Small-for-Gestational Age Birth Confers Similar Educational Performance through Middle School

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Objective To estimate the association between small for gestational age (SGA) at birth and educational performance on standardized testing and disability prevalence in elementary and middle school.

Study design Through linked birth certificates and school records, surviving infants born at 23-41 weeks of gestation who entered Florida's public schools 1998-2009 were identified. Twenty-three SGA definitions (3rd-25th percentile) were derived. Outcomes were scores on Florida Comprehensive Assessment Test (FCAT) and students' disability classification in grades 3 through 8. A "sibling cohort" subsample included families with at least 2 siblings from the same mother in the study period. Multivariable models estimated independent relationships between SGA and outcomes.

Results Birth certificates for 80.2% of singleton infants were matched to Florida public school records (N = 1 254 390). Unadjusted mean FCAT scores were 0.236 SD lower among <10th percentile SGA infants compared with non-SGA infants; this difference declined to −0.086 SD after adjusting for maternal and infant characteristics. When siblings discordant in SGA status were compared within individual families, the association declined to −0.056 SD. For SGA <10th percentile infants, the observed prevalence of school-age disability was 15.0%, 7.7%, and 6.3% for unadjusted, demographics-adjusted, and sibling analyses, respectively. No inflection or discontinuity was detected across SGA definitions from 3rd to 25th percentile in either outcome, and the associations were qualitatively similar.

Conclusions The associations between SGA birth and students' standardized test scores and well-being were quantitatively small but persisted through elementary and middle school. The observed deficits were largely mitigated by demographic and familial factors. *(J Pediatr 2019;212:159-65)*.

Infants born small for gestational age (SGA) are at risk of increased morbidity[1] and mortality regardless of underlying etiology.[2] A growing body of knowledge relates SGA births to growth disturbances,[3] cognitive delays with decreased academic achievement,[4] and a small increased risk of neurologic disorders, including cerebral palsy.[5,6] All risks are amplified in infants born <32 weeks of gestation.[7] Placental insufficiency and restricted intrauterine nutrition may also contribute toward adult disease.[8] In adulthood, epidemiologic studies have associated SGA with cardiovascular disease and diabetes mellitus.[9,10] These findings support the hypothesis that an adverse intrauterine environment may contribute to future health and developmental consequences.

The effect of SGA on educational performance, another functional and policy-relevant outcome, is less well understood.[7,11] Among premature children born <32 weeks of gestation, elevated risks of adverse cognitive development have been demonstrated through 14 years of age.[7,12] However, no long-term population-level follow-up studies of children in the US have evaluated the relationship between SGA birth and educational performance. A persistent challenge in such studies is the variability in the definition of SGA,[2,10,12-14] though birth weight <10th percentile is commonly used,[12] and the comparative morbidities related to these different definitions have not been fully described.

In this retrospective analysis, using population-level data from the state of Florida, we tested 4 hypotheses regarding the relationship between SGA and child outcomes. First, SGA infants exhibit lower educational performance compared with non-SGA peers at the standard 10th percentile definition, as well as other set points across the spectrum of definitions from 3rd to 25th percentile. Second, across the studied spectrum there is an inflection point in the effect of SGA on

SGA	Small for gestational age
FCAT	Florida Comprehensive Assessment Test

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educational performance. Third, the magnitude of the association is mitigated by maternal, infant, familial, and environmental factors. Fourth, across the spectrum of gestational ages, SGA birth is independently associated with the presence of school-age diagnosed disabilities.

Methods

This study was approved by the Institutional Review Boards of Northwestern University, the University of Florida, and Florida's education and health agencies. These reviews incorporated the compliance of statutes in the Family Educational Rights and Privacy Act and the Health Insurance Portability and Accountability Act regulations.

Singleton infants born at 23-41 weeks of gestation between 1994 and 2002 and surviving to 1 year of age were identified using their birth certificates, obtained from the Florida Bureau of Vital Statistics. Certificates were matched to Florida public school educational records maintained in the Education Data Warehouse of the Florida Department of Education according to 4 variables: first name, last name, date of birth, and social security number. Children were included if they were born in Florida, lived in Florida until school age, and attended Florida public schools. Thus, children attending private schools were omitted from the analyses. Match rates were compared with findings from the American Community Survey,[15] a 1% representative sample of the US population, to confirm that observed match rates reflected the proportion of Florida children that go on to attend public schools.

When comparing siblings, we restricted the analysis to mothers with at least 2 singleton births between 1994 and 2002, which we verified as biological siblings. Sibling matches were made based on the same household of residence address in the school records that we verified against the relevant students' birth records using maternal date of birth. Children with mismatched maternal information were excluded from the analysis (less than 1%).

SGA was the exposure variable and was derived using both sex- and gestation-specific birth weight percentiles of the entire Florida cohort. Multiple definitions of SGA were employed, from the 3rd to 25th percentile,[14,16] because there is no consensus on an optimal definition of SGA and knowing if there are natural discontinuities in the relationship at particular percentiles could better inform neonatal practice.

Administrative public school records include annual information on achievement, disciplinary actions, demographic characteristics, and special needs of students. The educational outcome was the average mathematics and reading score on the Florida Comprehensive Assessment Test (FCAT). Available scores were pooled across grades 3 to 8, resulting in up to 6 observations per individual. The FCAT score was standardized for each subject, grade, and school year to a mean of 0 and SD of 1.[7,17] A second outcome was presence of a disability in child's school records. The classifications of disability are the Florida Department of Education's standard definitions for "primary exceptionality" recorded by school districts[18] (and, therefore, were not derived by the investigative team), excluding gifted status. Test scores and disabilities were analyzed for the same cohort of children.

