .81$  and  $.95$ , respectively).

Our first SEM model, to predict adult educational attainment directly (Model 1) based on the full sample, had a good fit [NFI = .99, CFI = .99, RMSEA = .001, 90% CI = 0.0001–0.033, and  $\chi^2(2) = 1.3$ ,  $p = .52$ ]. Indices for the multigroup model also demonstrated a good fit [NFI = .99, CFI = .99, RMSEA = .001, 90% CI = 0.0001–0.026, and  $\chi^2(4) = 3.0$ ,  $p = .55$ ]. Our second SEM model (Model 2), to predict adult educational attainment mediated through childhood learning-related abilities based on the full sample, also had a good fit (NFI = .996, CFI = .998, RMSEA = .025, 90% CI = 0.009–0.039). We reached this conclusion despite the significant  $\chi^2$  test of model fit,  $\chi^2(13) = 25.1$ ,  $p = .02$ , as this test is known to be especially sensitive to large sample size and captures even small deviations from the causal model (Byrne, 2001), while all other indices indicated an excellent fit. Indices for the multigroup model also demonstrated a very good fit [NFI = .994, CFI = .998, RMSEA = .016, 90% CI = 0.001–0.027, and  $\chi^2(26) = 37.5$ ,  $p = .07$ ].

**Table II.** Mean (SD) and adjusted mean (SE) of IQ and Learning Ability Scores at 7 Years of Age by Birth-term and Small for Gestational Age Status

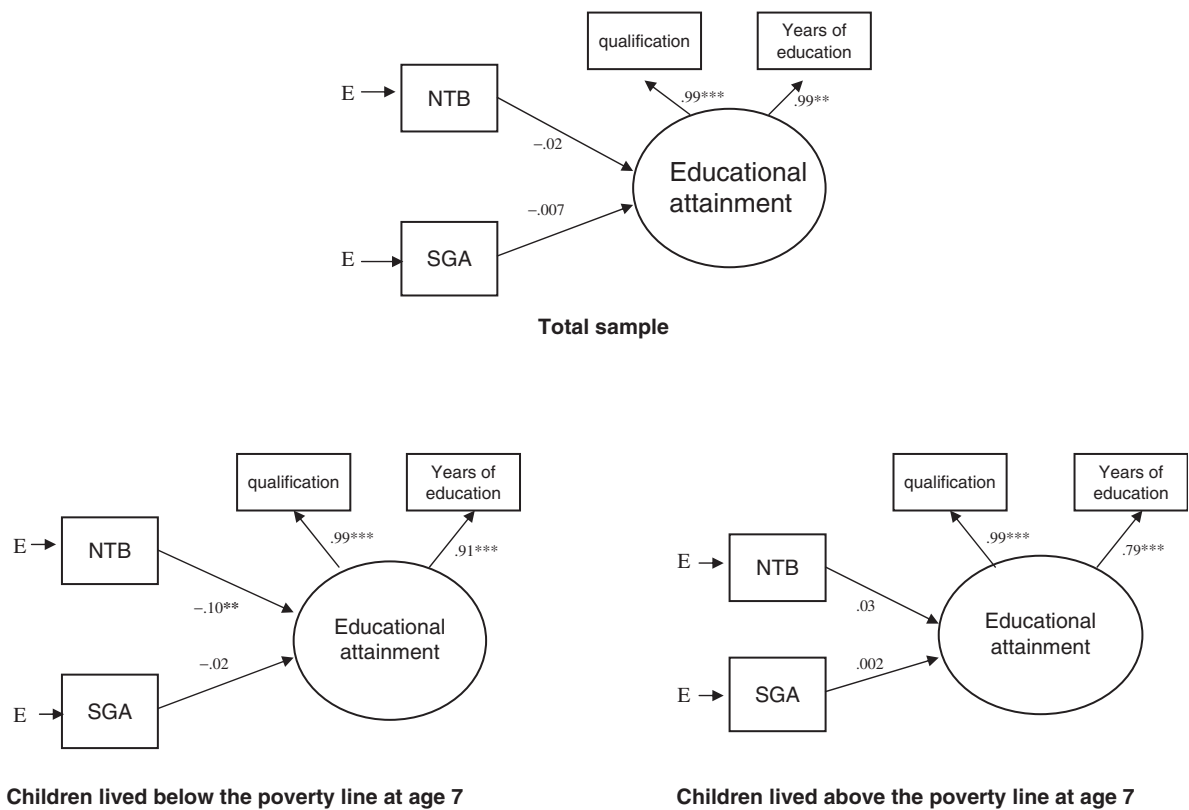
Outcomes	Birth-term status				Small for gestational age			
	Full-term (n = 1393)	Near-term (n = 226)	p-value	Cohen's d <sup>a</sup> (95% CI)	Normal (n = 1372)	Small (n = 63)	p-value	Cohen's d <sup>a</sup> (95% CI)
IQ	93.5 (11.6)	88.9 (11.8)	0.0001	0.396 (0.391–0.410)	93.4 (11.8)	89.2 (12.7)	<0.0001	0.400 (0.391–0.410)
	92.0 (0.5)	88.9 (0.9)	<0.0001		92.4 (0.4)	88.5 (0.9)	<0.0001	
Reading	31.8 (9.6)	28.8 (10.6)	0.004	0.308 (0.295–0.321)	31.8 (9.7)	29.1 (10.8)	0.001	0.311 (0.302–0.318)
	30.7 (0.4)	28.8 (0.7)	0.005		31.1 (0.4)	28.4 (0.8)	0.0001	
Spelling	22.8 (5.1)	21.0 (5.4)	0.01	0.350 (0.341–0.359)	22.8 (5.1)	21.1 (5.7)	<0.0001	0.374 (0.361–0.379)
	22.1 (0.2)	21.2 (0.4)	0.014		22.5 (0.2)	20.8 (0.4)	<0.0001	
Arithmetic	19.5 (3.7)	17.7 (4.4)	0.001	0.474 (0.458–0.482)	19.5 (3.8)	17.7 (4.8)	<0.0001	0.528 (0.517–0.543)
	18.7 (0.2)	17.9 (0.3)	0.003		19.2 (0.1)	17.5 (0.3)	<0.0001	

