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Education

Gestational age at birth and academic performance: population-based cohort study

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Abstract

Background: Numerous studies suggest pre-term birth is associated with cognitive deficit. However, less is known about cognitive outcomes following post-term birth, or the influence of weight variations within term or post-term populations. We examined associations between gestational age (GA) and school performance, by weight-for-GA, focusing on extremely pre- and post-term births.

Method: Record linkage study of Swedish children born 1973–94 ($n = 2\ 008\ 102$) with a nested sibling comparison ($n = 439\ 629$). We used restricted cubic regression splines to examine associations between GA and the grade achieved on leaving secondary education, comparing siblings to allow stronger causal inference with regard to associations between GA and school performance.

Results: Grade averages of both pre- and post-term children were below those of full-term counterparts and lower for those born small-for-GA. The adjusted grades of extremely pre-term children (at 24 completed weeks), while improving in later study periods, were lower by 0.43 standard deviations (95% confidence interval 0.38–0.49), corresponding with a 21-point reduction (19 to 24) on a 240-point scale. Reductions for extremely post-term children (at 45 completed weeks) were lesser [–0.15 standard deviation (–0.17 to –0.13) or –8 points (–9 to –7)]. Among matched siblings, we observed weaker residual effects of pre-term and post-term GA on school performance.

Conclusions: There may be independent effects of fetal maturation and fetal growth on school performance. Associations among matched siblings, although attenuated, remained consistent with causal effects of pre- and post-term birth on school performance.

Key words: gestational age, academic performance, Sweden, whole-population cohort, siblings, post-term

Key Messages

- On leaving compulsory secondary education, both pre- and post-term children had lower grades than term counterparts.
- The grades of small-for-gestational age children were lowest irrespective of gestational age (GA) at birth.
- Despite potential familial confounding, there may be residual causal effects of pre- and post-term GA on school-leaving-age academic performance.

Introduction

In developed countries, 5–7% of births occur pre-term ($\leq$36 weeks) comprising a major determinant of infant mortality and health.[1] Rates of post-term birth ($\geq$42 weeks) vary considerably (0.5–8% in Europe and the US), possibly reflecting differences in local obstetric practice.[2,3] In recent years, change in obstetric practice has resulted in greater numbers of induced deliveries,[4] influencing rates of post-term birth over time.[5] Although it is often assumed that term and post-term births are homogeneous with respect to health outcomes, post-term delivery has been associated with infant mortality[6,7] and longer-term health problems.[8–10] However, whereas risk of neurodevelopmental problems in pre-term infants is well established,[11–21] little is known about risk post-term.[11,18,22] Evidence suggests cognitive abilities improve with gestational age (GA) toward term, reaching a peak at 40 weeks before decreasing towards late term.[22,23] However, most studies remain underpowered to assess whether ability continues to decline with GA post-term,[11,18] or examine the influence of variations in birth weight in post-term populations.[11–14,17,18,21,24–28] Moreover, it is possible that genetic or shared environmental factors contribute to a non-optimal GA and also influence later cognitive abilities.[12] Such confounding has not yet been examined in post-term children. We used a Swedish whole-population cohort to detail the relationship between GA and school grades across the full range of gestation (22–45 weeks).

Our aims were to: (i) estimate school-leaving grade averages for children born at varying GA, taking account of weight-for-GA; (ii) examine associations between GA and school grades, focusing specifically on extremely pre- or post-term children; and (iii) explore confounding by unmeasured familial factors among matched siblings.

Methods

Study cohort

In the Swedish Medical Birth Register (MBR), we identified live births between 1973 and 1994 ($n = 2\ 277\ 940$) and linked these, via the registration number, with the National School Register and other registers from Statistics Sweden and the National Board of Health and Welfare (NBHW). Individuals were linked with parents, who in turn were linked with demographic, socio-economic and psychiatric data. We excluded (Figure 1) multiple births, children with missing GA or birth weight, implausible combinations of GA and birth weight (Supplement Figure 3, Table 3 available as Supplementary data at *IJE* online), who died or emigrated before 16, had no final grade record, resided abroad within 2 years of attaining their grade or who could not be linked with parents, leaving 2 008 102 individuals for population-level analyses. To analyse matched siblings, we excluded adoptees, children without full siblings in the cohort and sex-discordant siblings (excluding the least common sex or retaining females where numbers equalled), leaving 302 718 same-sex siblings born pre-term to term and 136 911 born term to post-term.

