

REGULAR ARTICLE

A longitudinal study of cognitive and educational outcomes of those born small for gestational age

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Keywords

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INTRODUCTION

Birth characteristics, including low birthweight, preterm birth or being born SGA, are correlated with adverse health outcomes over the course of an individual's life (1,2). A large international literature has also investigated the relationship between birthweight, gestational age and cognitive and educational outcomes (3). Given the evident cognitive difficulties individually associated with low birthweight and preterm birth, a group of studies has focused on the detrimental cognitive and educational outcomes of being born SGA. The reported results have not been completely consistent. Several have failed to find cognitive differences between various groups of SGA and appropriate for gestational age (AGA) adolescents and adults. Few differences have been observed between pre- and early adolescents classified as SGA when compared with controls on a battery of attention and executive function tests (4,5). Some differences have been noted on

Abbreviations

95% CI, 95% confidence interval; AGA, Appropriate for gestational age; DSM, Difference of the standardised means; GA, Gestational age; IQ, Intelligence quotient; LGA, Large for gestational age; OLS, Ordinary least squares; OR, Odds ratio; SD, Standard deviation; SGA, Small for gestational age.

ABSTRACT

Aim: This study examined the long-term cognitive and educational outcomes of being born small for gestational age (SGA) and assessed whether the family's attitude towards education modified the effect of being born SGA on educational attainment.

Methods: We used anonymised data on 9598 individuals from the Stockholm Birth Cohort. This study focused on babies born in 1953 in the Stockholm metropolitan area, who were followed up for 50 years, and included educational data at the age of 13 and 48. Ordinary least squares regression analyses, modification analyses and logistic regression analyses were conducted.

Results: The findings suggested that individuals who were born SGA ($n = 798$) had lower mean verbal, spatial and numerical test scores than those born appropriate for gestational age (AGA) ($n = 7364$) and large for gestational age ($n = 1436$). The SGA/AGA differences were small, but statistically significant, and the effects of being born SGA on the test scores was modified by the family's attitude towards education. The findings also suggested that attaining higher education was largely, but not entirely, explained by the family's attitude towards education.

Conclusion: The detrimental effects of being born SGA were limited on cognitive and educational outcomes, but may have been reduced by positive family attitudes.

two subtests of attention for term-born SGA individuals (4). Others have concluded that adult cognitive ability was not affected in near-term SGA and individuals with intra-uterine growth restriction (6). However, the relatively small size of the analytical groups in these studies may have made it difficult to detect statistically significant differences between them.

In another small study of 50 Swedish children aged 10 years, the group of SGA children performed more poorly than the AGA children on the Wechsler Intelligence Scale for Children in each domain area (7). However, no performance differences were found among the subgroup

Key notes

- We examined the long-term cognitive and educational outcomes of being born small for gestational age (SGA) using data on 9598 individuals born in 1953 in Stockholm, Sweden, and followed up for 50 years.
- SGA individuals ($n = 798$) had lower mean verbal, spatial and numerical test scores than those born appropriate for ($n = 7364$) and large for gestational age ($n = 1436$).
- The effects of an SGA birth were modified by the family's attitude towards education.

of full-term SGA children. A second, related study with an even smaller SGA group of 14 children found no intelligence quotient (IQ) test score differences between SGA and AGA girls. No analysis was carried out for the boys as only four were classified as SGA (8). Statistical power to detect the effects was clearly limited.

In contrast to these studies, findings from previous studies suggested worse cognitive and educational outcomes among individuals born SGA than AGA (7–10). A systematic meta-analysis of 28 studies that compared the neurodevelopmental results of 7861 term-born SGA infants with those of 91 619 AGA control infants reported lower scores for the SGA infants, with an effect size of -0.32 standard deviations (SD) and a 95% confidence interval (CI) of -0.38 to -0.25 (9). Other studies not included in that systematic review have reported similar findings among older children and young adults. Very preterm SGA infants, classified as classic SGA (<10th percentile) and mild SGA (10th–19th percentile), have been reported to show impaired cognitive and academic performance at eight years of age (10). IQ subtests also showed lower domain scores in visuospatial, language and working memory areas among SGA individuals between 19 and 20 years of age (11). Similarly, findings from a study that assessed the relationship between SGA and IQ test scores among full-term children at the age of 17, demonstrated significantly different, but slightly lower, IQ scores for SGA children relative to those of AGA children (12). A large study of almost 14 000 children who were six-and-a-half years of age consistently found lower verbal IQ scores and poorer academic performance in maths and writing among those classified as SGA. These differences were small, but statistically significant (13). There have also been several studies that have shown differences in cognitive outcomes between children born SGA and AGA that became statistically nonsignificant after the confounding effects of the home environment, namely how the child was stimulated and supported, or their social background, such as paternal education level, were accounted for (14,15). These findings underscored the importance of controlling for the main effects of social background and characteristics of the home environment.