Note. SD, standard deviation. SE, standard error.

IQ was measured by WISC-full and scores were age adjusted at the time of the exam. Spelling, reading, and arithmetic performance was measured by WRAT and scores were based on the raw scores.

Values in the first row represents unadjusted mean (SD) based on ANOVA. Values in the second row represents adjusted mean (SE) with race and sex as covariates in ANCOVA.

<sup>a</sup>Cohen's d is used for effect size (0.3–0.5 = medium effect).



**Figure 1.** Hypothesized model of the relations between perinatal problems (NTB and SGA) and learning-related abilities in childhood.

**Adult Educational Attainment as a Function of Perinatal Problems (NTB and SGA): Direct Model (Model 1)**

Figure 1 shows the results based on the direct effect model (Model 1). It shows that neither NTB ( $\beta = -.02, p = .13$ ) nor SGA ( $\beta = -.007, p = .60$ ) is directly associated with a lower level of educational attainment in adulthood.

However, multigroup SEM demonstrates that NTB is associated with a significantly lower educational attainment ( $\beta = -.10, p = .006$ ) only among children who lived below the poverty line in childhood but not among those who lived above ( $\beta = .03, p = .52$ ). As standardized path coefficients ( $\beta$ ) have been used, the magnitude of difference for perinatal risk (NTB and SGA) between the two groups could be easily calculated: The effect of NTB on

**Table III.** Goodness of Fit Statistics for Tests of Invariance Between Children Who Were Grown-up in Poverty and Children who were not Grown-up in Poverty

