Socioeconomic Attainment of Extremely Low Birth Weight Survivors: The Role of Early Cognition

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abstract

OBJECTIVES: To determine: (1) if childhood cognitive and academic abilities mediate the association between being born at extremely low birth weight (ELBW) and socioeconomic attainment at age 29 to 36 years; (2) which cognitive abilities (IQ, verbal abilities, fluid intelligence, mathematical abilities, or academic achievement) most strongly mediate this association; and (3) if the mediating role of cognition is different in ELBW survivors with significant neurosensory impairment (NSI).

METHODS: A prospective, longitudinal cohort of 100 Canadian ELBW survivors born between 1977 and 1982 and 89 normal birth weight comparison participants were used to examine the mediating role of childhood cognition by using 5 cognitive mediators assessed at age 8 years (overall IQ, verbal IQ, performance IQ, quantitative ability, and academic achievement) on socioeconomic attainment at adulthood. Socioeconomic attainment was defined as personal annual earnings and full-time employment assessed via self-report at age 29 to 36 years.

RESULTS: Mediation models revealed that childhood cognition mediated the association between ELBW status and income attainment, with mathematical abilities and overall IQ each accounting for 26% of the direct effect. Mediated effects were not statistically significant in full-time employment models. For both outcomes, the mediating effect of cognition was stronger for ELBW survivors with NSI.

CONCLUSIONS: Childhood cognitive abilities partially mediate associations between ELBW status and adult income attainment. Early life cognition is a critical predictor of socioeconomic attainment in ELBW survivors, particularly in those born with NSI. Interventions aimed at enhancing early cognition in ELBW survivors may help optimize their later socioeconomic attainment.

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Ms Dobson conceived the study and its design, analyzed and interpreted the data, and drafted the initial manuscript; Drs Ferro and Boyle helped to conceive the study and its design, aided in the analysis and interpretation of the data, and reviewed and revised the manuscript; Dr Saigal started the cohort, helped to conceive the study and its design, selected the data collection instruments, supervised data collection, aided in the analysis and interpretation of the data, and reviewed and revised the manuscript; Dr Schmidt helped to conceive the study and its design, selected the data collection instruments, supervised data collection, aided in the analysis and interpretation of the data, and reviewed and revised the manuscript; Dr Van Lieshout helped to conceive the study and its design, selected the data collection instruments, aided in the analysis and interpretation of the data, and reviewed and revised the manuscript; all authors participated

WHAT'S KNOWN ON THIS SUBJECT: Little is known about the socioeconomic attainment of extremely low birth weight (ELBW) survivors or its determinants. Research suggests that enhanced childhood cognitive function is associated with greater adult socioeconomic attainment; however, this has never been examined in ELBW survivors.

WHAT THIS STUDY ADDS: Childhood intelligence accounted for 26% of the association between ELBW status and personal earnings at age 30. Mathematical abilities, academic achievement, and verbal abilities also mediated this association. Mediation by childhood cognition was particularly strong among survivors with neurosensory impairment.

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More extremely low birth weight (ELBW; <1000 g) survivors are living into adulthood than ever before.[1] However, very little is known about their socioeconomic attainment in adulthood, a critical marker of success and an important determinant of health.[2] This information is crucial at an individual level and at a population level to model human capital, a function of the current health and its depreciation rate of the labor force in developed countries.[3] As roughly 9% of all infants are born preterm,[4] a significant proportion of the labor force will face perinatal adversities.

Studies utilizing European registry data suggest that very low birth weight (<1500 g)[5] and preterm individuals are at greater risk of lower earnings and unfavorable employment outcomes in adulthood[6,7]; however, the mechanisms linking perinatal adversity to lower socioeconomic attainment remain unclear. Research in general population samples suggests that enhanced early cognitive functioning is positively associated with educational attainment, income attainment, and labor stability in adulthood.[8–10] Cognitive dysfunction is among the most common disabilities experienced by ELBW survivors,[11] with up to 50% of extremely premature survivors suffering from some form of neurodevelopmental disability (ie, cerebral palsy or intellectual disability).[12]

Only 1 study to date has examined the mediating role of cognitive abilities on socioeconomic outcomes in high-risk pediatric survivors. Basten et al[13] reported that early cognitive abilities partially mediated the association between preterm birth (28 to 38 weeks' gestation) and wealth at age 40. However, it is unclear how many ELBW survivors (generally born before 28 weeks' gestation with greater perinatal risk) were included in their study. Secondly, their aggregated wealth estimate (consisting of family income, social class, housing tenure, employment status, and self-perceived financial situation) may be dependent on multiple contextual factors such as sex, marital status, or if the individual has children. Additionally, this may inadvertently obscure the intricacies of how different cognitive abilities influence individual socioeconomic outcomes.

Using data from the oldest, longitudinal cohort of ELBW survivors, the current study explored 3 objectives to determine: (1) if childhood cognitive and academic abilities at age 8 mediated associations between being born at ELBW and socioeconomic outcomes (personal income attainment and full-time employment) at age 29 to 36; (2) which cognitive or academic ability (IQ, verbal abilities, fluid intelligence, mathematical abilities, or overall academic achievement) most strongly mediated this association; and (3) if the mediation pathway for ELBW survivors differed for those born with or without serious neurosensory impairment (NSI).