It has frequently been hypothesised that home environment and aspects of social background, especially parental education level, could modify the effect of being born SGA on cognitive and educational outcomes (15–17). Most studies have not tested this hypothesis, although there have been a few exceptions. However, the findings have not been supported (15,17).

The primary aim of this study was to examine the long-term effects of being born SGA on cognitive performance in early adolescence and educational attainment in adulthood. The secondary aim was to determine whether the family's attitude towards education modified the effects of being born SGA on cognitive performance. Finally, we assessed if SGA individuals attainment of higher education was affected by the family's attitude towards education.

METHODS

Study cohort

This study used data from the Stockholm Birth Cohort, which was created in 2004–2005 by a probability match of two comprehensive, longitudinal data sets: the Stockholm Metropolitan Study and the Swedish Work and Mortality Database. The first data set included survey and registry data, which provided extensive social and health information from birth to adulthood on all children born in 1953 and living in the Stockholm metropolitan area in 1963. The second anonymous data set provided population-wide data on income, work and education, as well as inpatient visits, state benefits and mortality from mid-life on all individuals born before 1985 and living in Sweden in 1980 or 1990. The data were mainly collected by surveys and from routine registries covering different periods.

The cohort encompassed a 50-year long follow-up of the original 1953 birth cohort's 14 294 members (18). A total of 4696 individuals were excluded from the current study, including 67 with a congenital malformation and those missing information on whether they were born SGA ($n = 3014$), one of the subtest scores ($n = 1514$), educational attainment ($n = 763$) or information on the type of pregnancy and their mother's age when they were born ($n = 4$). The final analytical sample included 9598 subjects. Subjects with missing information on any of the following characteristics were assigned to the information missing category for that characteristic: the marital status of the mother, the father's income, parental social class, the family's attitude towards education when the child was 13 and the number of books that the child read each week during their leisure time. Because there were some missing data for many of the independent variables, a sensitivity analysis was undertaken to assess if the missing data biased the main results. We found no substantive difference in our main results when we compared analyses that included or excluded subjects with missing data.

Dependent variables

Cognitive performance was assessed at the age of 13 by a series of tests in three domain areas – verbal, spatial and numerical ability – each with a 40-point scale. Test scores were standardised with a mean of zero and SD of one. The outcome of whether the subject attained higher education or not was assessed at the age of 48. Those who had postsecondary or a higher level of education were classified as having attained higher education.

Independent variables

The SGA classification was based on birthweight, gestational age (GA), sex and parity. Subjects were categorised into three groups: (i) an SGA group ($n = 798$) with a birthweight for GA below the 10th percentile; (ii) an AGA group ($n = 7364$) with a birthweight for GA of between the 10th and 90th percentile and (iii) a large for gestational age (LGA) group ($n = 1436$) with a birthweight for GA above the 90th percentile. This classification was derived from a sex and parity-specific reference for birthweight by GA (19).

The mother's age at the birth of the child, type of pregnancy – namely single or multiple births, – the number of siblings, marital status of the mother, school grade level at the time of testing, child's school class size, father's income, parental social class, the family's attitude towards education when the child was 13 and the number of books read by the child per week were also included in the statistical models. We controlled for the child's grade level because a small number of children took these tests after being exposed to more advanced instruction at school.