Model No. and description	Comparative model	$\chi^2$	df	$\Delta\chi^2$	$\Delta df$	p-value
Multi-group comparison (Model 1)						
1. Below poverty	–	0.4	2	–	–	–
2. Above poverty	–	2.6	2	–	–	–
3. Multi-group (by poverty status)	–	3.0	4	–	–	–
4. Multi-group structural parameters invariant	3	10.8	7	7.8	3	0.05
5. SGA to educational attainment invariant	4	10.1	6	0.7	1	0.40
6. NTB to educational attainment invariant	4	4.2	6	6.6	1	0.01
Multi-group comparisons (Model 2)						
1. Below poverty	–	15.8	13	–	–	–
2. Above poverty	–	21.7	13	–	–	–
3. Multi-group (by poverty status)	–	37.5	26	–	–	–
4. Multi-group structural parameters invariant	3	56.9	35	19.4	9	0.02
5. SGA to learning abilities invariant	4	55.8	34	1.1	1	0.29
6. NTB to learning abilities invariant	4	53.1	34	3.8	1	0.05
7. SGA to educational attainment invariant	4	55.2	34	1.7	1	0.19
8. NTB to educational attainment invariant	4	53.7	34	3.2	1	0.07
9. Learning to educational attainment invariant	4	50.8	34	6.1	1	0.01

Note.  $\Delta\chi^2$  = change in the  $\chi^2$  statistics between the model being studied and the comparative model.  $\Delta df$  = change in the degree of freedom between the model being studied and the comparative model.

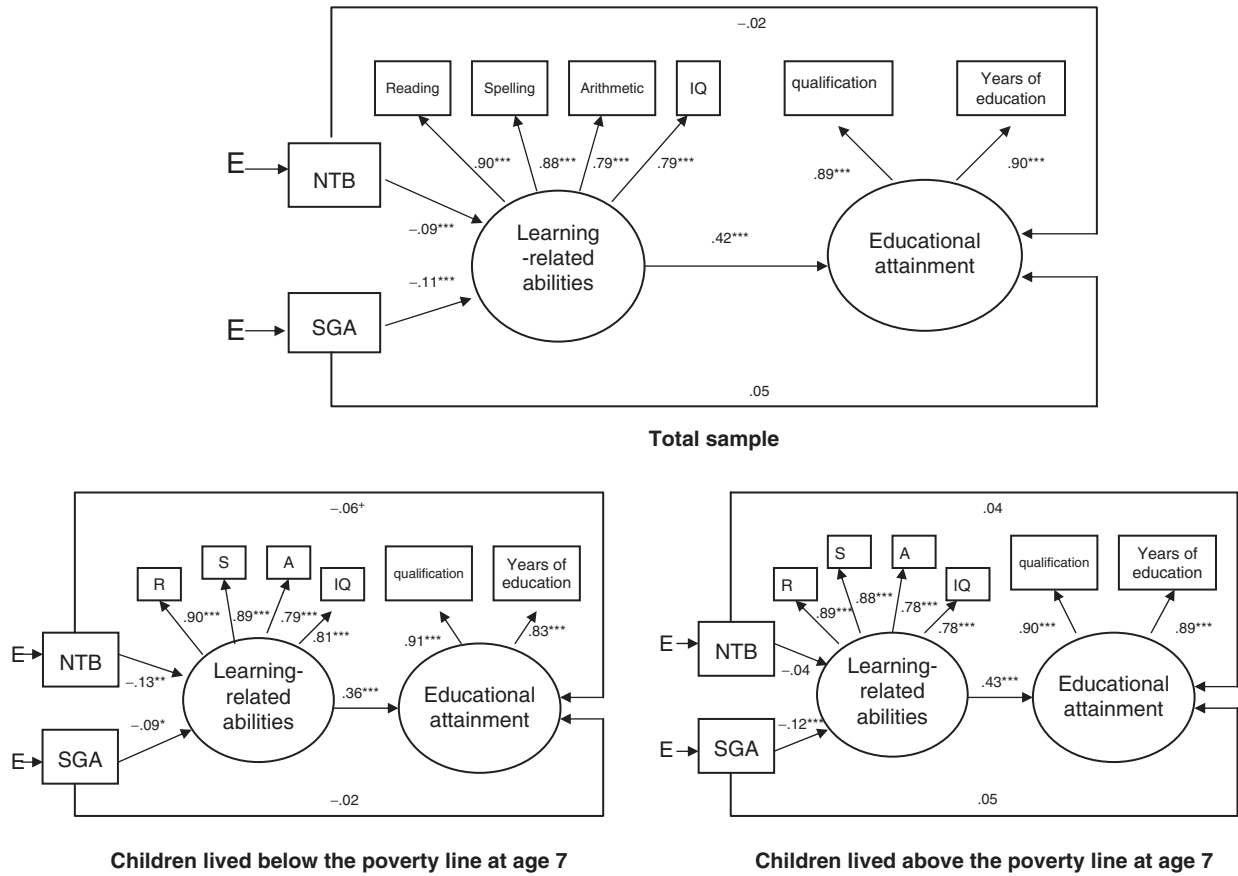
adult educational attainment was over three times stronger in children who lived below than above the poverty line. The formal test of overall path invariance (Table III) confirmed that the two groups were significantly different,  $\chi^2_{\text{difference}}(3) = 10.8, p = .05$ . The source of this difference between the two groups among all the paths was found to be due to the path from NTB to educational attainment in adulthood,  $\chi^2_{\text{difference}}(1) = 6.6, p = .01$ , suggesting that poverty in childhood was a moderator for the association between NTB and a lower level of educational attainment in adulthood. SGA had no association with the level of educational attainment in adulthood ( $\beta = -.007, p = .59$ ), nor was there a moderating effect of childhood poverty between SGA and educational attainment,  $\chi^2_{\text{difference}}(1) = .7, p = .40$ .