Exposure

A categorical measure of GA distinguished between extremely pre-term (22–27 weeks), very pre-term (28–31), pre-term (32–33), late pre-term (34–36), early term (37–39) or full-term (40–41) and those born in any of the post-term weeks (42, 43, 44, 45). We defined GA in days for use in statistical analyses. For the sibling comparison, sibling-averaged GA captured between-family variation in gestational duration.[29]

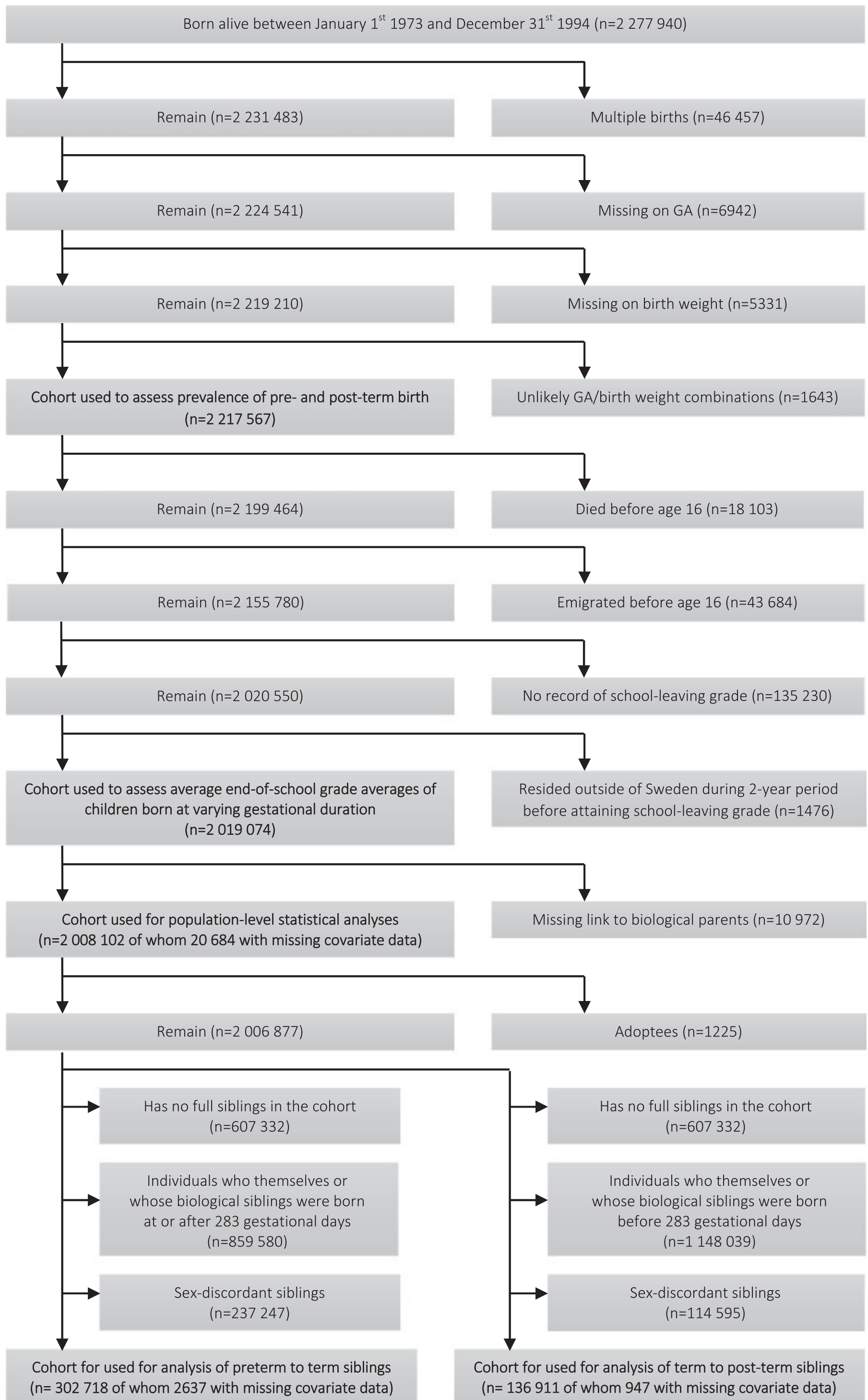

Figure 1. Selection process for the study cohort.

Outcome

Academic performance was measured by the final grade achieved on completing secondary education at 16. For those completing before 1998, this was the average across completed subjects (ranging from 1 to 5), whereas, for those completing from 1998 onwards, we used the summary score for completed subjects (80 to 320). As this study covers both grading systems, we calculated year- and sex-standardized *z*-scores based on the original grades to ensure comparability between grading systems (Supplement 1, available as Supplementary data at *IJE* online).