A reliable measure of parental education was unavailable due to a lack of responses from the cohort participants. Although parental education level is often considered a proxy for a variety of factors that can be advantageous or disadvantageous to the development of a child, we used the family's attitude towards education as a proxy measure for the cognitive stimulation and support a child is likely to have received. Hence, we treated the educational attitude of the family as a confounder, but also as a potential moderator of the SGA effect on cognitive performance.

Statistical analyses

Ordinary least squares (OLS) regression was used to examine the relationship between the SGA grouping and cognitive performance. Regression coefficients with 95% CIs are presented in the results. To test the role of the family's attitude towards education as a potential moderator in the relationship between SGA and cognitive performance, the effects of the different dichotomised combinations of SGA and the family's attitude towards education were added to the regression models to reduce the number of multiplicative terms. There were eight possible combinations. The measure of SGA was dichotomised into an SGA group and a non-SGA group which combined the AGA and LGA groups. The standardised test scores for each subject area were regressed on these SGA and non-SGA dichotomies according to parental educational attitudes. These models were adjusted for maternal age at the birth of the child, the type of pregnancy, number of siblings and marital status of the mother, the father's income level, parental social class, the child's grade level and the number of books that the child read each week during their leisure time. Planned, pairwise contrasts of the difference of the standardised means (DSM) between the non-SGA and SGA groups were conducted within the categories of the family's attitude towards education. Logistic regression was used to examine the relationship between SGA and the log odds of later attainment of a higher education. Results are presented in odds ratios (OR) with 95% CIs.

We also conducted a set of sensitivity analyses. Models were first estimated, with controls, for a preterm and post-term birth. Then we ran models that excluded any preterm births ($GA < 37$ weeks). Models were estimated with GA in weeks, along with our SGA and LGA dichotomies. We included the linear, quadratic and cubic products of GA in these models to search for a nonlinear effect of GA on our outcomes. Finally, we re-estimated all models with different cut-off points for the SGA and LGA classification. We set

the alternative cut-off points to -2 SDs for SGA and $+2$ SDs for LGA based on the earlier cited sex and parity-specific references for birthweight by GA (19). SAS version 9.4 (SAS Institute Inc, Cary, NC, USA) was used for all the statistical analyses.

RESULTS

The descriptive characteristics of the study population are presented in Table 1. Slightly more than 8% of the study cohort members were classified as SGA and 15% as LGA. SGA individuals were more frequently represented among multiple births. The prevalence of SGA was higher among infants from families with lower middle and working class backgrounds, with a chi-square of 7.825; degrees of freedom (df) of 3 and $p < 0.049$. The mean GA for individuals in this study was 39.9 weeks. The range of GAs was from 25 to 43.9 weeks. By the age of 48, 34% of SGA individuals had attained a postsecondary or higher level of education, compared with 40% of AGA individuals and 43% of LGA individuals.

Results from the OLS regression analyses between SGA and cognitive performance are shown in Table 2. The results of the bivariate associations suggested that when SGA subjects were compared with the AGA group, they scored 0.21 of an SD lower ($p < 0.001$) on the verbal and numerical tests and 0.17 of an SD lower ($p < 0.001$) on the spatial test. On average, the LGA children had higher scores than the AGA group. The results from models one to five showed that the associations between SGA and the test scores weakened as covariates were included. Adjustment for grade level and class size produced an attenuation of the main association (model three). Additional control for the family's socio-economic status, the family's educational attitude and the number of books that the child read each week during their leisure time further explained some of the test score differences between the SGA and AGA children. In the fully adjusted model (model five), the average z-scores of the SGA children were 0.1 of an SD lower on the spatial and numerical tests and 0.08 of an SD lower on the verbal test. These differences remained statistically significant $p < 0.01$, but the effect sizes were small (Cohen's d verbal = 0.10, spatial = 0.10 and numerical = 0.11). Compared with the AGA group, LGA children also had a slight performance advantage on the verbal and spatial subtests.