METHODS

Participants

The study cohort consisted of 100 ELBW survivors and 89 normal birth weight (NBW; ≥2500 g) comparison individuals born in central west Ontario, Canada. Between 1977 and 1982, 397 ELBW survivors were recruited at birth; 179 survived to hospital discharge (Fig 1).[14] At 8 years, 143 ELBW survivors participated in cognitive assessments. At age 22 to 26 years, 142 survivors participated in sociodemographic and health assessments[15]; of these, 100 (70%) participated and provided socioeconomic information at age 29 to 36 years.[1]

At age 8, 145 NBW individuals group-matched for age, sex, and parental socioeconomic status (SES) were recruited from the Hamilton Public School System. At age 22 to 26, 133 NBW individuals participated in data collection and were eligible to participate in the latest data assessment. Of these 133 NBW individuals, 89 (67%) provided data on socioeconomic outcomes at ages 29 to 36. Written informed consent was received from all participants in adulthood and from their parents during childhood. This study received ethics approval from the McMaster University Health Sciences Research Ethics Board.

Mediator: Childhood Cognitive Abilities

Childhood cognitive and academic abilities were assessed at age 8 years; assessment procedures have been previously described.[16] We examined overall intelligence (IQ), verbal abilities, fluid intelligence, mathematical abilities, and academic achievement as mediators, as they have been previously studied as mediators of adult wealth in preterm and general population samples.[8,13] All cognitive tests have adequate psychometric properties.[17–22]

IQ, verbal abilities, and fluid intelligence were assessed by using the *Wechsler Intelligence Scale for Children-Revised* (WISC-R). The WISC-R consists of 10 subtests, each with a mean of 10 and SD of 3. Combining these subtests creates a performance IQ, an assessment of fluid intelligence evaluating visuospatial abilities, alertness to detail, and processing speed; and a verbal IQ, an assessment of reading, verbal, and language abilities.[23] These 2 IQ scores are then combined to calculate an overall IQ (mean = 100, SD = 15), estimating overall intelligence.[23]

Mathematical abilities were assessed by using the *Wide Range Achievement Test-Revised* (WRAT-R) arithmetic

subscale. The subscale comprises questions pertaining to counting, reading numerical symbols, and solving mathematical problems through numerical computation; it has a mean of 100 and SD of 15.[21,24]

The *Woodcock–Johnson Psychoeducational Battery* was used to assess academic achievement. Three subscales of reading (letter–word identification, work attack, and passage comprehension) were administered. The subscales are combined into a single score (mean = 100, SD = 15).[25]

Outcomes: Personal Income Attainment and Full-Time Employment

We examined annual personal income and full-time employment as socioeconomic attainment outcomes. These 2 variables were assessed by using standardized questions from the Ontario Child Health Study questionnaires.[26] Personal annual income was assessed by summing the amount of Canadian income earned over the past 12 months from the following: wages and salaries before deductions, self-employment, employment-insurance benefits, child benefits at provincial and federal levels, social assistance, child/spousal support, and any other income sources such as dividends, interests, capital gains, and gratuities. The median total income in Canada in 2013 was approximately $32 020.[27] Full-time employment was assessed by asking participants if they had been employed 30 hours or more per week for the past 12 months.

Covariates

We included variables associated with poor cognitive function, low birth weight, socioeconomic outcomes, and attrition as covariates within mediation models. These variables included childhood SES, sex, number of years of education completed, age, marital status, and dependent status.[7,28] Childhood

