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Preterm Birth and Adult Wealth: Mathematics Skills Count

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Abstract

Each year, 15 million babies worldwide are born preterm. Preterm birth is associated with adverse neurodevelopmental outcomes across the life span. Recent registry-based studies suggest that preterm birth is associated with decreased wealth in adulthood, but the mediating mechanisms are unknown. This study investigated whether the relationship between preterm birth and low adult wealth is mediated by poor academic abilities and educational qualifications. Participants were members of two British population-based birth cohorts born in 1958 and 1970, respectively. Results showed that preterm birth was associated with decreased wealth at 42 years of age. This association was mediated by decreased intelligence, reading, and, in particular, mathematics attainment in middle childhood, as well as decreased educational qualifications in young adulthood. Findings were similar in both cohorts, which suggests that these mechanisms may be time invariant. Special educational support in childhood may prevent preterm children from becoming less wealthy as adults.

Keywords

preterm birth, wealth, mathematics, reading, intelligence, adulthood outcomes

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Worldwide, 11% of infants are born preterm (< 37 weeks gestation), which amounts to around 15 million births per year (Blencowe et al., 2012; Goldenberg, Culhane, Iams, & Romero, 2008). Rates of preterm birth are increasing globally, rising from 7.2% to 8.6% between 1990 and 2010 in developed countries alone (Blencowe et al., 2012). Preterm birth is a syndrome resulting from multiple causes (Goldenberg et al., 2008) and is associated with widespread brain alterations (Volpe, 2009). Prematurity is associated with adverse developmental and psychological outcomes across the life span (Johnson & Wolke, 2013; Moster, Lie, & Markestad, 2008; Saigal, 2014).

Recent registry-based studies have documented decreased wealth in adulthood following preterm birth (Heinonen et al., 2013; Lindstrom, Winbladh, Haglund, & Hjern, 2007; Moster et al., 2008). In a Scandinavian sample, adults born preterm had, on average, lower job-related incomes and were found to be more likely to receive social security benefits at the ages of 20 to 36 years than adults born at term (Moster et al., 2008). These negative outcomes do not apply only to high-risk groups, such as those born very preterm (< 32 weeks gestation); they have also been found for adults born moderately preterm (32–33 weeks gestation) and late preterm (34–36 weeks gestation; Heinonen et al., 2013; Lindstrom et al., 2007), who together comprise up to 84% of all preterm births (Shapiro-Mendoza & Lackritz, 2012). These registry-based studies have important strengths, including unbiased measures and the use of large, unselected samples. However, they do not provide information on potential mechanisms leading to decreased wealth in adulthood that could aid the development of intervention strategies.

Mediators that may explain decreased wealth in preterm adults include poor abilities in several academic fields. Preterm birth is associated with low intelligence (Jaekel, Baumann, & Wolke, 2013; Kerr-Wilson, Mackay, Smith, & Pell, 2012) and learning difficulties in several domains, including reading and spelling (Poulsen et al., 2013; Schneider, Wolke, Schlagmuller, & Meyer, 2004). Problems with mathematics have been found to be especially common in preterm children (Simms et al., 2014) and are associated with global cognitive deficits (Jaekel & Wolke, 2014; Simms et al., 2014). Academic difficulties in preterm children have a cascading effect on low educational success in adolescence (Schneider et al., 2004) and adulthood (Nomura et al., 2009). Such lower educational qualifications may result in decreased wealth in adulthood through lower-skilled occupations and lower salaries.

Understanding the mechanisms that explain decreased wealth in adulthood following preterm birth requires follow-up studies over decades. However, findings from longitudinal studies may be outdated by the time they are reported, given ongoing advances in antenatal and neonatal care. Therefore, it is important to study individuals born at different times to test whether the mechanisms leading to decreased wealth are consistent. Identifying time-invariant predictors would have two advantages. First, important childhood markers of later outcomes could be assessed in recent cohorts across multiple follow-up visits. Second, findings may help to develop interventions to improve long-term outcomes for children born preterm today.

This study examined the relationship between preterm birth and adulthood wealth in two large population-based UK cohorts born in 1958 and 1970, respectively. The mediating roles of mathematics, reading, and intelligence in childhood and of educational qualifications in young adulthood were tested.