Figure 1 shows the effects of dichotomised combinations of SGA and non-SGA and the family's attitude towards education. For each subtest, there was a clear gradient for both the SGA and non-SGA groups. Lower average z-scores were found among children whose family had a negative attitude towards education, while higher average z-scores were found among those whose family had a positive educational attitude. For the verbal test, a positive family educational attitude had a somewhat more positive effect on the average z-scores of non-SGA children relative to their SGA peers (DSM = 0.104; $t = 2.05$; $p < 0.04$; $d = 0.13$). A similar but marginally statistically significant difference (DSM = 0.108; $t = 1.86$; $p < 0.063$; $d = 0.13$) was found

Table 1 Numbers and percentages of 9598 individuals and selected characteristics divided by the three categories of birthweight

	SGA group (n = 798)		AGA group (n = 7364)		LGA group (n = 1436)		All (n = 9598)	
	n	%	n	%	n	%	n	%
Sex								
Male	398	49.9	3716	50.5	719	50.1	4833	50.4
Female	400	50.1	3648	49.5	717	49.9	4765	49.6
Maternal age at birth								
<25 years	206	25.8	1905	25.9	373	26.0	2484	25.9
25–34 years	442	55.4	4269	58.0	799	55.6	5510	57.4
≥35 years	150	18.8	1190	16.2	264	18.4	1604	16.7
Type of pregnancy								
Single birth	738	92.5	7236	98.3	1431	99.7	9405	98.0
Multiple births	60	7.5	128	1.7	5	0.3	193	2.0
Number of siblings								
0	167	20.9	1425	19.4	266	18.5	1858	19.4
1	323	40.5	3253	44.2	666	46.4	4242	44.2
≥2	308	38.6	2686	36.5	504	35.1	3498	36.4
Marital status of mother								
Not married	13	1.6	80	1.1	9	0.6	102	1.1
Married	710	89.0	6746	91.6	1353	94.2	8809	91.8
Widowed or divorced	66	8.3	479	6.5	63	4.4	608	6.3
Information missing	9	1.1	59	0.8	11	0.8	70	0.8
Grade level								
Lower than 6th grade	90	11.3	498	6.8	76	5.3	664	6.9
6th grade	699	87.6	6708	91.1	1309	91.2	8716	90.8
Higher than 6th grade	9	1.1	158	2.1	51	3.6	218	2.3
Class size								
1–20 pupils	79	9.9	702	9.5	114	7.9	895	9.3
21–40 pupils	615	77.1	5955	80.9	1183	82.4	7753	80.8
Information missing	104	13.0	707	9.6	139	9.7	950	9.9
Father's income level								
Higher level	227	28.4	2584	35.1	543	37.8	3354	34.9
Middle level	227	28.4	2009	27.3	411	28.6	2647	27.6
Lower level	217	27.2	1753	23.8	315	21.9	2285	23.8
No income or unknown	127	15.9	1018	13.8	167	11.6	1312	13.7
Parental social class								
Upper & upper middle class	109	13.7	1170	15.9	256	17.8	1535	16.0
Lower middle class	331	41.5	3139	43.4	587	40.9	4111	42.8
Working class	332	41.6	2821	38.3	569	39.6	3722	38.8
Information missing	26	3.3	180	2.4	24	1.7	230	2.4
Family's attitude towards education at age 13								
Negative attitude	244	30.6	1775	24.1	316	22.0	2335	24.3
Neutral attitude	214	26.8	1961	26.6	408	28.4	2583	26.9
Positive attitude	278	34.8	3046	41.4	610	42.5	3934	41.0
Information missing	62	7.8	582	7.9	102	7.1	746	7.8
Books read by child each week in their leisure time								
>1 book	195	24.4	2031	27.6	437	30.4	2663	27.7
≤1 book	336	42.1	3021	41.0	596	41.5	3953	41.2
Never or seldom	255	32.0	2237	30.4	396	27.6	2888	30.1
Information missing	12	1.5	75	1.0	7	0.5	94	1.0

between SGA and non-SGA children whose family had a neutral educational attitude. In contrast, a negative family educational attitude had a somewhat smaller, but statistically nonsignificant effect, on the mean test score difference between SGA and non-SGA children (DSM = 0.079; $t = 1.44$; $p < 0.149$; $d = 0.10$). In the spatial domain, a negative or neutral family attitude towards education had a

more negative effect on the SGA children (DSM = 0.164; $t = 2.56$; $p < 0.011$; $d = 0.17$; DSM = 0.216; $t = 3.21$; $p < 0.001$; $d = 0.23$). A positive family attitude towards education had a negligible effect on the SGA and non-SGA difference (DSM = 0.021; $t = 0.36$; $p < 0.723$; $d = 0.02$). In the numerical domain, a neutral family educational attitude had a slightly larger effect on the relationship between SGA