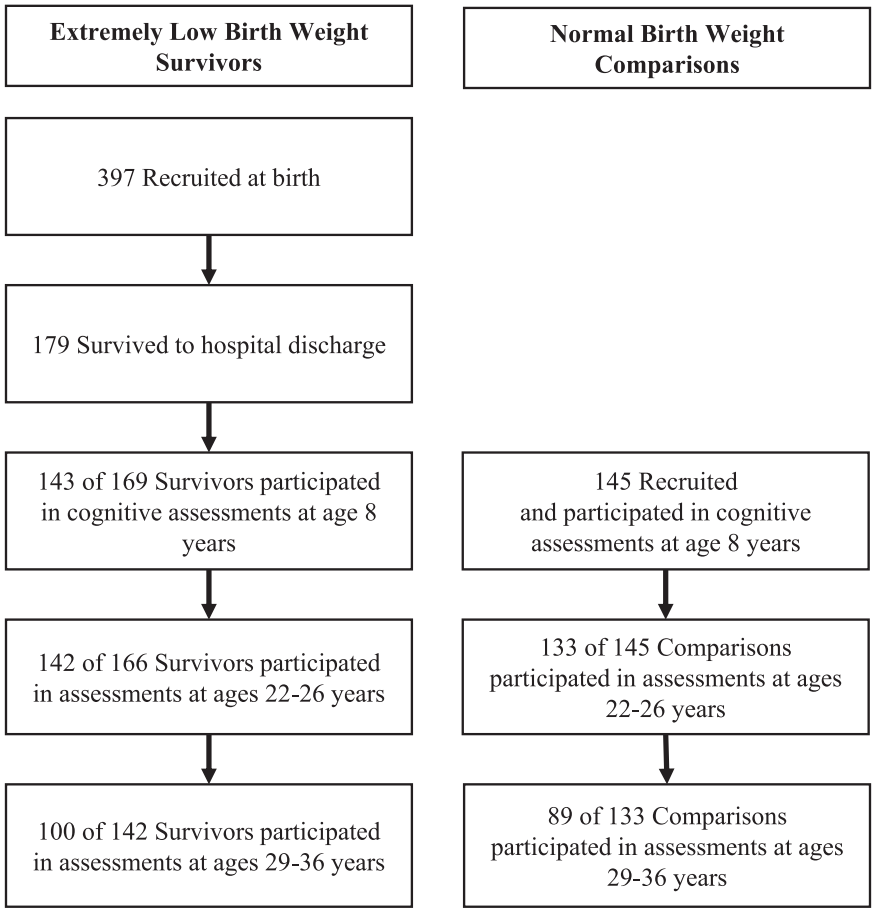

FIGURE 1
Participant flowchart. This figure briefly highlights participation of ELBW survivors and NBW comparisons.

SES was assessed via reports by participants' parents at age 8 by using the Hollingshead 2-factor index of social position.[29] This index has 5 levels, where 1 indicates the highest SES level and 5 indicates the lowest SES level. Educational attainment was self-reported and calculated by summing the years of education each cohort member had successfully completed at the time of testing. Marital status was self-reported and defined as those who were married or living common-law with a partner versus those who were not. Dependent status was self-reported and defined as having at least 1 child versus no children.

Statistical Analysis

Statistical analyses were performed by using SAS version 9.3 (SAS Institute, Cary, NC). Descriptive statistics were examined by using independent sample t tests for continuous variables and χ^2 tests for categorical variables. To determine the influence of attrition in our cohort, we compared participants and nonparticipants on variables used to match ELBW and NBW participants at age 8, and childhood cognitive abilities.

To explore the mediating role of childhood cognitive and academic abilities on socioeconomic outcomes (objectives 1 and 2), we performed the product of coefficient mediation method.[30] We performed single mediator bias-corrected bootstrap models (n = 10 000) to examine the mediating influence of each childhood cognitive factor (overall IQ, verbal

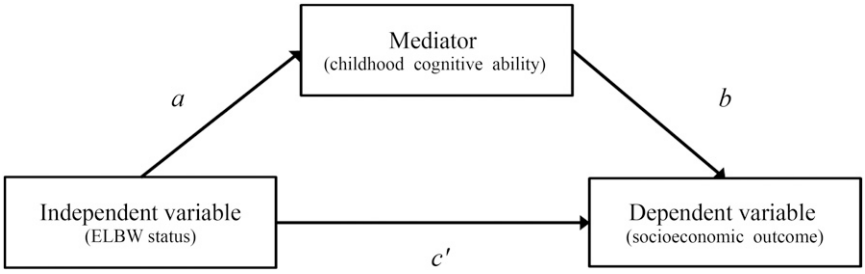

FIGURE 2
Single mediator model. This figure highlights the mediation models used for objectives 1 and 2.

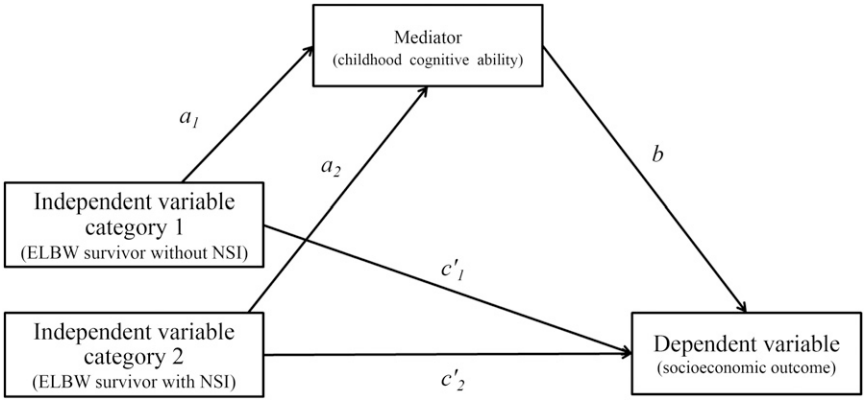

FIGURE 3
Multicategorical independent variable mediator model. This figure highlights the mediation models used for objective 3.

IQ, performance IQ, mathematical abilities, and academic achievement) separately (Fig 2).[30,31] In each model, the independent variable was birth weight status, and the dependent variable was either annual personal income or full-time employment status.

To address our first objective, the mediated effect was calculated by multiplying the *a* and *b* coefficients (indirect effect, *ab*) and computing its 95% confidence interval (CI) to determine statistical significance. To address our second objective, we qualitatively compared the magnitude of each mediated effect for significant models by calculating the proportion mediated for each model.[30]

To attempt to address the influence of missing data in our models, we performed a multiple imputation analysis creating 10 imputed data sets. The average value for each continuous predictor from these 10 data sets was used to replace missing data in subsequent analyses. As the results from these mediation analyses did not statistically differ, we report results only for participants with complete data.