Covariates

Data on sex, birth weight (grams), parity (first-born), parental age, birth condition (APGAR ≤6), birth complications (Caesarean section, assisted delivery), medical risk factors (gestational diabetes or hypertension, preeclampsia), congenital malformation and labour induction (for 1990–94) were extracted from the MBR. Standardizing birth weight distributions to sex and number of completed weeks' gestation, we constructed a continuous measure of weight-for-GA, with children in the lower and upper deciles considered small- and large-for-gestational age (SGA/LGA). Parental psychiatric history and diagnoses of intellectual disability were obtained from the National Patient Register, and parental country of birth (Sweden/other) from the Register of the Total Population. We obtained family income around birth from the Income and Taxation Register and the Longitudinal Integration Database for Health Insurance and Labour Market Studies, adjusting for family size, and coding income quintiles as described previously.[30] Parental educational achievement (pre-upper-secondary/upper-secondary/post-upper-secondary) and receipt of welfare benefits were obtained for 1990–94.

Statistical analysis

Analyses were performed in Stata/SE version 12.1. We assessed prevalence of pre- and post-term birth between 1973 and 1994; calculated grade averages for children born at varying GA and weight-for-GA; compared characteristics by GA; and examined associations between GA and school performance in three adjacent study periods (1973–79, 1980–86, 1987–94) to allow change in association over time. We used restricted cubic regression splines to model non-linear associations between GA and school performance, calculating seven knots at the 2.5th, 17.5th, 33.3rd, 50th, 66.6th, 82.5th and 97.5th percentiles of the GA distribution (the maximum when knot locations are not specified) delineating the range of GA values included in each spline.[31] We analysed the data using mixed models, specifying a random effect to take account of within-family correlation in school performance. Covariates (missing for 1%) included weight-for-GA including a quadratic term, birth year, parity, parental age, maternal medical risk, parental psychiatric history, parental country of birth and family income. We calculated effects on school performance (expressed as the expected standard deviation change in school grade) across the full range of GA using *xbrcspline* post-estimation with those born at 40 weeks and 4 days as the referent. We then replaced the continuous weight-for-GA variables with indicators for SGA and LGA birth to assess effects of fetal growth restriction and macrosomia on school performance irrespective of GA, and assessed the size of these effects specifically in those born post-term. We did not control for Apgar, congenital malformation, induced or complicated births, as these are potential causal pathway characteristics.

To explore familial confounding, we examined associations after adjustment for sibling-averaged GA. These effects are interpreted as associations between GA and school grades, holding constant the tendency of families to deliver offspring early or late. Sibling-averaged GA therefore acts as a proxy for unmeasured familial traits which may result in non-optimal GA and poorer school performance and, when adjusted for, provides an estimate of the within-family effect of variation in GA.[29] In the absence of, or on adjustment for, sibling non-shared confounders, residual within-family association is consistent with a causal effect of GA on school performance.[32]

To avoid comparison of pre-term siblings (for whom advancing GA is supposedly beneficial) with post-term counterparts (for whom this may be detrimental), we examined two cohorts: one in which all were born pre-term to term; the other with term to post-term individuals. Replicating our population-level model, we specified the same knot locations; estimated associations with mixed models; and calculated effects on school performance across the full range of GA. The influence of sibling non-shared confounders was assessed by including covariates for first-birth, parental age, maternal medical risk factors and family income.

Sensitivity analyses

We assessed whether associations varied by gender, children born with or without congenital abnormalities, or characteristics potentially on the causal pathway (Supplement 4, available as Supplementary data at *IJE* online). Individuals with complete socio-economic data (1989–94) were examined to assess residual socio-economic confounding (Supplement 5, available as Supplementary data at *IJE* online).

Results

Prevalence of pre- and post-term birth

Pre-term delivery (≤36 weeks) was stable between 4% and 5% (Figure 2), whereas post-term delivery (≥42 weeks) decreased from 14% to 6% during 1973–84, potentially following changed practice in relation to induction of delivery, and stabilized between 6% and 7% until 1994.