Method

Participants

Participants were members of the National Child Development Study (NCDS), born in 1958, and the British Cohort Study (BCS), born in 1970. Both longitudinal studies recruited all children born in 1 week in England, Scotland, and Wales, and follow-up assessment have been performed in several waves through to adulthood. In the current study, we included all individuals who were born between 28 and 42 weeks of gestational age and who had information on wealth at age 42 years. In the NCDS, of the 17,415 children recruited in 1958, 13,063 were born between 28 and 42 weeks gestation, and 8,573 (66%) of these had information on wealth at 42 years. In the BCS, 16,568 children were recruited in 1970; 11,535 were born between 28 and 42 weeks gestation, and 6,698 (58%) of these had information on wealth at 42 years. Data files are available from the University of London, Institute of Education, Centre for Longitudinal Studies (2008–2014; 2013–2014).[1] Baseline characteristics for both cohorts are provided in Table 1.

[TS: Please insert Table 1 about here.]

Measures

We obtained data on gestational age at birth; wealth outcomes at age 42 years; mathematics, reading, and intelligence in early childhood; and educational qualifications in young adulthood. In addition, several covariates were assessed at birth. (For the mathematics, reading, and intelligence variables, more detailed descriptions are available in Tables S1 through S3 in the Supplemental Material available online.)

For both cohorts, gestational age at birth was calculated using maternal reports of the last menstrual period. We categorized gestational age into three groups: preterm (< 37 weeks), early term (37–38 weeks), and full term (39–41 weeks).

A latent wealth variable was developed based on five indicators assessed during home interviews: (a) family income, (b) family social class, (c) housing tenure, (d) employment status, and (e) self-perceived financial situation. Family income was assessed differently across cohorts. For the NCDS, it was calculated according to the method of Goodman, Joyce, and Smith (2011) and included participants' and partners' net income from employed work as well as other types of income, such as social benefits (e.g., unemployment). Family income was log-transformed and adjusted for marital status ("married or living together" or "single"). BCS participants were asked to report on their total family income using 18 income categories, with separate questions for couples and singles. Scores were standardized, and variables were combined into one family-income variable.

The remaining four indicators of wealth were assessed in the same way for both cohorts. Family social class was based on the highest occupational social class of the participant and his or her partner and was scored on a 6-point scale using the Registrar General's Social Classes (RGSC) categories: 1 = *Class V: unskilled manual*, 2 = *Class IV: semiskilled manual or nonmanual*, 3 = *Class IIIM: skilled manual*, 4 = *Class IIIN: skilled nonmanual*, 5 = *Class II: managerial and technical*, 6 = *Class I: professional*. Housing status was categorized as "rent," "owned with mortgage," and "owned outright." Employment status was defined as "unemployed and looking for a job" versus "employed or self-employed." Participants out of the labor market for other reasons were excluded. Self-perceived financial situation was reported on a 5-point scale ranging from 1, *finding it very difficult*, to 5, *living comfortably*.

For the NCDS, a latent mathematics variable was constructed from four measures: (a) the Problem Arithmetic Test (Pringle, Butler, & Davie, 1966; Shepherd, 2012) at age 7 years, (b) teachers' ratings of participants' number skills at age 7, (c) the Arithmetic/Mathematics Test (Shepherd, 2012) at age 11 years, and (d) teachers' ratings of participants' number skills at age 11. A latent mathematics variable for the BCS was constructed from three measures at age 10 years: (a) the Friendly Maths Test (Parsons, 2014), (b) teachers' reports about whether participants received or were in need of extra math help, and (c) mothers' ratings of participants' difficulties in mathematics.

In the NCDS, a latent reading variable was based on five measures: (a) the Southgate Group Reading Test (Shepherd, 2012; Southgate, 1962) completed at age 7 years, (b) teachers' ratings of participants' reading abilities at age 7, (c) the basic reading level of books the participants were able to read at age 7 reported by the teacher, (d) the Reading Comprehension Test (Shepherd, 2012) at age 11 years, and (e) teachers' ratings of participants' reading abilities at age 11. The latent reading variable in the BCS was constructed from three measures at age 10 years: (a) a shortened version of the Edinburgh Reading Test (Godfrey Thompson Unit, University of Edinburgh, 1978; Parsons, 2014), (b) teachers' reports about whether participants received or were in need of extra reading help, and (c) mothers' ratings of participants' difficulties in reading.

In the NCDS cohort, a latent intelligence variable was estimated using a general ability test (Pigeon, 1964; Shepherd, 2012) administered at age 11 years, which included a verbal and a nonverbal component. In the BCS cohort, a latent intelligence variable was estimated from four subtests of the British Ability Scales (Elliott, Murray, & Pearson, 1978; Parsons, 2014): Word Definitions, Word Similarities, Recall of Digits, and Matrices.

At 33 years in the NCDS cohort and at 34 years in the BCS cohort, participants were asked about their highest academic or vocational qualifications. Responses were coded according to the National Vocational Qualifications 6-point scale ranging from *no education* to *higher degree level*. Missing values were replaced by educational qualifications assessed at 42 years.