When exploring associations between cognitive abilities and socioeconomic attainment in ELBW survivors, it is critical to account for this population's high rate of NSI. Therefore, for our third objective we performed mediation analyses by using a multicategorical independent variable (Fig 3) and compared the magnitude of mediated effects in ELBW survivors with and without NSI.[32] NSI were diagnosed at age 3 by developmental pediatricians and were defined as follows: cerebral palsy, mental retardation, blindness, deafness, or microcephaly.

RESULTS

Sample Characteristics

Table 1 contains the characteristics of the study participants. No differences were seen in current age, sex, childhood SES, or total years of education between ELBW and NBW participants. At age 8, ELBW survivors scored significantly lower in all cognitive domains compared with NBW participants ($P < .001$). ELBW participants reported annual personal incomes approximately $20 000 lower than NBW participants ($P < .001$). Nearly 77% of NBW participants and 62% of ELBW participants reported having full-time employment over the past year ($P = .042$). Twenty-six ELBW participants and 1 NBW participant had an NSI.

When comparing the demographic characteristics of participants and nonparticipants (Table 2), male sex was a predictor of attrition in both ELBW and NBW groups. In ELBW survivors, lower childhood SES was a predictor of attrition. Nonparticipants generally had lower scores on childhood cognitive assessments compared with participants. It was found that cognitive scores in both participants and nonparticipants followed the same trend in that higher socioeconomic participants generally had higher cognition scores compared with those in lower socioeconomic strata, suggesting that nonparticipants were missing at random.

Objective 1 and 2: Personal Income Mediation Models

Of the 189 participants, 157 (83%) had complete data on all variables and were included in mediation models. In each mediation model, ELBW participants scored significantly lower on all cognitive assessments at age 8 compared with NBW participants (*a* pathway, $P <$

TABLE 1 Participant Characteristics

	ELBW, *n* = 100			NBW, *n* = 89			
	n	Mean	SD	*n*	Mean	SD	*P*
Cohort demographics							
Birth weight, g	100	834.90	132.74	89	3388.12	465.63	<.001
Average for gestational age							
n (%)		71	(71.00)		—	—	
Small for gestational age							
n (%)		29	(29.00)		—	—	
Age, y	100	32.08	1.69	89	32.47	1.37	.084
Sex male, %	100	39	39	89	33	37.00	.074
Childhood (parental) SES, *n* (%)	95			89			.620
I		5	(5.26)		7	(7.87)	
II		16	(16.84)		20	(22.47)	
III		44	(46.32)		32	(35.96)	
IV		27	(28.42)		26	(29.21)	
V		3	(3.16)		4	(4.49)	
NSI, *n* (%)	100	26	(13.76)	89	1	(1.12)	<.001
Married, *n* (%)	100	45	(45.00)	89	53	(59.55)	.046
Have children, *n* (%)	100	20	(20.00)	89	29	(32.58)	.049
Adult SES variables, age 29–36							
Total years of education	97	16.00	2.75	88	16.67	3.12	.126
Personal annual income, $	88	26 484.65	23 721.36	81	46 551.62	31 263.84	<.001
Total household annual income, $	91	54 450.55	41 004.41	81	78 148.15	41 985.45	<.001
Full-time employment this year, *n* (%)	78	48	(61.54)	77	59	(76.62)	.042
Cognitive variables, age 8							
WISC-R full scale IQ	89	93.40	15.77	89	106.20	11.73	<.001
WISC-R verbal IQ	89	93.47	15.00	89	103.60	12.35	<.001
WISC-R performance IQ	89	94.87	16.94	89	108.10	12.45	<.001
Woodcock–Johnson standard score	89	91.60	15.98	89	99.78	13.86	<.001
WRAT-R arithmetic standard score	89	83.36	16.16	89	95.28	13.64	<.001

—, gestational age information pertains only to ELBW participants.

.01). Higher scores on all early life cognitive measures were associated with higher reported personal income at age 30 (*b* pathway, $P < .01$), except for the WISC-R Performance IQ ($P = .10$).

Significant indirect effects (*ab*) were seen in all models except for the WISC-R Performance IQ (Table 3), supporting the presence of mediation. Our results indicate that ELBW children with lower scores on these cognitive and academic measures in childhood reported lower annual incomes in adulthood. However, because ELBW status was still a significant predictor of income attainment in our models, cognitive abilities only partially mediated the association between ELBW status and income attainment.

In addressing our second objective (Table 3), the largest mediated effects were seen by overall IQ, accounting for 26% (*ab* = –$4516, 95% CI: –$9810 to –$730) of the total effect (*c* = –$17 210) in ELBW survivors, and mathematical abilities, also accounting for 26% (*ab* = $–4424, 95% CI: –$9012 to –$1403) of the total effect in ELBW survivors. The smallest significant mediated effect was seen with the Woodcock–Johnson academic achievement score, accounting for 16% of the total effect between ELBW status and adult earnings.

Full-Time Employment Mediation Models

Of the 189 participants, 151 (80%) had complete data and were used in models. Our models suggest that childhood cognitive and academic abilities may not mediate the association between ELBW status and full-time employment (Table 3), because the indirect effect (*ab*) was not statistically significant in any model. When performing logistic regressions of full time on employment ELBW status, cognitive mediators, and covariates, the most significant predictor of full-time employment was sex. Compared with men, the odds of full-time employment were 3 times lower for women.