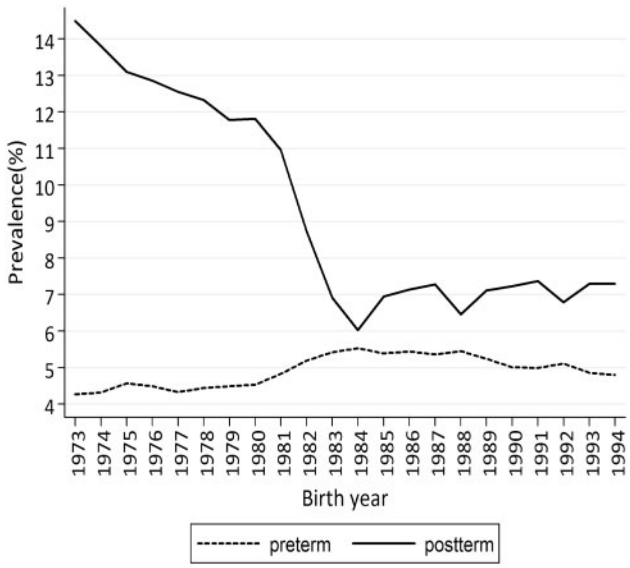

Figure 2. Prevalence of pre- and post-term birth over time (*n* = 2 217 567).

Characteristics of children born at varying gestational age

Between 1973 and 1994, 4.6% of births were pre-term and 9.4% post-term (Table 1). Late pre-term children (3.6%) were more likely to have been exposed to maternal medical risk, birth complications or low Apgar, with highest rates among children born extremely pre-term. Moderately post-term children (7.8%) more commonly suffered complicated deliveries or low Apgar, but were less exposed to maternal medical risk. Rates did not change materially for children born exceedingly post-term. Parental age decreased with increasing GA. Birth weight increased with GA to term, but decreased for post-term children.

Grade averages for individuals born at varying gestational age

The grades of children born at appropriate weight-for-GA (AGA) improved with GA towards term (40–41 weeks) and then declined. Irrespective of GA, the grades of SGA children appeared lowest (Figure 3). Knot locations for splines were calculated at 252, 271, 277, 281, 285, 290 and 299 gestational days. Following covariate adjustment (Figure 4), the grades of extremely pre-term children (24 weeks 0 days) in three study periods were 0.43 standard deviations (SD) (0.38–0.49), 0.41 SD (0.36–0.46) and 0.32 SD (0.28–0.36) below those of full-term counterparts, suggesting they had improved over time. For extremely post-term children (45 weeks 0 days), grade averages were lower by 0.15 SD (0.13–0.17), 0.11 SD (0.08–0.15) and 0.12 SD (0.09–0.16) across study periods. Models with indicators for SGA and LGA birth (Supplement 6, available as Supplementary data at *IJE* online) suggested growth restriction was associated with reduced performance irrespective of GA [–0.13 SD (–0.14 to –0.12) in the most recent study period] and with reduced performance among those born SGA post-term compared with AGA post-term counterparts [–0.12 SD (–0.16 to –0.09) in the most recent study period].

Associations among matched siblings

Four knots were specified for pre-term siblings (252, 271, 277 and 281 days) and three for post-term siblings (285, 290 and 299 days). In matched siblings (Figure 5), effects diminished after adjustment for sibling-averaged GA (darker shading), particularly in the pre-term sibling cohort [before: –0.29 SD (–0.34 to 0.24) at 24 weeks, after: –0.18 SD (–0.23 to –0.12) at 24 weeks] an to a lesser extent for post-term siblings [before: –0.11 SD (–0.14 to –0.07) at 45 weeks, after: –0.07 SD (–0.11 to –0.03) at 45 weeks].

Sensitivity analyses

Effects of extremely pre-term birth (Supplement 4, available as Supplementary data at *IJE* online) were stronger in males, or when occurring with congenital anomalies or low Apgar. Post-term effects were stronger when occurring with low Apgar. For births following induction, there was no association between post-term GA and school performance. Importantly, the grades of pre- and post-term children remained lower than those of term counterparts when considering only uncomplicated spontaneous deliveries, with normal Apgar and without congenital anomalies. Additional adjustment for parental educational attainment and welfare benefits resulted in moderately weaker pre- and post-term effects (Supplement 5, available as Supplementary data at *IJE* online).

Discussion

This is the first study to detail associations between GA and school performance across the full range of gestation. There were three main findings. First, grade averages were lower for pre- and post-term children than term counterparts, although outcomes appeared to improve over time. Second, grades of SGA children were lowest irrespective of GA. Third, despite weaker within-family associations, there were residual pre- and post-term effects among matched siblings.