Table 2 OLS regression models of the association between the birthweight for gestational age groupings and cognitive performance (n = 9598)

	Unadjusted B (95% CI)	Model 1 B (95% CI)	Model 2 B (95% CI)	Model 3 B (95% CI)	Model 4 B (95% CI)	Model 5 B (95% CI)
Mean standardised verbal test score						
AGA (reference)						
SGA	-0.21* (-0.28, -0.14)	-0.20* (-0.27, -0.13)	-0.20* (-0.27, -0.12)	-0.14* (-0.20, -0.07)	-0.12** (-0.18, -0.05)	-0.08** (-0.14, -0.02)
LGA	0.11* (0.05, 0.17)	0.11* (0.05, 0.16)	0.10* (0.05, 0.16)	0.07** (0.02, 0.12)	0.07*** (0.02, 0.12)	0.05*** (0.00, 0.10)
Adjusted R ²	0.022	0.022	0.035	0.177	0.228	0.341
Mean standardised spatial test score						
AGA (reference)						
SGA	-0.17* (-0.24, -0.10)	-0.17* (-0.24, -0.10)	-0.17* (-0.24, -0.10)	-0.13* (-0.20, -0.06)	-0.11** (-0.18, -0.04)	-0.10** (-0.16, -0.03)
LGA	0.13* (0.07, 0.18)	0.12* (0.07, 0.18)	0.12* (0.07, 0.18)	0.10* (0.05, 0.16)	0.10* (0.05, 0.15)	0.10** (0.04, 0.15)
Adjusted R ²	0.009	0.009	0.011	0.067	0.085	0.114
Mean standardised numerical test score						
AGA (reference)						
SGA	-0.21* (-0.28, -0.14)	-0.20* (-0.28, -0.13)	-0.20* (-0.27, -0.12)	-0.14* (-0.21, -0.08)	-0.13* (-0.19, -0.06)	-0.10** (-0.16, -0.03)
LGA	0.07*** (0.02, 0.13)	0.07*** (0.02, 0.13)	0.07*** (0.01, 0.12)	0.04 (-0.02, 0.09)	0.03 (-0.02, 0.09)	0.02 (-0.03, 0.07)
Adjusted R ²	0.014	0.014	0.020	0.129	0.163	0.230

OLS, Ordinary least squares.
 *p < 0.001, **p < 0.01, ***p < 0.05.
 Model 1 adjusted for maternal age at the birth of the child and the type of pregnancy. Model 2 additionally adjusted for the number of siblings and marital status of the mother. Model 3 additionally adjusted for grade level and class size. Model 4 additionally adjusted for father's income and parental social class. Model 5 additionally adjusted for the family's attitude towards education and number of books read by the child each week during their leisure time.