#### **Adult Educational Attainment as a Function of Perinatal Problems (NTB and SGA), Mediated Through Learning Abilities at Age 7: Mediation Model (Model 2)**

The results of the mediation model (Model 2) are presented in Fig. 2. It shows both NTB ( $\beta = -.09, p < .0001$ ) and SGA ( $\beta = -.11, p < .0001$ ) were associated with a decrease in learning-related abilities at age 7. Learning-related abilities were then positively associated with educational attainment ( $\beta = .43, p < .0001$ ). However, there was no significant direct path from either NTB or SGA to educational attainment.

#### **Multigroup Model Examining Moderating Effects of Poverty Status**

Multigroup SEM demonstrated that among children living below the poverty line, NTB was associated with significantly lower learning-related abilities ( $\beta = -.13, p = .006$ ) but not among those who lived above it ( $\beta = -.04, p = .21$ ). The effect of NTB on childhood learning abilities was over three times stronger in children living below the poverty line than in those living above it. The test of overall path invariance (Table IV) found a significant difference between the two groups,  $\chi^2_{\text{difference}}(9) = 19.4, p = .02$ . Three sources of the significant or marginally significant differences between the two groups were identified: a path from NTB to childhood learning-related abilities,  $\chi^2_{\text{difference}}(1) = 3.8, p = .05$ ; a direct path from NTB to adult educational attainment,  $\chi^2_{\text{difference}}(1) = 3.2, p = .07$ ; and a path from childhood learning abilities to educational attainment,  $\chi^2_{\text{difference}}(1) = 6.1, p = .01$ . Those findings suggest that poverty in childhood moderates the association between NTB and learning-related abilities at age 7 and educational attainment in adulthood. Specifically, NTB was more strongly associated with childhood learning-related abilities among those who grew up in poverty than those who did not ( $\beta = .13, p = .006$  vs.  $\beta = -.04, p = .38$ ). The direct effect of NTB on adult educational attainment also differed between the two groups. Moreover, among children who lived below the poverty line, there was a marginally significant direct



**Figure 2.** Hypothesized model of the relations between perinatal problems (NTB and SGA) and learning-related abilities in childhood and educational attainment in adulthood.