On the basis of previous studies (Jefferis, Power, & Hertzman, 2002; Yang, Bergvall, Cnattingius, & Kramer, 2010), we considered the following variables as potential confounds in both cohorts: sex, multiple-birth status, birth weight (standardized per week of gestation and sex according to Jefferis et al., 2002, and categorized into five groups: < −2 *SD*, −2 to −1 *SD*, −1 to 1 *SD*, 1 to 2 *SD*, > 2 *SD*), maternal smoking during pregnancy, maternal diabetes, lack of antenatal care (defined as one or no antenatal visits), high (> 30) or low (< 18.5) maternal body mass index before pregnancy (available only in the NCDS cohort), maternal age at birth, parity (defined as whether a participant was a first child), parental education (defined as whether the mother or the father stayed in school beyond the minimum age at which leaving is allowed), and paternal social class (measured by the RGSC, with categories identical to those used for participants' social class at 42 years). For missing values of social class at birth, the social class of the father or the mother when the child was at school age was used.

Data analysis

To examine the effects of gestational age on wealth and the mediating role of childhood mathematics, reading, and intelligence and of later educational qualifications, we performed structural equation modeling in Mplus (Version 7.3; Muthén & Muthén, 2012). The same procedure was followed for the NCDS and BCS cohorts. We used a robust weighted least-squares procedure with adjusted means and variance estimation (Flora & Curran, 2004). First, latent variables of wealth, mathematics, reading, and intelligence were estimated. Covariance between observed variables of mathematics, reading, and intelligence that were assessed at the same time point or by the same respondent was taken into account. We examined the associations between gestational age and wealth, mathematics, reading, intelligence, and educational qualifications using linear regression analyses. Gestational age groups were dummy-coded with the full-term group as the reference. We tested whether associations remained after adjustment for all covariates.

Next, we constructed a path model to examine the direct effect of gestational age on wealth and indirect effects via childhood mathematics, reading, and intelligence and later educational qualifications. All pathways were adjusted for all covariates. Covariance among mathematics, reading, and intelligence was taken into account. Goodness of model fit was determined with the root-mean-square error of approximation (RMSEA), the comparative fit index (CFI), and the Tucker-Lewis index (TLI; Hu & Bentler, 1999). For the RMSEA, values of .05 or lower indicate close fit. For the CFI and TLI, values greater than .90 indicate acceptable fit. The strength of the pathways were indicated using standardized regression coefficients. Coefficients less than 0.10 indicate a small effect, values around 0.30 indicate a typical or medium effect, and values round 0.50 indicate large effects (Kline, 2005). Indirect effects were estimated by calculating the product of path coefficients, and the significance of indirect effects was tested using 1,000 bootstrap samples (Preacher & Hayes, 2008).

Percentages of missing data for the various mathematics, reading, and intelligence assessments ranged between 8.6% and 13.4% for the NCDS cohort and between 12.0% and 21.3% for BCS cohort. Percentages of missing data for covariates were all less than 5%. In both cohorts, we imputed missing values in Mplus using the Markov-chain Monte Carlo technique, and we generated 20 imputed data sets. The imputation model included all variables that were used for further analyses. Analyses were performed separately on each completed data set and thereafter combined into pooled estimates.

Comparison of excluded and included participants

We compared baseline characteristics of participants included in analyses with those excluded because of missing data at 42 years. In the NCDS, included participants (*n* =

8,573) did not differ from excluded participants (*n* = 4,490) in prevalence of preterm birth (4.7% vs. 5.3%, respectively), $\chi^2(1, N = 13{,}063) = 2.18$, $p = .140$, and birth weight (mean difference = 9 g), $F(1, 12629) = 0.78$, $p > .250$. Included participants were more likely than excluded participants to have parents that stayed at school beyond the minimum age at which leaving is allowed (37.3% vs. 32.9%, respectively), $\chi^2(1, N = 13{,}058) = 24.10$, $p < .001$, and to come from a family with a higher social class (managerial or professional; 19.6% vs. 17.3%, respectively), $\chi^2(5, N = 12{,}781) = 40.71$, $p < .001$.