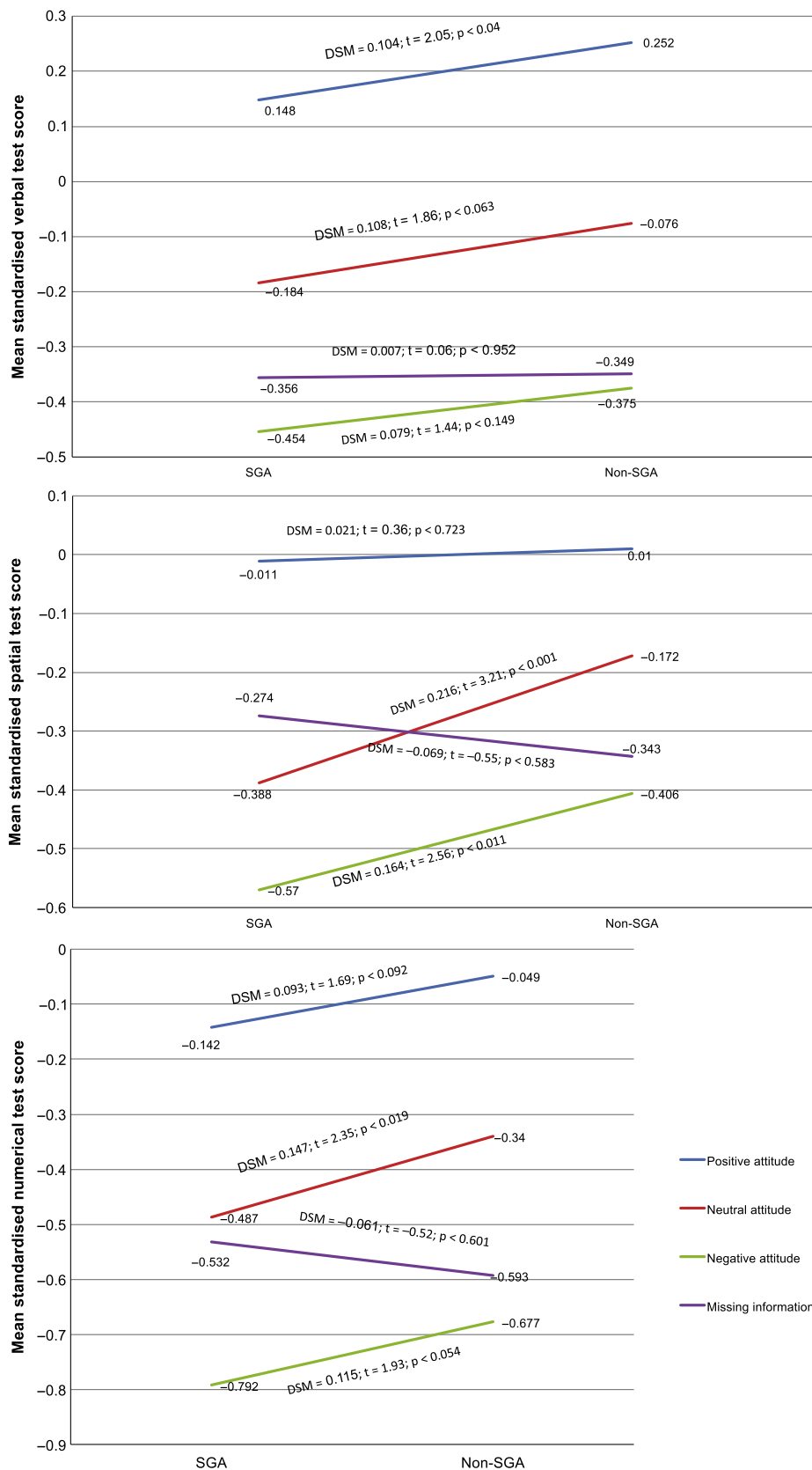


Figure 1 Mean group standardised test scores and planned contrasts (DSMs, t and p values) for dichotomised combinations of SGA/non-SGA and the family's attitude towards education. Results derived from fully adjusted OLS effect modification analyses (n = 9598, SGA n = 798, non-SGA n = 8800).

and non-SGA test scores ($DSM = 0.147$; $t = 2.35$; $p < 0.019$; $d = 0.17$). It was less clear if this was the case for children from families that had a positive or negative attitude towards education. Finally, it was noteworthy that in each domain area, the DSM was similar for those SGA and non-SGA children who were missing information on the family's educational attitude. This suggested that this missing information was unlikely to bias our results. Considered together, these findings suggested a degree of effect modification for SGA and non-SGA children that was different in each domain area. For example, the disadvantageous effect of a negative parental attitude towards education was equally harmful to the verbal development of SGA and non-SGA children. A positive and perhaps a neutral attitude were somewhat more beneficial to those who were classified as non-SGA. In contrast, a negative or neutral educational attitude was more detrimental to the average SGA child's performance in the spatial domain. However, there was no difference between SGA and non-SGA children who had parents with a positive educational attitude.