**Table IV.** Intercorrelations among Study Variables

	NTB	SGA	IQ	Read	Spell	Arith	Edu	Qual	poverty	Race	Sex	MS
NTB	1	0.29	$-0.09^{**}$	$-0.07^{**}$	$-0.06^+$	$-0.08^{**}$	$-0.01$	$-0.03$	$0.08^{**}$	0.04	$-0.02$	0.03
SGA		1	$-0.11^{**}$	$-0.09^{**}$	$-0.10^{**}$	$-0.14^{**}$	$-0.01$	$-0.02$	0.03	$-0.002$	$-0.003$	$-0.03$
cognitive function (IQ)			1	$0.55^{**}$	$0.59^{**}$	$0.65^{**}$	$0.28^{**}$	$0.30^{**}$	$-0.19^{**}$	$-0.90^{**}$	0.04	$-0.001$
Reading (Read)				1	$0.85^{**}$	$0.71^{**}$	$0.35^{**}$	$0.35^{**}$	$-0.21^{**}$	$-0.04$	$0.11^{**}$	$-0.02$
Spelling (Spell)					1	$0.70^{**}$	$0.34^{**}$	$0.33^{**}$	$0.17^{**}$	$-0.03$	$0.16^{**}$	$-0.03$
Arithmetic (Arith)						1	$0.28^{**}$	$0.29^{**}$	$-0.19^{**}$	$-0.10^{**}$	$0.06^+$	$-0.02$
Years of education (Edu)							1	$0.80^{**}$	$-0.19^{**}$	$0.26^{**}$	$-0.08^{**}$	0.01
Qualifications (Qual)								1	$-0.17^{**}$	$0.17^{**}$	$-0.01$	0.009
Poverty									1	0.02	0.004	0.01
Race										1	0.008	$-0.05$
Sex											1	0.03
Marital status (MS)												1

$^+P < .05$ .  $^{**}P < .01$ .

effect from NTB on educational attainment ( $\beta = -.06$ ,  $p = .08$ ), whereas among those who lived above the poverty line, there was no significant direct effect ( $\beta = .04$ ,  $p = .35$ ). The magnitude of the path from childhood learning-related abilities to adult educational attainment was also significantly different between children lived below

the poverty line ( $\beta = .36$ ,  $p \leq .0001$ ) and those who lived above it ( $\beta = .43$ ,  $p \leq .0001$ ). Unlike these findings on NTB, the effect of SGA was not moderated by childhood poverty, though SGA was directly associated with a decrease in childhood learning-related abilities.



## Discussion

To our knowledge, this is the first study that has examined whether adults born near-term, relative to full-term, face long-term negative consequences for their educational success, and whether the negative consequences of NTB are stronger when they lived in poverty during childhood. The magnitude of the negative impact of NTB on adult educational attainment was approximately three times greater among those who lived below the poverty line in childhood than those who lived above it, but the effect was mediated through lower learning-related abilities at age 7. SGA, already established as a risk factor for learning-related and cognitive function problems in childhood, was also found to be a risk factor for learning-related problems at age 7 but not educational attainment in adulthood. In sum, the study clearly documented that the adverse consequences of NTB on educational attainment are not limited to children born extremely (<24 weeks) or very (<32 weeks) early. Children born with NTB are at increased risk for more compromised educational development, which provides potential for more targeted clinical interventions.

In response to the World Health Organization's recent call to examine the increased risk for childhood problems among those born near-term instead of very preterm (29–32 weeks) or extremely preterm (<28 weeks), research on the relationships between perinatal factors (e.g., birthweight, IUGR, and preterm birth) and child and adult outcomes has begun to examine outcomes among near-term infants (Huddy et al., 2001; Kirkegaard et al., 2006). However, except for regional birth cohort studies (Breslau, Chilcoat, DelDotto, Andreski, & Brown, 1996; Kirkegaard et al., 2006; Klebanov, Brooks-Gunn, & McCormick, 1994; Matte, Bresnahan, Begg, & Susser, 2001; Richards, Hardy, Kuh, & Wadsworth, 2001; Sorensen, Saboe, Olsen, & Rothman, 1997), which utilized retrospective reports of BW, the majority of prior research used high-risk samples from clinical settings to evaluate the perinatal risk of learning-related difficulties, such as survivors of the NICU with very low birthweight (VLBW) (Litt et al., 2005; Richards et al., 2001; Saigal & Steiner, 1995) or extremely low birthweight (ELBW) (Hack & Fanaroff, 1999; Hack et al., 1994; Saigal et al., 1991, 2003). Our findings are consistent with those from Kirkegaard et al.'s and Huddy et al.'s studies, which showed the detrimental effect of suboptimal perinatal problems on cognitive functioning and learning among the NTB and confirmed evidence that the adverse consequences are not limited to children born extremely or very early and are long term. Further, we extended the prior literature by demonstrating