In the BCS, included participants (*n* = 6,698), compared with excluded participants (*n* = 4,837), were less likely to be born preterm (4.8% vs. 6.1%, respectively), $\chi^2(1, N = 11{,}535) = 10.30$, $p = .001$, but there was no significant difference in birth weight (mean difference = 14 g), $F(1, 11523) = 2.01$, $p = .156$. Included participants were more likely to have parents that stayed at school beyond the minimum age at which leaving is allowed (51.0% vs. 44.7%, respectively), $\chi^2(1, N = 11{,}461) = 44.85$, $p < .001$, and were more likely to come from a family with higher social class (managerial or professional; 21.0% vs. 15.6%, respectively), $\chi^2(5, N = 11{,}309) = 113.02$, $p < .001$.

Results

Prematurity and wealth

Associations between gestational age and adulthood wealth; childhood mathematics, reading, and intelligence; and adulthood educational qualifications are shown in Table 2. In both cohorts, preterm birth was associated with decreased wealth at 42 years; decreased mathematics, reading, and intelligence at 7 to 11 years; and decreased educational qualifications at 33 to 34 years (βs = –0.19 to –0.45, all *p*s < .01). These associations remained after adjustment for covariates. Early-term birth was not associated with decreased wealth, but in the NCDS cohort, early-term birth was associated with decreased reading (adjusted β = –0.09, p = .004) and intelligence (adjusted β = –0.07, p = .031). (Correlations between wealth, mathematics, reading, intelligence, and educational qualifications are shown in Table S4 in the Supplemental Material.)

[TS: Please insert Table 2 about here.]

The differences in wealth between preterm and full-term adults were as follows: In the NCDS cohort, 32.5% (preterm) versus 25.1% (full term) were manual workers (*Class III skilled manual* or lower), 3.3% versus 2.5% were unemployed, 22.3% versus 15.5% did not own a house, 34.5% versus 28.5% had self-reported financial difficulties, and 57.6% versus 49.1% had below-average family income. In the BCS cohort, 26.3% (preterm) versus 20.9% (full term) were manual workers, 4.4% versus 2.4% were unemployed, 22.8% versus 22.3% did not own a house, 34.7% versus 29.8% had self-reported financial difficulties, and 55.3% versus 47.1% had below-average family income.

Mediating role of mathematics, reading, intelligence, and educational qualifications

We examined the mediating role of mathematics, reading, and intelligence in childhood and of later educational qualifications in the pathway from preterm birth to adult wealth while adjusting for possible confounds. The NCDS model is presented in Figure 1 and the BCS model in Figure 2. The NCDS model (Fig. 1) fit the data well (RMSEA = .032, CFI = .96, TLI = .94). Preterm birth was negatively associated with mathematics (β = –0.31, p < .001), reading (β = –0.34, p < .001), and intelligence (β = –0.30, p < .001) at the ages of 7 to 11 years. Subsequently, mathematics (β = 0.14, p = .004), reading (β =

0.33, $p < .001$), and intelligence ($\beta = 0.09$, $p = .001$) predicted educational qualifications at 33 years, which predicted wealth at 42 years ($\beta = 0.34$, $p < .001$). Additionally, there was a direct effect of mathematics on wealth ($\beta = 0.27$, $p < .001$).[2]

[TS: Please insert Figures 1 and 2 about here.]

The model for the BCS cohort (Fig. 2) also fit the data well (RMSEA = .035, CFI = .94, TLI = .92). Again, preterm birth was negatively associated with mathematics ($\beta = -0.34$, $p < .001$), reading ($\beta = -0.24$, $p = .001$), and intelligence ($\beta = -0.27$, $p < .001$) at age 10 years. Subsequently, mathematics ($\beta = 0.20$, $p < .001$) and intelligence ($\beta = 0.19$, $p < .001$) were associated with educational qualifications at age 34 years, but reading was not. Educational qualifications ($\beta = 0.28$, $p < .001$), as well as mathematics ($\beta = 0.28$, $p < .001$) and intelligence ($\beta = 0.13$, $p < .001$), predicted wealth at age 42 years.[3]

Table 3 shows the direct, total indirect, and specific indirect effects of preterm birth on adult wealth at age 42 years. In both cohorts, there was a significant total indirect effect of preterm birth on wealth (NCDS: $\beta = -0.14$, $p < .001$; BCS: $\beta = -0.15$, $p < .001$), which arose through several pathways. For the NCDS cohort, specific pathways were via mathematics ($\beta = -0.08$, $p = .001$), via mathematics and educational qualifications ($\beta = -0.01$, $p = .019$), via reading and educational qualifications ($\beta = -0.04$, $p < .001$), and via intelligence and educational qualifications ($\beta = -0.01$, $p = .009$). For the BCS cohort, specific indirect effects were again via mathematics ($\beta = -0.10$, $p < .001$), via mathematics and educational qualifications ($\beta = -0.02$, $p < .001$), via intelligence ($\beta = -0.03$, $p = .012$), and via intelligence and educational qualifications ($\beta = -0.01$, $p = .002$).