Table 3 presents the results from the logistic regression analyses. The unadjusted bivariate model suggested that SGA individuals had a lower probability of attaining higher education with an odds ratio (OR) of 0.77 and a 95% CI of 0.66–0.90. LGA individuals had a slightly higher probability (OR = 1.13, 95% CI: 1.00–1.26) compared to their AGA peers. The magnitude of these ORs remained almost unchanged in model one after adjustment for prenatal factors and family structure and after concurrent adjustment for the father's income and parental social class in model two. For SGA individuals the lower probability of attainment of higher education became statistically non-significant once the family's educational attitude was included in model three along with parental social class and in model four along with the father's income. Adjustment for just the three subtest scores in model five attenuated the effect for the SGA group to a larger extent (OR = 0.93, 95% CI: 0.79–1.10). Finally, the full model results in model six suggested that the association between SGA and attainment of higher education, net of all covariates, was negligible (SGA OR = 0.95, 95% CI: 0.79–1.13 and LGA OR = 1.04, 95% CI: 0.91–1.18).

Importantly, the sensitivity analyses revealed that our main results were robust. There were no substantive differences between the analyses that included or excluded preterm individuals. We found no evidence of a nonlinear effect of GA. Finally, there were no substantive differences between our original results and those that used the more restrictive SGA and LGA cut-off points.

DISCUSSION

Our study findings suggested small adverse cognitive effects at the age of 13 for those classified as SGA. When they were compared with their AGA peers, those born SGA had significantly lower mean standardised scores on verbal, spatial and numerical tests after full adjustment. The family's attitude towards education also modified the effect

Table 3 Logistic regression models of the association between the birthweight for gestational age groupings and attainment of higher education (n = 9598)

	Unadjusted OR (95% CI)	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)	Model 4 OR (95% CI)	Model 5 OR (95% CI)	Model 6 OR (95% CI)
SCA							
AGA (reference)							
SGA	0.77** (0.66, 0.90)	0.77** (0.66, 0.90)	0.81* (0.69, 0.95)	0.85 (0.72, 1.01)	0.87 (0.74, 1.03)	0.93 (0.79, 1.10)	0.95 (0.79, 1.13)
LGA	1.13* (1.00, 1.26)	1.12 (0.99, 1.26)	1.11 (0.98, 1.25)	1.10 (0.97, 1.25)	1.10 (0.97, 1.24)	1.03 (0.91, 1.17)	1.04 (0.91, 1.18)
-2 LL	12 909.65	12 720.85	12 038.96	11 425.27	11 618.09	11 232.41	10 620.75
Cox & Snell's R ²	0.002	0.021	0.088	0.145	0.128	0.162	0.214
Nagelkerke's R ²	0.002	0.029	0.119	0.196	0.172	0.219	0.289

**p < 0.01, *p < 0.05.

Model 1 adjusted for maternal age at birth of the child, the type of pregnancy, number of siblings and marital status of the mother. Model 2 adjusted for the father's income level and parental social class only. Model 3 adjusted for family's attitude towards education and parental social class only. Model 4 adjusted for the family's attitude towards education and father's income level only. Model 5 adjusted just for the three mental test scores. Model 6 adjusted for all covariates described above.

of being born SGA on cognitive performance, but this modification was different in each domain area. Finally, SGA individuals had a lower probability of having attained higher education at the age of 48 than AGA individuals. Statistical control for social class and income was not, on its own, sufficient to explain the difference. However, this difference disappeared after adjustment for the family's educational attitude, along with separate mutual adjustment for parental social class or income. Controlling for just prior cognitive performance also explained the difference. Additional findings from the OLS regression analyses demonstrated that prior cognitive performance was most strongly predicted by the family's educational attitude and classroom size and grade level.

These findings were both consistent and inconsistent with two similar older Swedish studies (7,8). Our study used a larger analytical group with greater statistical power to detect effects and a standard SGA classification. The divergent findings can be explained by these differences.

It is important to note that a complete consensus has not been reached in the literature concerning the persistent disadvantageous effects of SGA on cognitive outcomes in early adulthood (11,20). Many studies have found small cognitive disadvantages for those born SGA (21,22). Similarly, the DSMs between SGA and AGA individuals in our study were about 0.10 of an SD on the verbal, spatial and numerical tests. Our findings also largely agreed with those of an earlier study that used the same SGA cut-off points that we used in our study (12). Another study also found small differences in cognitive abilities between an SGA group and the non-SGA group at the age of 14 (17). But these differences were not statistically significant.