Objective 3

To address our third objective, we performed mediation models by using a multicategorical independent variable separating ELBW survivors with and without NSI (Table 4). Our results suggest that the mediating role of cognitive abilities on annual income attainment may be stronger in ELBW survivors with NSI because this group had larger indirect effects in every model. For example, overall IQ accounted for 24% (*ab* = –$4023) of the total effect (*c* = –$16 871) in ELBW survivors without NSI, but accounted for 37%

(*ab* = –$6828) of the total effect (*c* = –$18 664) in ELBW survivors with NSI. This trend was seen with every cognitive mediator. For ELBW survivors without NSI, indirect effects for overall IQ, verbal IQ, and mathematical abilities were statistically significant. For ELBW survivors with NSI, indirect effects for overall IQ, mathematical abilities, and academic abilities were statistically significant. When exploring the mediating role of childhood cognition on full-time employment, the indirect effect estimates were not statistically significant.

TABLE 2 Demographic Factors of Participants and Nonparticipants at Current Sweep

Characteristics	Participants	Nonparticipants	*P*
Number of participants			
Overall	189	135	
NBW	89	56	
ELBW	100	79	
Male, *n*			
NBW	33	33	.01
ELBW	39	45	.02
Birth weight, g (SD)			
NBW	3388.1 (465.6)	3348.5 (526.5)	.64
ELBW	834.9 (132.7)	840.5 (110.0)	.76
Gestational age, mean (SD), wk			
NBW	40	40	
ELBW	26.8 (2.0)	27.1 (2.4)	.36
NSI			
NBW	1	2	.31
ELBW	26	25	.41
Small for gestational age			
NBW			
ELBW	29	14	.08
Childhood SES			
NBW	3	3	.42
ELBW	3	4	<.01
WISC-R full scale IQ			
NBW	106.2 (11.7)	100.1 (12.3)	<.01
ELBW	93.4 (15.8)	87.2 (15.4)	.03
WISC-R performance IQ			
NBW	108.1 (12.5)	103.0 (12.4)	.02
ELBW	94.9 (16.9)	91.1 (16.6)	.21
WISC-R verbal IQ			
NBW	103.6 (12.4)	97.6 (13.1)	.01
ELBW	93.5 (15.0)	85.8 (15.0)	.01
Woodcock–Johnson standard score			
NBW	99.8 (13.9)	95.9 (14.4)	.11
ELBW	91.6 (16.0)	85.5 (14.6)	.03
WRAT-R arithmetic standard score			
NBW	95.3 (13.6)	92.5 (13.0)	.22
ELBW	83.4 (16.2)	80.3 (17.9)	.31

DISCUSSION

Our study suggests that childhood cognition partially mediated the association between being born at ELBW and socioeconomic attainment in the fourth decade of life. Single mediator models suggest that mathematical abilities and overall IQ had the strongest influence on this link, each accounting for 26% of the association between being born at ELBW and personal income attainment. However, given the large yet nonsignificant mediated effects, our results are inconclusive as to whether cognitive abilities mediate the association between ELBW status and employment status. In posthoc power analyses, it was observed that personal income models were sufficiently powered (β = .80), but full-time employment models were not (β = .52), limiting the ability to identify significant effects. Additionally, perhaps the ELBW survivors and NBW participants who reported having children were not working full time to support their family in the home. Therefore, this association warrants further study in larger samples.

The direction and magnitude of our results align with those previously reported by Basten et al.[13] In their study, they report a medium-sized effect estimate for mathematical abilities (accounting for ~35% to 36% of the total effect) and a small effect for general IQ (accounting for ~4% to 19% of the total effect).[13] Our study extends the results of their important work by suggesting that this association is upheld in the most vulnerable infants surviving preterm birth, and that their other comorbidities (ie, NSI) strongly influence this link.

In addressing our third objective, we found that the cognitive mediation pathway for personal income attainment was stronger in ELBW survivors with NSI. Many individuals with NSI report it is difficult to gain and maintain employment.[33] According to the *2010 Survey of Americans With Disabilities*, many individuals with NSI cite that gaining employment is challenging because they cannot perform, receive accommodation, or find employment in their desired field; they may face discrimination at their job; or having employment would lead to a loss of their government benefits.[34]

There are multiple reasons why cognitive abilities may influence employment and income attainment in ELBW survivors. Perhaps their poorer cognitive and academic

TABLE 3 Bootstrapped Direct and Indirect Effects of Childhood Cognition and ELBW on Income Attainment and Full-Time Employment