Table 1. Characteristics of children born at varying GA ($n = 2\,008\,102$)

Gestational age category		Extremely pre-term	Very pre-term	Pre-term	Late pre-term	Early term	Full-term	Moderately post-term	Post-term	Very post-term	Extremely post-term
Gestational age in completed weeks		22–27	28–31	32–33	34–36	37–39	40–41	42	43	44	45
Number of individuals		n = 1207	n = 6746	n = 10 358	n = 72 998	n = 783 409	n = 945 693	n = 156 467	n = 25 171	n = 4675	n = 1378
Percentage of the sample		0.1 %	0.3 %	0.5 %	3.6 %	39.0 %	47.1 %	7.8 %	1.3 %	0.2 %	0.1 %
		%	%	%	%	%	%	%	%	%	%
Sex	Male	49.5	53.2	55.4	54.4	51.2	50.3	51.8	51.4	50.0	51.4
	Female	50.5	46.8	44.6	45.6	48.8	49.7	48.2	48.6	50.0	48.6
Parity	Primiparous	49.8	50.2	50.9	48.9	39.8	41.8	47.9	50.3	46.9	45.7
	Multiparous	50.2	49.8	49.1	51.1	60.2	58.2	52.1	49.7	53.1	54.4
Apgar score[a]	≤6	56.7	35.1	21.8	8.4	3.2	3.5	5.1	5.9	6.1	5.3
	>6	37.7	60.9	75.3	90.3	96.1	95.9	94.2	93.2	92.7	92.5
	Missing	5.7	4.0	2.9	1.3	0.7	0.6	0.7	0.9	1.3	2.3
Maternal medical risk factors[b]	No	88.7	83.4	85.4	91.4	96.5	98.0	98.5	98.5	98.5	98.6
	Yes	11.0	16.4	14.3	8.5	3.5	2.0	1.5	1.4	1.2	1.3
	Missing	0.3	0.2	0.3	0.2	0.1	0.0	0.1	0.1	0.3	0.2
Maternal psychiatric history[c]	No	81.4	81.9	81.8	83.1	85.7	87.0	86.7	85.6	85.4	82.2
	Yes	18.6	18.1	18.3	17.0	14.3	13.0	13.3	14.4	14.7	17.8
Paternal psychiatric history[c]	No	84.8	84.6	84.6	85.4	87.1	87.6	87.2	86.3	83.9	83.2
	Yes	15.2	15.4	15.4	14.6	12.9	12.4	12.8	13.7	16.1	16.8
Birth complications[d]	No	55.8	43.2	51.3	72.3	81.8	88.1	82.2	79.3	82.3	85.3
	Yes	44.2	56.8	48.7	27.7	18.2	11.9	17.8	20.7	17.8	14.7
Mother's country of birth	Sweden	83.4	87.2	88.2	88.5	88.6	90.3	90.7	90.5	90.8	89.2
	Other	16.7	12.8	11.8	11.5	11.4	9.7	9.3	9.5	9.2	10.8
Father's country of birth	Sweden	84.3	87.0	87.0	88.1	88.2	89.6	90.1	89.6	89.9	88.2
	Other	15.7	13.0	13.0	11.9	11.8	10.4	9.9	10.4	10.1	11.8
Family income in quintiles	1st (lowest)	19.7	18.1	17.7	18.7	21.1	19.5	17.0	14.3	13.3	12.1
	2nd	23.0	18.4	18.3	18.8	20.6	19.8	17.5	14.7	12.5	12.1
	3rd	18.3	21.1	21.2	20.6	20.0	19.7	19.3	17.9	17.5	16.7
	4th	20.6	21.1	21.8	20.9	19.1	19.9	21.6	24.0	25.0	26.9
	5th (highest)	16.3	20.0	19.7	19.8	18.2	20.2	23.6	28.4	31.0	31.5
	Missing	2.1	1.4	1.2	1.2	1.0	0.9	0.9	0.9	0.6	0.7
		Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Maternal age (in years)		29.1	28.6	28.1	28.1	28.3	28.0	27.6	27.0	26.3	26.3
Paternal age (in years)		32.1	31.3	30.9	30.9	31.1	30.8	30.4	29.9	29.3	29.4
Birth weight (in grams)		973	1512	2060	2742	3394	3675	3803	3766	3713	3654

[a]Low Apgar was defined as ≤ 6 on any of the 1-, 5- or 10-minute measurements.
[b]Maternal medical risk factors were defined as gestational diabetes and/or (pre-) eclampsia.
[c]Parental psychiatric history was defined as a record of in-patient psychiatric care.
[d]Birth complications were defined as birth by Caesarean section or assisted delivery.