[TS: Please insert Table 3 about here.]

Discussion

In this study, we examined the associations between preterm birth and wealth at 42 years of age in two large population-based cohorts, specifically testing the mediating roles of mathematics, reading, and intelligence in childhood as well as educational qualifications in adulthood. As a group, preterm children had lower mathematics and reading achievement and lower intelligence in primary school compared with their term-born peers. These decreased academic abilities predicted decreased educational qualifications and subsequent decreased wealth in adulthood. Notably, mathematics achievement in primary school was also directly associated with wealth in adulthood independent of later educational qualifications. The indirect effects of preterm birth on adult wealth were found despite controlling for the well-known effects of socioeconomic status at birth and were replicated in both the 1958 and 1970 birth cohorts.

The findings that individuals born preterm are at risk for decreased wealth in adulthood are consistent with the findings of previous Scandinavian registry-based studies on outcomes such as income, occupational attainment, and receipt of social security benefits (Heinonen et al., 2013; Lindstrom et al., 2007; Moster et al., 2008). Similar to these studies, our study revealed effect sizes that were small but that should be interpreted in light of the 42-year time span. This study provides new evidence of a developmental cascade in which decreased academic abilities following preterm birth lead to decreased educational qualifications, which subsequently decrease wealth in adulthood. A similar developmental cascade from decreased mathematics and reading achievement to shorter full-time education and decreased socioeconomic attainment has been described in the general population (Ritchie & Bates, 2013). Brain injury in preterm children, which includes a combination of destructive and developmental disturbances (Volpe, 2009), is likely to result in cognitive deficits that may cause the development of learning difficulties and subsequently put these children at risk of following this pathway of underachievement.

Notably, we found for both cohorts a medium-sized direct effect of mathematics achievement in childhood on adult wealth, independent of later educational qualifications (see also Ritchie & Bates, 2013). This may be explained by findings of recent studies showing that individuals born preterm are at risk to continue to have decreased cognitive functioning in multiple domains in adulthood (Eryigit Madzwamuse, Baumann, Jaekel, Bartmann, & Wolke, 2015; Pyhala et al., 2011). Compared with their term-born peers, preterm individuals may be employed in lower status jobs because of their educational qualifications, but their lower mathematical skills and problems in dealing with increased memory workload (Jaekel et al., 2013) may make them less successful in their work. This may result in a lower job-related income, as was found previously by Moster et al. (2008), and decreased chances of achieving promotion. In addition, numerical ability is important for financial judgments and decision making, which in turn have been linked to wealth outcomes (Banks & Oldfield, 2007; Peters et al., 2006). Numerical ability has, for example, been related to mortgage default (Gerardi, Goette, & Meier, 2013). Individuals born preterm who have difficulties in mathematics may thus be less able to manage their personal finances adequately.

The importance of mathematics achievement compared with reading for adult economic outcomes has been previously reported in the NCDS and BCS cohorts by Parsons and Bynner (2005). The authors suggest that basic mathematical skills have become increasingly important in modern jobs. However, apart from mathematics, reading and intelligence may also play a significant role in the pathway from preterm birth to decreased wealth in adulthood. Preterm birth had comparable negative effects on mathematics, reading, and intelligence, which reflects that these children have global aberrant neurodevelopment leading to deficits in multiple general cognitive domains. The smaller and less consistently found paths of reading and intelligence to educational qualifications and wealth in our study should be interpreted carefully because mediators were highly correlated, and the effects of reading and intelligence on educational qualifications and wealth may therefore have been overadjusted in our models.

In the NCDS cohort, we found that individuals born early term, that is at 37 or 38 weeks of gestation, were not at risk for decreased wealth in adulthood but showed decreased academic abilities, whereas this relation was not found in the BCS cohort 12 years later. Improvements in medical care or in the educational system over the years may have resulted in better outcomes among early-term individuals. However, findings regarding early-term birth and learning abilities in more recent cohorts are mixed (MacKay, Smith, Dobbie, & Pell, 2010; Poulsen et al., 2013; Yang et al., 2010). Clarification is needed, because early-term birth comprises around 30% of all births (Ananth, Friedman, & Gyamfi-Bannerman, 2013) and may account for a substantial proportion of children experiencing difficulties in school (MacKay et al., 2010).