that the consequences of NTB were associated with poorer adult educational attainment mediated through childhood learning-related abilities (i.e., early markers) and were amplified by childhood poverty. In a higher risk population, Saigal, Stoskopf, Streiner, and Boyle (2006) found children with ELBW (weighing <1,000 g), as compared to the normal control (normal BW, weighing >2,500 g), had equivalent qualifications but fewer years of education in their adulthood. In the current study, although we used an NTB and not an ELBW sample, we also had mixed findings. NTB was associated with a lower educational attainment but only among those who grew up in poverty.

This study needs to be evaluated in light of its strengths and weaknesses. It has several methodological strengths. The study has a long follow-up time (over 30 years). The cohort was prospectively and systematically followed from birth, as a part of the NCPP, and studied longitudinally. BW was recorded by a nurse observer in the delivery room rather than based on retrospective self-report. Cognitive functioning (IQ) and learning ability scores at age 7 were assessed systematically across the 12 sites that participated in the NCPP (Hardy, 2003) by trained child psychologists who were blind to the child's perinatal risk status. The use of SEM allows simultaneous evaluations of potential mediation (i.e., childhood learning-related abilities) and moderation (childhood poverty) on adult educational attainment.

The study also has limitations. First, although our sample was of randomly selected regional representatives, the area that they were drawn from was populated in the early 1960s by a poor minority (especially Blacks). Thus, while our sample consists of 18% White, external validity may be limited. Second, gestational age was determined by the mother's self-report based on her recollection of the date of her last menstrual period and therefore subject to recall bias. Third, only the raw scores and the grade equivalent scores for learning abilities were available, and not standardized scores based on the population norm for each subject area. However, since offspring's learning performance was assessed within a very narrow age range (between 6 years 10 months and 7 years 3 months), the lack of standard scores is not a serious concern. Because of the well-known psychometric difficulties inherent in grade scores (Anatasi & Urbina, 1997), we chose to use raw scores for our main analyses. Fourth, we need to interpret our findings in light of the level of obstetric care in the 1960s. Our sample was born in the pre-NICU era and the mortality rate for those born very early was higher than the current mortality rate. The concept of special or remedial education, and a realization of the need for early

intervention, has also advanced considerably since the late 1960s. It is plausible that the risk of learning impairment as a function of perinatal signs and problems could have been greater had we been able to include children who died during the neonatal period. In addition, more effective and targeted remedial assistance in school by age 7 is available today for those with a mild learning impairment. We are left to speculate whether the children who might have qualified for, and benefited from, such services are those with mild perinatal problems. We should remind ourselves that both NTB and SGA were associated with poorer IQ and learning scores, but childhood poverty amplified only an adverse effect of NTB and not of SGA on childhood learning-related abilities, and that in turn was associated with lower educational attainment. This suggests that relatively mild suboptimal perinatal conditions are risk factors for poor childhood academic functioning, and that social and psychological disadvantages, such as poverty, can either amplify the biological risk brought by NTB or result in children having limited access to remedial services. Further delineation of the underlying mechanisms to understand modifiable conditions would be beneficial in future studies. Lastly, although we found associations between perinatal risks (NTB and SGA) and childhood learning-related problems, as well as associations between NTB and adult educational attainment among those who grew up in poverty, the effect size was small with the one exception of arithmetic ability, which had a medium effect size.