	Overall IQ		Verbal IQ		Performance IQ		Mathematical Abilities		Academic Achievement Abilities	
	Effect Estimate	95% CI	Effect Estimate	95% CI	Effect Estimate	95% CI	Effect Estimate	95% CI	Effect Estimate	95% CI
Annual personal income attainment models										
Total effect	−17 209.95*	−25 853.32 to −8566.58	−17 209.95*	−25 853.32 to −8566.58	−17 209.95*	−25 853.32 to −8566.58	−17 209.95*	−25 853.32 to −8566.58	−17 209.95*	−25 853.32 to −8566.58
Direct effect of ELBW status on personal income attainment	−12 693.97*	−22 066.54 to −3321.40	−13 632.84*	−22 584.87 to −4680.80	−14 118.26*	−23 489.43 to −4647.10	−12 785.86*	−21 675.44 to −3896.28	−14 493.71*	−23 079.49 to −5907.93
Indirect effect of cognitive mediator on personal income attainment	−4515.98*	−9809.60 to −730.03	−3577.11*	−8336.21 to −8720.95	−3091.68	−7443.28 to 278.46	−4424.09*	−9012.40 to −1403.12	−2716.24*	−6713.30 to −520.61
Proportion mediated, %[a]	26		21		18		26		16	
Full-time employment models										
Total effect	−0.91*	−1.69 to −0.13	−0.91*	−1.69 to −0.13	−0.91*	−1.69 to −0.13	−0.91*	−1.69 to −0.13	−0.91*	−1.69 to −0.13
Direct effect of ELBW on Full-time employment	−0.62	−1.46 to 0.22	−0.72	−1.54 to 0.09	−0.67	−1.51 to 0.18	−0.68	−1.51 to 0.15	−0.83*	−1.62, to −0.03
Indirect effect of mediator on full-time employment	−0.32	−0.80 to 0.05	−0.23	−0.61 to 0.02	−0.24	−0.71 to 0.12	−0.23	−0.65 to 0.07	−0.09	−0.36 to 0.06
Proportion mediated, %[a]	35		25		26		25		10	

[a] % mediated = ab/c × 100.

* Significant effect at the α = .05 level.

TABLE 4 Mediation Effects for NSI Subgroup Models

Mediator	Total Effect	Direct Effect	Indirect Effect	95% CI	% Mediated[a]
ELBW survivors without NSI impairments					
Personal income models					
Overall IQ (WISC-R full scale)	−16 871	−12 848	−4023*	−87 886 to −159	24
WISC-R verbal IQ	−16 871	−13 618	−3252*	−6418 to −87	19
WISC-R performance IQ	−16 871	−14 206	−2665	−6281 to 951	16
Mathematical abilities (WRAT-R M)	−16 871	−13 107	−3764*	−7068 to −460	22
Academic abilities (WJ)	−16 871	−14 804	−2066	−4679 to 545	12
Full-time employment models					
Overall IQ (WISC-R full scale)	−0.89	−0.64	−0.08	−0.23 to 0.07	31
WISC-R verbal IQ	−0.89	−0.75	−0.06	−0.17 to 0.06	23
WISC-R performance IQ	−0.89	−0.68	−0.06	−0.21 to 0.08	23
Mathematical abilities (WRAT-R M)	−0.89	−0.70	−0.06	−0.19 to 0.07	23
Academic abilities (WJ)	−0.89	−0.83	−0.02	−0.09 to 0.05	8
ELBW survivors with NSI impairments					
Personal income models					
Overall IQ (WISC-R full scale)	−18 664	−11 836	−6828*	−13 397 to −260	37
WISC-R verbal IQ	−18 664	−13 701	−4963	−10 000 to 74	27
WISC-R performance IQ	−18 664	−13 593	−5071	−11 885 to 1742	27
Mathematical abilities (WRAT-R M)	−18 664	−11 110	−7554*	−13 759 to −1349	40
Academic abilities (WJ)	−18 664	−13 010	−5654*	−10 964 to −363	30
Full-time employment models					
Overall IQ (WISC-R full scale)	−0.98	−0.42	−0.16	−0.46 to 0.14	54
WISC-R verbal IQ	−0.98	−0.58	−0.11	−0.34 to 0.11	39
WISC-R performance IQ	−0.98	−0.55	−0.13	−0.44 to 0.19	43
Mathematical abilities (WRAT-R M)	−0.98	−0.58	−0.11	−0.37 to 0.14	39
Academic abilities (WJ)	−0.98	−0.79	−0.09	−0.24 to 0.13	20

Total effect = the association between ELBW status and income attainment, while adjusting for covariates; direct effect = the association between ELBW status and income attainment, while adjusting for covariates and cognitive mediator; indirect effect = mediated effect. WJ, Woodcock–Johnson Psychoeducational Battery.

[a] % mediated = ab/c × 100.

* Significant indirect effect at the α = .05 level.

abilities result in ELBW survivors being less integrated into their educational and occupational environments, resulting in fewer opportunities for socioeconomic gains.[35] For example, educators of ELBW survivors with impaired verbal abilities (ie, reading and public speaking) may not encourage their ELBW students to partake in extracurricular activities such as athletics, arts, or student councils. This may result in smaller social networks and a lost opportunity for these individuals to gain networking skills and socializing skills in early life that may be beneficial in starting their career.[36]

Secondly, due to their impairments in mathematical abilities, ELBW individuals may not be pursuing advanced education or quantitatively focused careers, such as those in mathematics, engineering, or sciences, those typically known to have higher entrance incomes.[37] Of their current educational attainment, only 48 ELBW individuals reported completing college or university and 8 reported having a graduate or professional degree.[1] Compared with ELBW participants (57.2%), more NBW participants (63.6%) reported completing college/university or a graduate degree.[1]

Lastly, ELBW survivors are at increased risk for many other impairments, including difficulties with social skills and psychiatric illness.[38,39] It may be that their multiple comorbidities place ELBW survivors at greater disadvantage in adulthood, which may be associated with reduced productivity or increased absenteeism,[40] resulting in fewer opportunities for upward social mobility.