To predict the long-term outcomes of children born preterm today, one needs to rely on data from earlier cohorts. Similar findings for individuals born in 1958 and in 1970 suggest that the mechanisms from preterm birth to reduced adult wealth may be consistent over time. If these mechanisms are time invariant, they may also affect children born preterm today. Even though neonatal care has improved enormously over the years, more recent data sets such as the Millennium Cohort Study including children born from 2000 to 2002 still show that preterm children are at risk for decreased cognitive functioning (Poulsen et al., 2013). A meta-analysis on the relation between preterm birth and intelligence also found no change in effects across cohorts (Kerr-Wilson et al., 2012). In 1958 and 1970, the prevalence of very preterm birth was substantially lower than it is today, with only a very small number of individuals being born before 32 weeks of gestation (0.2–0.3% in our study samples). The increasing number of preterm births and the higher survival of extremely preterm children born as early as 23 or 24 weeks, who have the highest risk for cognitive problems, has led to more children being at risk for decreased academic abilities in the community (Blencowe et al., 2012). Our findings suggest that cognitive deficits experienced by preterm children born today may have negative effects on their future wealth, affecting both individual success and societal productivity.

Our study has important strengths, including the use of two large population-based studies and the long-term follow-up over 42 years. Also, we used achievement tests as well as teacher and parent reports of children’s mathematics and reading skills, and we included multiple indicators of wealth. There are also limitations. Even though response was very high given the long follow-up period, a positive selection occurred toward individuals born at term and with high socioeconomic family background. While selective dropout reduces statistical power, it may have little biasing influence on estimates in regressions in prospective studies (Wolke et al., 2009). Second, our studies were performed in the United Kingdom. Our findings need replication in other countries.

Third, gestational age was based on the mother's report of her last menstrual period. Misclassification of gestational age may have led to an underestimation of prematurity effects. Finally, we adjusted our analyses for a wide range of confounds, including several indicators of socioeconomic background, prenatal lifestyle, and maternal health. We were not able to adjust for other possible confounds, such as alcohol and drug exposure during pregnancy. Therefore, residual confounding cannot be excluded.

In conclusion, this study showed that decreased academic abilities in preterm children have long-lasting consequences on their educational qualifications and their attained wealth in adulthood. Decision makers should be aware that the economic costs of preterm birth are not limited to neonatal intensive and ongoing health care and educational support in childhood (Petrou, Sach, & Davidson, 2001) but extend into adulthood. These early predictors in childhood could be studied as markers of the cascade to later wealth in recent cohorts. Extra educational support that aims to improve children's mathematics and reading skills may prevent these children from becoming less wealthy than their term-born peers and reduce the economic and societal costs of preterm birth. We recently found that there is a large gap in knowledge about the long-term effects of preterm birth in the United Kingdom among school teachers and educational psychologists, compared with neonatal clinicians (Johnson, Gilmore, Gallimore, Jaekel, & Wolke, 2015). Communicating information about the learning needs of preterm children to education professionals may be an important step toward improving the life chances of the growing population of children born preterm.

Author Contributions

All authors contributed to the study concept. M. Basten analyzed and interpreted the data under the supervision of J. Jaekel and D. Wolke. M. Basten drafted the manuscript, and J. Jaekel, D. Wolke, S. Johnson, and C. Gilmore provided critical revisions. All authors approved the final version of the manuscript for submission.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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Supplemental Material

Additional supporting information can be found at http://pss.sagepub.com/content/by/supplemental-data

Open Practices

Data files are available from University of London, Institute of Education, Centre for Longitudinal Studies via the UK Data Service (http://ukdataservice.ac.uk/). Safeguarded data are provided under the UK Data Service's end user license. The UK Data Service states that "eventually, all safeguarded data should, theoretically, be available to anyone and for any purpose, but redistribution will always be explicitly denied since the audit trail provided by authentication would be broken."

Notes

1. For the BCS cohort, we used the following data files: Birth and 22-Month Subsample, 1970–1972, Study number (SN) 2666; 10-Year Follow-Up, 1980, SN 3723; 34-Year Follow-Up, 2004–2005, SN 5585; 42-Year Follow-Up, 2012, SN 7473. For the NCDS cohort, we used the following data files: Childhood Data Sweeps 0–3, 1958–1974, SN 5565; Sweep 5, 1991, SN 5567; Sweep 6, 1999–2000, SN 5578.

2. The most important covariates predicting wealth were parental education (direct path: $\beta = 0.11$, $p < .001$; indirect path: $\beta = 0.27$, $p < .001$) and paternal social class (direct path: $\beta = 0.07$, $p < .001$; indirect path: $\beta = 0.13$, $p < .001$). The explained variance in wealth (R^2) was .38. The three childhood variables were highly correlated—mathematics and intelligence: $r = .84$, mathematics and reading: $r = .92$, intelligence and reading: $r = .82$.