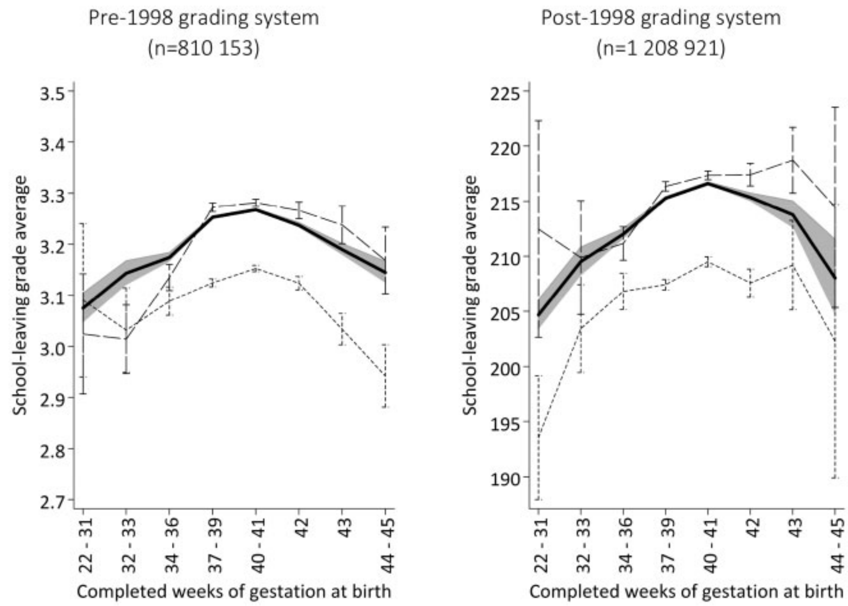

Figure 3. School-leaving grade averages of children born at varying gestational duration and small-, appropriate or large-for-gestational age ($n = 2\ 019\ 074$).
Solid lines describe school grade averages for individuals born at appropriate weight-for-gestational age with 95% confidence intervals in grey shading. The short-dotted lines show school grade averages with 95% confidence intervals for individuals born SGA. The long-dashed lines show school grade averages with 95% confidence intervals for individuals born LGA.

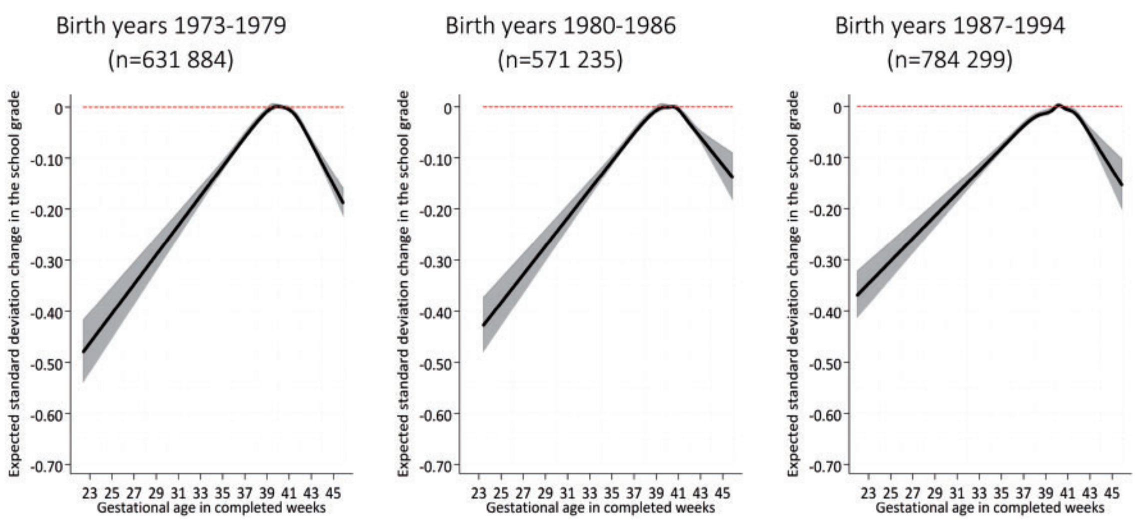

Figure 4. Association between age 16 school performance and gestational age at birth in three adjacent study periods ($n = 1\ 987\ 418$).
Curves show the expected standard deviation change in school-leaving grade associated with earlier or later GA compared with those born full-term (95% confidence intervals in grey shading). On the horizontal axis, variation in GA is shown by completed weeks to facilitate interpretation. Associations were adjusted for weight-for-gestational age with a quadratic term, birth year, parity, parental age, maternal medical risk factors, parental psychiatric history, parental migration status and family income.