However, the findings of our study suggest that the negative effect on cognitive outcomes was not only partially mediated by parental educational attitudes, but also moderated by them. A small number of other modification analyses have been undertaken in the literature with inconsistent results. A Swedish study suggested that the adverse impact of preterm birth on language performance was only confined to children who had parents with a low education background (23). This finding was not completely consistent with our findings in the verbal domain. The difference may be partly due to a difference in the moderator measure used. We suggest that parental educational level may not be the best proxy for capturing the attitude that parents have towards education. At least one other study showed that the relative risk of learning difficulties for an SGA group compared with a non-SGA group was similar within each stratum of each social risk level, for example maternal education level, age and single parent status (17). These findings suggest no evident effect modification of social risk level on the main relationship and may highlight the challenge of using parental education level as a proxy for parental educational attitudes.

We also estimated similar models using social class as a moderator instead but found no effects. A more egalitarian Swedish society in the 1960s may have made it difficult to detect small differences in this study. Our study used the

family's attitude towards education, partially because we believe that it more directly reflected the extent to which parents invested in their children's educational development. We also assumed that parents who had a more positive attitude towards education were more capable and more likely to provide a stimulating environment for their children's cognitive development. In turn, they may have invested more time and resources to facilitate the educational success of their children (24).

The unadjusted findings from this study also suggest that the negative effect of SGA had a later effect on the attainment of higher education. This difference was explained completely by the tests scores at the age of 13 and mostly by the parental attitude towards education in combination with separate controls for parental income and social class. Because the family's attitude towards education moderated the effect of being born SGA on these test scores, we suggest that the family's attitude towards education was the most important explanatory variable. It is also notable that the family's attitude towards education at the age of 13 explained the unadjusted difference between SGA and AGA individuals who had attained higher education by the age of 48. Although we only had information on the family's attitude towards education and the number of books that the child read each week during their leisure time, these findings could suggest that the unadjusted difference in the log odds of attainment of higher education was likely to be reduced by how parents engaged their SGA children.

Our results agreed with the findings of at least two other previous studies on educational attainment. The difference in the unadjusted OR of college attendance between a low birthweight and normal birthweight groups was similar in magnitude to our findings. However, the difference was not statistically significant (25). After full adjustment for a variety of covariates, there was no evidence of a difference between 17-year-old SGA and AGA individuals in the probability of having less than 11 years of schooling or vocational school attendance (12). Results for the unadjusted models were not presented in this study.

Importantly, LGA individuals in our study had better cognitive performance in early adolescence than AGA individuals. This finding was consistent with some studies that demonstrated advantages in cognitive performance and educational outcomes when LGA children were compared with AGA children (26,27).

A particular strength of our study was that it was based on a population cohort. The study sample was representative and could be generalisable to the Swedish population including all the individuals born in Stockholm in 1953. A main limitation of this study was that our definition of SGA was not able to make a distinction between those who were constitutionally small and pathologically small.

CONCLUSION

The findings of this study suggested that being born SGA had small, but statistically significant, independent effects on cognitive performance in early adolescence. The family's

attitude towards education moderated the effects of SGA on cognitive performance differently in the verbal, spatial and numerical domains. Our results also suggest that the unadjusted difference in the log odds of attainment of higher education was largely explained by the family's attitude towards education and prior test score performances at the age of 13, which was itself strongly predicted by the educational attitude of the parents. Importantly, the limited influence of being born SGA on cognitive outcomes has, to some extent, confirmed the point of view that the impact of poor birth characteristics decreases for children with the increasing age. Social and environmental factors seem to be more important. The results of this study suggest that a positive parental attitude towards education had some educational benefits for SGA individuals. It is likely that a positive parental attitude, even when measured in early adolescence, is likely to have reflected supportive practices that led to better school performance. There is a large literature that has demonstrated this more generally, but not specifically, in SGA children. Hence, this remains an attractive hypothesis in the SGA context that warrants future research.

CONFLICT OF INTEREST

The authors have no conflict of interests to declare.

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