3. The most important covariates predicting wealth were parental education (direct path: $\beta = 0.09$, $p = .003$; indirect path: $\beta = 0.25$, $p < .001$) and paternal social class (direct path: $\beta = 0.07$, $p < .001$; indirect path: $\beta = 0.12$, $p < .001$). The explained variance in wealth (R^2) was .35. The three childhood variables were highly correlated—mathematics and intelligence: $r = .70$, mathematics and reading: $r = .78$, intelligence and reading: $r = .71$.

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Table 1.

Sample Characteristics for National Child Development Study (NCDS; *N* = 8,573) and British Cohort Study (BCS; *N* = 6,698) Cohorts

Characteristic	NCDS cohort				BCS cohort			
	Preterm: 28–36 weeks (*n* = 403; 4.7%)	Early term: 37–38 weeks (*n* = 1,406; 16.4%)	Full term: 39–41 weeks (*n* = 6,764; 78.9%)	Group comparison (*p*)[a]	Preterm: 28–36 weeks (*n* = 320; 4.8%)	Early term: 37–38 weeks (*n* = 1,046; 15.6%)	Full term: 39–41 weeks (*n* = 5,332; 79.6%)	Group comparison (*p*)[a]
Sex (% male)	50.1	52.6	49.0	.048	49.4	51.5	47.0	.025
Multiple birth (% twins)	13.2	5.5	1.3	< .001	15.0	4.7	0.8	< .001
Mean birth weight (grams)	2,630 (619)	3,101 (492)	3,399 (468)	< .001	2,570 (655)	3,077 (466)	3,401 (457)	< .001

Mean gestational age	35.2 (1.7)	38.2 (.5)	40.4 (.8)	< .001	35.2 (1.7)	38.2 (.5)	40.4 (.8)	< .001
Parity (% first child)	42.9	35.7	37.2	.030	38.2	37.1	39.1	.499
Mean maternal age at birth (years)	27.2 (6.0)	28.2 (5.9)	27.6 (5.5)	< .001	26.4 (5.9)	26.9 (5.7)	26.1 (5.1)	< .001
Maternal smoking during pregnancy (%)	40.1	35.0	31.8	< .001	45.5	40.3	41.9	.257
Maternal diabetes (%)	1.4	0.0	0.1	< .001	2.2	1.0	0.5	< .001
Antenatal care (% < 2 antenatal visits)	2.5	0.4	0.4	< .001	4.0	1.3	0.4	< .001
Maternal BMI before pregnancy (%)[b]				.203				
< 18.5	3.3	3.3	2.3		—	—	—	
> 30.0	3.9	4.0	3.9		—	—	—	
Parental education beyond	28.3	33.6	38.5	< .001	43.9	48.8	51.9	.006

minimum age for leaving school (%)								
Paternal social class[c] (%)				.030				.003
V: unskilled	11.2	9.3	7.7		5.8	4.6	4.4	
IV: semiskilled	12.4	12.7	11.9		17.6	15.7	13.6	
III: skilled, manual	53.6	50.0	49.7		49.4	46.4	44.0	
III: skilled, nonmanual	7.6	9.8	10.5		11.9	13.9	16.3	
II: managerial and technical	11.7	13.5	15.2		12.8	13.1	15.1	
I: professional	3.6	4.7	5.1		2.6	6.2	6.6	

Note: Standard deviations are given in parentheses.

[a]Significance values were obtained by comparing preterm, early-term, and full-term participants using analyses of variance (ANOVAs) for continuous variables and chi-square tests for categorical variables. [b]Maternal body mass index (BMI) before pregnancy was not available for the BCS cohort. [c]Classes for this variable were taken from the Registrar General’s Social Classes categories.

Table 2.

Associations Between Gestational-Age Groups and Key Variables in the Two Cohorts

	Wealth in adulthood		Mathematics in childhood		Reading in childhood		Intelligence in childhood		Educational qualifications in adulthood	
Gestational-age group	Unadjusted β	Adjusted β	Unadjusted β	Adjusted β	Unadjusted β	Adjusted β	Unadjusted β	Adjusted β	Unadjusted β	Adjusted β
National Child Development Study cohort (*N* = 8,573)										
Preterm	–0.31***	–0.23***	–0.41***	–0.31***	–0.45***	–0.34***	–0.38***	–0.30***	–0.23***	–0.16***
	[–0.43, –0.19]	[–0.35, –0.12]	[–0.52, –0.30]	[–0.42, –0.20]	[–0.57, –0.34]	[–0.45, –0.24]	[–0.49, –0.27]	[–0.40, –0.20]	[–0.33, –0.13]	[–0.24, –0.07]
Early term	–0.03	0.00	–0.10**	–0.06	–0.15***	–0.09**	–0.11**	–0.07*	–0.06*	–0.03
	[–0.10, 0.03]	[–0.07, 0.06]	[–0.16, –0.04]	[–0.12, 0.00]	[–0.21, –0.08]	[–0.14, –0.03]	[–0.17, –0.04]	[–0.13, –0.01]	[–0.12, –0.01]	[–0.08, 0.02]