Strengths and limitations

We used robust statistical methods to assess school performance by GA, examining extremely pre- and post-term births. Exploring familial confounding among matched siblings, our findings allow stronger causal inference with regard to associations between GA and school performance.

We note the following limitations. First, we could not examine children without a grade record (6.3%), limiting the generalisability of our findings to children in mainstream education. Coincidentally, most children with intellectual disability, a known correlate of pre-term birth,[33] were excluded from analyses (Supplement 2, available as Supplementary data at *IJE* online), which may have led to conservative estimates of pre-term effects. Second, for most of the cohort, GA was estimated by last menstrual period (LMP) rather than ultrasound. Measurement error

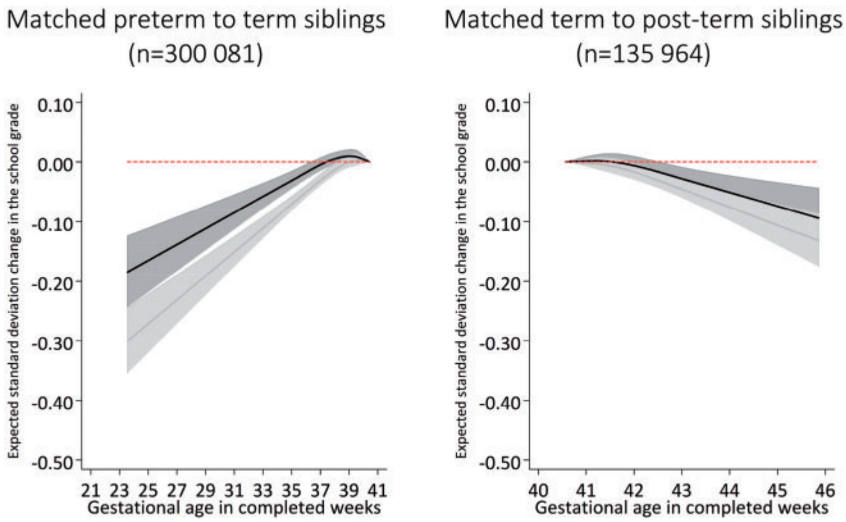

Figure 5. Association between school performance and continuously varying GA at birth among matched siblings ($n = 1\ 035\ 209$). Curves show the expected standard deviation change in school grade with 95% confidence intervals in grey shading. Associations are shown before (lighter shading) and after (darker shading) adjustment for sibling-averaged GA. On the horizontal axis, variation in GA is shown by completed weeks to facilitate interpretation. Associations were adjusted for weight-for-gestational age including a quadratic term, birth year, parity, parental age, maternal medical risk factors and family income. Collinearity statistics suggested individual gestational age and sibling-averaged gestational duration were correlated, but not collinear in the preterm to term (VIF: 2.35, condition number: 2.69) and term to post-term sibling cohorts (VIF: 2.13, condition number: 2.52).

in exposure may therefore have resulted in underestimation of population-level[34] and within-family associations.[35] Third, the sibling comparison design, while controlling for characteristics that may be missed by covariate adjustment, is sensitive to bias by sibling non-shared confounding.[35,36] In addition to a causal effect on school performance, our findings are therefore consistent with alternative causal scenarios depending on the similarity or dissimilarity of siblings in exposure and confounding characteristics as described by Frisell *et al.*[35] Fourth, rates of post-term birth are overestimated when based on LMP.[37,38] Given that GA was determined by LMP for most of the cohort (personal communication with Milla Bennis at NBHW), the trends in Figure 2 may exaggerate rates of post-term pregnancy. However, the decline in post-term pregnancy occurred between 1973 and 1984 when GA would still have been routinely assessed with LMP rather than ultrasound. This would suggest other factors, potentially a greater number of induced deliveries, may have influenced rates of post-term pregnancy over time. Fifth, in our sensitivity analyses of the influence of potential causal pathway characteristics, there may have been bias from unmeasured confounders of associations between these potential mediators (e.g. induction of labour, low Apgar or birth complications) and offspring school performance outcomes. However, our finding of associations where these mediators were absent suggests they did not explain the poorer school performance outcomes of children born at early or late GA.

Comparison with previous findings

The improving outcomes of pre-term infants over time are in line with Danish evidence of reduction in risk of autism spectrum disorder associated with pre-term birth in recent birth cohorts,[39] and may indicate advances in quality of perinatal care. Notwithstanding, the lower grades of SGA children irrespective of GA suggest an independent effect of fetal growth restriction on later school performance outcomes[18,28] which has persisted over time.