However, we believe that these findings will contribute to understanding the long-term effects of NTB and the elucidation of the mechanism by which NTB affects educational attainment in adulthood. Even a small impact at an early stage of development can lead to compromised outcomes later in life. Our research has attempted to delineate the mechanism that results in poor educational attainment, considering mediating and moderating factors that could shed light on the underlying processes of risk and the outcome at different times in the life cycle of children born near-term. It is beyond the scope of this study to examine the relative impact of low educational attainment on the physical, psychological, and social quality of life. It could be that the earlier the potential problems are recognized, the easier the intervention will be, and this would minimize unnecessary hardship among NTB individuals, especially those who grow up in poverty. Delineation of the mechanism over time to identify links may be the first step toward achieving effective interventions. Simultaneously, more focused examinations of the underlying mechanism in the area of cognitive functioning,

using more advanced technology such as functional magnetic resonance imaging between children living in different socioeconomic groups, could help design more effective interventions.

This study has both clinical and future research implications. First, the rate of NTB is growing, and the number of surviving NTB is increasing. However, survival of extremely preterm and very preterm babies is also increasing. As NTB infants look healthier and bigger, they could be neglected in light of the more immediate needs of supporting extremely preterm and very preterm infants. It is, therefore, essential to have pediatricians and psychologists evaluate the effect of NTB in a developmental framework since the consequences of milder forms of perinatal health problems such as NTB may take more than a decade to become evident, when the portion of the central nervous system underlying the behavior is more developed (Kandel, Wu, & Davies, 1994). Executive functioning, for example, does not reach full maturity until puberty (Blakemore & Choudhury, 2006). As the level of impairment in learning-related abilities associated with NTB is relatively small and could be overlooked in a classroom setting, it may be helpful for pediatricians to routinely ask parents how their children are doing in basic academic skills at the child's annual physical checkup. This will make it possible for the children born near-term to be monitored for emergence of problems, even subtle ones, that arise as a result of NTB at different developmental stages, and may serve as an effective first step toward designing more focused and effective intervention strategies.

Our study suggests that monitoring academic performance among survivors of NTB, especially from poor families, may be an effective strategy. However, our study did not evaluate the level of functioning and problems after age 7 until adulthood. Thus, it is clear that SGA has a negative impact on childhood learning abilities but not on adult educational attainment, whereas NTB continues to negatively affect developmental trajectories, especially among the poor. One explanation for the difference could be that NTB is associated with different areas of impairments other than learning and cognitive functioning in children's lives, which could influence their chance of acquiring a better educational status. It is possible that SGA may be more influenced by genetic propensities and after catching-up early in life, affected children will do as well as people with normal-for-gestation age (NGA).

These data also suggest that the etiology of SGA and NTB may differ. Although important, development of this is beyond the scope of this study. Clarification on the differences in mechanisms between SGA and NTB could

indeed provide useful information to both clinicians and parents and inform effective interventions. In the meantime, as poverty and NTB interact and influence the level of learning abilities in childhood and educational attainment in adulthood, it is useful to examine what aspects of poverty, i.e., financial, emotional, and social difficulties, are aggravating the effect of NTB but not SGA.

Future studies should focus not only on the magnitude of the associations between the risk of NTB and problem outcomes but also on the elucidation of the mechanism through which NTB influences outcomes decades later. As we know that NTB may be a moderate but real risk to educational success, it is important to monitor the early academic performance among NTB and offer remedial support to foster the child's academic capabilities, as earlier intervention will almost always improve the prognosis (Bergh, 1990; Fisher, Gunnar, Chamberlain, & Reid, 2000).

### Acknowledgments

We are grateful for Janet Hardy and Sam Shapiro, PIs of "The Pathways to Adulthood: A Three-Generation Urban Study, 1960–1994" for allowing us to use their data and equally grateful for mothers who participated in the study and their children.

### Funding

National Institute of Mental Health (R03 MH067761 and K01MH080062 to Y.N.).

*Conflicts of interest:* None declared.

*Received January 5, 2008; revisions received August 9, 2008; accepted August 12, 2008*

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