	British Cohort Study cohort (*N* = 6,698)									
Preterm	–0.24** [–0.37, –0.10]	–0.16* [–0.29, –0.02]	–0.43*** [–0.58, –0.28]	–0.34*** [–0.49, –0.19]	–0.32*** [–0.47, –0.18]	–0.24** [–0.38, –0.09]	–0.37*** [–0.52, –0.22]	–0.27*** [–0.41, –0.13]	–0.19** [–0.31, –0.08]	–0.11* [–0.22, 0.00]
Early term	–0.05 [–0.13, 0.03]	–0.04 [–0.11, 0.04]	–0.02 [–0.10, 0.07]	0.00 [–0.08, 0.09]	–0.06 [–0.14, .02]	–0.03 [–0.11, .06]	–0.05 [–0.12, 0.03]	–0.03 [–0.10, 0.04]	–0.02 [–0.09, 0.04]	–0.01 [–0.07, 0.05]

Note: The coefficients shown indicate the mean differences in standard-deviation units between results for individuals in each gestational-age group and results for individuals born full term. Values in brackets are 95% confidence intervals. Adjusted coefficients controlled for sex, multiple birth, birth weight (standardized per week of gestation and sex), maternal smoking during pregnancy, maternal diabetes, lack of antenatal care, high and low maternal body mass index before pregnancy (for the NCDS cohort only), maternal age at birth, parity (whether a participant was a first child), parental education beyond the minimum age at which leaving school is allowed, and paternal social class.

*$p < .05$. **$p < .01$. ***$p < .001$.

Table 3.

Direct and Indirect Effects of Preterm Birth on Wealth at 42 Years of Age for the Two Cohorts

Effect	NCDS cohort β	NCDS cohort *p*	BCS cohort β	BCS cohort *p*
Total effect	–0.23	< .001	–0.16	.039
Total direct effect	–0.09	.099	–0.01	> .250
Total indirect effect	–0.14	< .001	–0.15	< .001
Indirect effect via mathematics	–0.08	.001	–0.10	< .001
Indirect effect via reading	–0.02	> .250	0.02	.206
Indirect effect via intelligence	0.01	.231	–0.03	.012
Indirect effect via mathematics and educational qualifications	–0.01	.019	–0.02	< .001
Indirect effect via reading and educational qualifications	–0.04	< .001	0.00	> .250
Indirect effect via intelligence and educational qualifications	–0.01	.009	–0.01	.002

Note: NCDS = National Child Development Study (*N* = 8,573), British Cohort Study (*N* = 6,698).

Figure legends

Fig. 1.

Results from the National Child Development Study cohort (*N* = 8,573): model showing the role of mathematics, reading, and intelligence in childhood and of educational qualifications in adulthood as mediators of the relation between pre- and early-term birth and wealth in adulthood. The pre- and early-term-birth groups were each compared with the full-term-birth group. Standardized coefficients are shown. Covariates, nonsignificant paths ($p > .05$), and residual variances are not presented to enhance readability. All pathways were adjusted for sex, multiple birth, birth weight (standardized per week of gestation and sex), maternal smoking during pregnancy, maternal diabetes, lack of antenatal care, high and low maternal body mass index before pregnancy, maternal age at birth, parity, parental education beyond the minimum age at which leaving school is allowed, and paternal social class.

Fig. 2.

Results from the British Cohort Study sample (*N* = 6,698): model showing the role of mathematics, reading, and intelligence in childhood and of educational qualifications in adulthood as mediators of the relation between preterm birth and wealth in adulthood. The preterm-birth group was compared with the full-term-birth group. Standardized coefficients are shown. Covariates, nonsignificant paths ($p > .05$), and residual variances are not presented to enhance readability. All pathways were adjusted for sex, multiple birth, birth weight (standardized per week of gestation and sex), maternal smoking during pregnancy, maternal diabetes, lack of antenatal care, maternal age at birth, parity, parental education beyond the minimum age at which leaving school is allowed, and paternal social class. Early-term birth is not represented in the model because there were no significant paths from that predictor.