Our findings are consistent with previous studies of cognitive and behavioural outcomes for pre-term children. Lipkind *et al.*,[13] Chyi *et al.*[20] and MacKay *et al.*[11] report increased special educational needs (SEN) and lower maths,[13,20] English[13] and reading test scores.[20] Morse and colleagues[19] report greater risk of developmental problems and Larroque *et al.*[15,16] report behavioural problems and increased SEN. In line with a prior Swedish study of matched siblings,[12] we found residual within-family effects of pre-term GA on school performance.

Fewer studies are available to compare findings for post-term children. MacKay *et al.*[11] report increased risk of SEN among children born at 42 and 43 weeks. Gunn Eide *et al.*[18] report lower IQ among military conscripts born between 42 and 44 weeks and Yang *et al.*[22] report lower IQ for children born at 42 and 43 weeks. Our findings extend on this earlier work by showing a modest negative association between post-term GA and school performance controlling for unmeasured familial traits in a matched sibling design.

Finally, our findings for post-term children are consistent with an earlier Danish study which reports increased mortality risk among post-term SGA infants compared with those born post-term at appropriate weight[40] and with our previous study on fetal growth, which suggests risk for ASD with intellectual disability is greatest among SGA infants born post-term.[41]

Interpretation

Our findings suggest there may be unmeasured familial traits influencing GA at birth and later school performance. Familial confounders of pre-term birth and offspring neurodevelopment may involve influences from the shared environment, such as residual socio-economic factors not captured by our covariates[42] or lifestyle factors such as poor diet, smoking during pregnancy[43–45] or maternal pre-pregnancy overweight or obesity[46–52] in as far as these occurred across pregnancies. A recent study of risk of Attention-Deficit Hyperactivity Disorder in a cohort of matched Swedish siblings suggests familial confounders of pre-term birth and offspring neurodevelopment may not be genetic.[53]

With respect to confounding in post-term effects, maternal pre-pregnancy obesity is known to influence risk of late delivery[54–57] and may have confounded associations with offspring neurodevelopment if occurring over multiple pregnancies.[47–52] Furthermore, given that the familial risk of prolonged pregnancy may be largely genetic,[54,58–60] maternal or fetal genetic factors might confound associations if they also influence offspring neurodevelopment. Two studies using data from the Swedish registers evidence a lesser role for non-genetic familial characteristics in explaining why some pregnancies exceed term,[61,54] which may account for the smaller attenuation in effect for post-term siblings in our study.

Residual associations within families suggest there may also be causal links between GA at birth and later school performance. Mechanisms linking pre-term birth with poorer performance may involve poor fetal or childhood brain development[62,63] that could precipitate cognitive or behavioural difficulties affecting school performance.[64–68] Intrauterine infection, which is associated with prematurity,[69] may also independently cause problems in fetal brain development and affect school performance.[70,71] Placental deterioration/insufficiency in prolonged gestation may result in fetal anoxia and nutritional deficiencies,[72,73] with more or less influence depending on the degree of post-maturity. Meconium aspiration is also common in post-term pregnancy[74,75] and may independently comprise fetal brain development.[76] Finally, the less favourable outcomes of post-term SGA infants suggest placental insufficiency may become particularly toxic to neurodevelopment the longer a pregnancy endures.

Conclusions

GA was associated with school performance across the entire range of gestation, with poorer outcomes for children born pre- or post-term and especially for those showing evidence of poor fetal growth. Our findings for matched siblings were consistent with causal effects of pre- and post-term delivery on later school performance, linking birth at early or late GA with modest reductions in grades on leaving secondary education at age 16.

Future directions

Studies are needed to examine these relationships in other populations. Regional differences in management of pre- and post-term pregnancy may help us understand better the variations in policy and practice than could help improve the longer-term cognitive outcomes of children born at non-optimal GA. Future work should also assess whether our findings for post-term children can be replicated for other health outcomes to help inform policies for induction of labour in pregnancies at risk of exceeding term. Modern datasets now tend to base GA on ultrasound rather than the mother's LMP which will reduce measurement error of GA in future studies, thereby lessening bias in the exposure-outcome association. Furthermore, a comparison of models using LMP and ultrasound based GA variables may help to quantify the likely extent of bias in studies where this information was unavailable. Finally, a comparison of outcomes for children born spontaneously at term, induced at term or allowed to progress post-term may provide useful new information for the management of prolonged pregnancy.

Supplementary Data

Supplementary data are available at *IJE* online.

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