Our study is not without limitations. Our self-reported socioeconomic outcomes may have been subject to reporting bias. We attempted to minimize this by asking participants clear questions about multiple sources of their annual income and providing explicit definitions of full-time employment. Secondly, cohort attrition has ensued over the past 30 years, limiting sample size and statistical power. Because nonparticipants had lower childhood SES and childhood cognition, this could potentially have led to an underestimate of our effect estimates. We attempted to minimize any bias caused by attrition by adjusting for factors associated with differential attrition over time (ie, male sex, childhood SES).

Thirdly, as the comparison group was recruited from a primary school setting, it is possible that children with severe disabilities may be less common in the NBW control group, which may have led our results to be overestimated. A fourth limitation of our study is that we only examined single mediation models and our mediated effect estimates could only be examined qualitatively, which did not take into account measurement error that may have occurred. Lastly, advances in neonatal care and differences in socioeconomic climates for ELBW infants born after our cohort may reduce the generalizability of our results. However, evidence suggests that later generations of ELBW survivors also suffer from impaired cognitive abilities[41,42]; therefore, our results may be useful for ELBW survivors of all ages.

CONCLUSIONS

This is the first study to provide evidence that early cognition can have a lasting impression on socioeconomic outcomes in ELBW survivors. Our findings suggest that childhood cognition, particularly overall intelligence and mathematical abilities, partially mediated the association between being born at ELBW and income attainment in adulthood, and that this association may be stronger in survivors born with NSI. Research should explore the mediating influence of childhood cognitive abilities in larger, more contemporary samples of preterm survivors. Clinical and public health interventions aimed at enhancing early cognitive functioning may be important to ensure that infants who face perinatal adversity can lead the healthiest and most productive lives possible.

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ABBREVIATIONS

CI: confidence interval
ELBW: extremely low birth weight
NBW: normal birth weight
NSI: neurosensory impairment
SES: socioeconomic status
WISC-R: *Wechsler Intelligence Scale for Children-Revised*
WRAT-R: *Wide Range Achievement Test-Revised*

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REFERENCES

1. Saigal S, Day KL, Van Lieshout RJ, Schmidt LA, Morrison KM, Boyle MH. Health, wealth, social integration, and sexuality of extremely low-birth-weight prematurely born adults in the fourth decade of life. *JAMA Pediatr*. 2016;170(7):678–686
2. Mikkonen J, Raphael D. *Social Determinants of Health: The Canadian Facts*. Toronto, Canada: York University School of Health Policy and Management; 2010
3. Almond D, Currie J. Killing me softly: the fetal origins hypothesis. *J Econ Perspect*. 2011;25(3):153–172
4. Blencowe H, Cousens S, Oestergaard MZ, et al. National, regional, and worldwide estimates of preterm birth rates in the year 2010 with time trends since 1990 for selected countries: a systematic analysis and implications. *Lancet*. 2012;379(9832):2162–2172
5. Black SE, Devereux PJ, Salvanes KG. From the cradle to the labor market? The effect of birth weight on adult outcomes. *Q J Econ*. 2007;122(1):409–439
6. Lindström K, Winbladh B, Haglund B, Hjern A. Preterm infants as young adults: a Swedish national cohort study. *Pediatrics*. 2007;120(1):70–77
7. Heinonen K, Eriksson JG, Kajantie E, et al. Late-preterm birth and lifetime socioeconomic attainments: the Helsinki birth cohort study. *Pediatrics*. 2013;132(4):647–655
8. Strenze T. Intelligence and socioeconomic success: A meta-analytic review of longitudinal research. *Intelligence*. 2007;35(5):401–426
9. Judge TA, Ilies R, Dimotakis N. Are health and happiness the product of wisdom? The relationship of general mental ability to educational and occupational attainment, health, and well-being. *J Appl Psychol*. 2010;95(3):454–468
10. Rowe DC, Vesterdal WJ, Rodgers JL. Herrnstein's syllogism: genetic and shared environmental influences on IQ, education, and income. *Intelligence*. 1998;26(4):405–423
11. Voss W, Jungmann T, Wachtendorf M, Neubauer AP. Long-term cognitive outcomes of extremely low-birth-weight infants: the influence of the maternal educational background. *Acta Paediatr*. 2012;101(6):569–573
12. Farooqi A, Hägglöf B, Sedin G, Gothefors L, Serenius F. Chronic conditions, functional limitations, and special health care needs in 10- to 12-year-old children born at 23 to 25 weeks' gestation in the 1990s: a Swedish national prospective follow-up study. *Pediatrics*. 2006;118(5). Available at: www.pediatrics.org/cgi/content/full/118/5/e1466
13. Basten M, Jaekel J, Johnson S, Gilmore C, Wolke D. Preterm birth and adult wealth: Mathematics skills count. *Psychol Sci*. 2015;26(10):1608–1619
14. Saigal S, Rosenbaum P, Hattersley B, Milner R. Decreased disability rate among 3-year-old survivors weighing 501 to 1000 grams at birth and born to residents of a geographically defined region from 1981 to 1984 compared with 1977 to 1980. *J Pediatr*. 1989;114(5):839–846
15. Boyle MH, Miskovic V, Van Lieshout R, et al. Psychopathology in young adults born at extremely low birth weight. *Psychol Med*. 2011;41(8):1763–1774
16. Saigal S, Szatmari P, Rosenbaum P, Campbell D, King S. Cognitive abilities and school performance of extremely low birth weight children and matched term control children at age 8 years: a regional study. *J Pediatr*. 1991;118(5):751–760
17. Covin TM. Stability of the WISC-R for 9-year-olds with learning difficulties. *Psychol Rep*. 1977;40(3 pt 2):1297–1298
18. Irwin DO. Reliability of the Wechsler Intelligence Scale for Children. *J Educ Meas*. 1966;3(4):287–292
19. Tuma JM, Appelbaum AS. Reliability and practice effects of WISC-R IQ estimates in a normal population. *Educ Psychol Meas*. 1980;40(3):671–678
20. Witt JC. Review of the Wide Range Achievement Test-Revised. *J Psychoed Assess*. 1986;4(1):87–90
21. Jastak S, Wilkinson GS. *Wide Range Achievement Test-Revised (WRAT-R)*. Wilmington, DE: Jastak Associates; 1984
22. Schrank FA, McGrew KS, Woodcock RW. *Technical Abstract (Woodcock-Johnson III Assessment Service Bulletin No. 2)*. Itasca, IL: Riverside Publishing; 2001
23. Wechsler D. *Manual for the Wechsler Intelligence Scale for Children, Revised*. New York, NY: Psychological Corporation; 1974
24. Reid N. Wide Range Achievement Test: 1984 Revised Edition. *J Couns Dev*. 1986;64(8):538–539
25. Woodcock R, Johnson M. *Woodcock-Johnson Psycho-Educational Battery*. Boston, MA: Teaching Resources; 1977
26. Boyle MH, Offord DR, Hofmann HG, et al. Ontario Child Health Study. I. Methodology. *Arch Gen Psychiatry*. 1987;44(9):826–831
27. Statistics Canada. Individuals by total income level, by province and territory. CANSIM, table 111-0008. 2015. Available at: www.statcan.gc.ca/tables-tableaux/

sum-som/l01/cst01/famil105a-eng.htm. Accessed April 4, 2016

28. Nomura Y, Halperin JM, Newcorn JH, et al. The risk for impaired learning-related abilities in childhood and educational attainment among adults born near-term. *J Pediatr Psychol*. 2009;34(4):406–418
29. Hollingshead A. *Two-Factor Index of Social Position (Mimeograph)*. New Haven, CT: Yale University Press; 1969
30. MacKinnon DP. *Introduction to Statistical Mediation Analysis (Multivariate Applications Series)*. New York, NY: Lawrence Erlbaum Associates; 2008
31. Hayes AF. *Introduction to Mediation, Moderation, and Conditional Process Analysis: A Regression-Based Approach*. New York, NY: Guildford Press; 2013
32. Hayes AF, Preacher KJ. Statistical mediation analysis with a multicategorical independent variable. *Br J Math Stat Psychol*. 2014;67(3):451–470
33. Potts B. Disability and employment: considering the importance of social capital. *J Rehabil*. 2005;71(3):20–25
34. Taylor H, Krane D, Orkis K. *The ADA, 20 Years Later*. New York, NY: Harris Interactive; 2010
35. Ng TWH, Eby LT, Sorensen KL, Feldman DC. Predictors of objective and subjective career success: A meta-analysis. *Person Psychol*. 2005;58(2):367–408
36. Judge TA, Klinger RL, Simon LS. Time is on my side: time, general mental ability, human capital, and extrinsic career success. *J Appl Psychol*. 2010;95(1):92–107
37. Ritchie SJ, Bates TC. Enduring links from childhood mathematics and reading achievement to adult socioeconomic status. *Psychol Sci*. 2013;24(7):1301–1308
38. Schmidt LA, Miskovic V, Boyle MH, Saigal S. Shyness and timidity in young adults who were born at extremely low birth weight. *Pediatrics*. 2008;122(1). Available at: www.pediatrics.org/cgi/content/full/122/1/e181
39. Van Lieshout RJ, Boyle MH, Saigal S, Morrison K, Schmidt LA. Mental health of extremely low birth weight survivors in their 30s. *Pediatrics*. 2015;135(3):452–459
40. Mauss D, Li J, Schmidt B, Angerer P, Jarczok MN. Measuring allostatic load in the workforce: a systematic review. *Ind Health*. 2015;53(1):5–20
41. Aarnoudse-Moens CS, Weisglas-Kuperus N, van Goudoever JB, Oosterlaan J. Meta-analysis of neurobehavioral outcomes in very preterm and/or very low birth weight children. *Pediatrics*. 2009;124(2):717–728
42. Kuban KCK, Joseph RM, O'Shea TM, et al; Extremely Low Gestational Age Newborn (ELGAN) Study Investigators. Girls and boys born before 28 weeks gestation: Risks of cognitive, behavioral, and neurologic outcomes at age 10 Years. *J Pediatr*. 2016;173:69–75.e1

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