Statistical Analyses

Descriptive statistics were used to quantify the maternal and infant characteristics in 4 samples after stratifying the eligible cohorts by SGA status: (1) all singleton births; (2) all singletons that had observed siblings; (3) all singletons tested in grade 3; and (4) all siblings tested in grade 3. For illustrative purposes, we chose 10th percentile as the definition of SGA.[2,16]

Both FCAT scores and disability were compared for varying definitions of SGA (3rd to 25th percentiles) using linear regression models. Each estimate for the disability diagnoses was scaled by the proportion of infants with disability in the population so that they could be interpreted as percent effect sizes at each definition of SGA.

Analyses were adjusted with maternal and child variables from the birth certificate.[19,20] Maternal variables included African American race, Hispanic ethnicity, born outside the US, age at the time of birth (<20, 20-29, 30-35, >36 years of age), education level (<12, 12-15, ≥16 years of education), number of prior births, health problems (eg, hypertension, diabetes), language spoken at home, start of prenatal care in first trimester, marital status, zip code of residence, and delivery paid by Medicaid. Child variables included gestational age, sex, congenital anomalies (eg, spina bifida, Down syndrome), abnormal conditions at birth (eg, meconium aspiration syndrome, seizures), timing of birth (month and year), and child's age in grade 3 to account for differences in "holding back" decisions that may have been related to SGA.

Siblings were compared in a restricted cohort analyses. In this case, variation in SGA stems from within-family comparisons of siblings with and without SGA. Each mother allowed us to account for time-invariant unobserved characteristics that are common to siblings, and thus, each mother was considered as a fixed effect. For example, maternal race (observed) and the maternal grandparents' educations (unobserved) were presumed constant across births, and maternal age (observed) and breastfeeding behavior (unobserved) varied. We also retained families without differences in SGA across siblings; inclusion of these children in the analysis helped reduce residual variation related to unobserved, time-varying factors that may correlate with both SGA and educational outcomes.

Two sensitivity analyses were conducted with subsets of the data. First, we analyzed women with healthier pregnancies, defined as those with no health problems, age <35 years, English or Spanish speaking, who received prenatal care started in first trimester, and had newborns without congenital anomalies or abnormal conditions at birth (**Figure 1** and **Figure 2**; available at www.jpeds.com). Second, for unmarried mothers, Florida statutes in place during the study period permitted paternal naming only with his consent on each birth certificate. Thus, for sibling analyses,

we completed a sensitivity analysis (**Figure 3**; available at www.jpeds.com) restricting the sample to siblings with the same named mother and father. In this case, the parental fixed effect also accounted for the genetic potential of the children, given that their parents' biological contributions may influence both SGA birth and educational performance.

We also conducted 2 secondary analyses probing the heterogeneity in our findings. First, we estimated the effect of SGA across gestational age groups. This analysis was restricted to the singletons cohort because we only identified 21 SGA-discordant families with 2 or more children born at <32 weeks of gestation. For brevity, this analysis reported results for 3rd, 10th, and 25th percentiles and was based on adjusted associations. Second, for FCAT scores, we explored differences in reading and mathematics as well as changes in estimated relationships between grades 3 and 8 (**Figures 4-6**; available at www.jpeds.com).

Analyses were conducted with Stata v 13 (StataCorp, College Station, Texas) and SEs corrected for correlation within individual over grades (singletons) and within family (siblings) were used to calculate 95% CI. Data analysis was performed from June 1, 2017 to October 25, 2018.

Results

There were 1 563 516 birth certificates issued in Florida for singleton infants born between 23 and 41 weeks of gestation from 1994 to 2002. Matches to educational data were made for 1 254 390 (80.2%) of these children. These findings were concordant with results from the American Community Survey indicating that 80.9% of Florida-born infants attended public schools. In comparing the full birth sample to those who enrolled and were tested in Florida schools, we noted that children in the study sample had less educated mothers who were more likely to be unmarried and African American compared with those who either left the state or enrolled in private school (**Table I**, column 1 vs column 4). Families with siblings were typically less affluent than families included in the primary analysis (**Table I**, column 1 vs **Table II**, column 1 [available at www.jpeds.com]). Prematurity rates, among tested children, were 8.2% and 8.0% for all singleton births and families with siblings, respectively.

The matched dataset contained FCAT scores for 1 058 126 students or 84.4% of Florida-born children who attended public schools in our cohort. Records for children who left the state prior to testing in grade 3 or who had missing test score information accounted for 14.1% and 1.5% of the remaining sample, respectively. Within this linked birth data set were 383 905 siblings from 176 211 families.

SGA birth was associated with a lower FCAT score in both unadjusted and adjusted analyses, for all considered definitions of SGA and in both singleton and sibling samples (**Figure 7**). In the cohort of singletons (**Figure 7**, A), the unadjusted estimates are largest for 3rd percentile SGA (−0.294 SD, 95% CI −0.304 to −0.284) and smallest for 25th percentile of SGA (−0.193 SD, 95% CI −0.197 to −0.189). In multivariable analyses, the magnitude of these estimates decreased but remained largest for the 3rd percentile SGA (−0.122 SD, 95% CI −0.130 to −0.114) and smallest at 25th percentile SGA (−0.063 SD, 95% CI −0.066 to −0.060). The difference in adjusted association with FCAT scores between the 3rd and 25th percentile SGA definitions was 0.059 SD, or 1/17th of a SD.

We observed a similar pattern among confirmed siblings (**Figure 7**, B). The unadjusted relationship varied from −0.342 SD (95% CI −0.360 to −0.324) at a 3rd percentile SGA to −0.227 SD (95% CI −0.234 to −0.220) at a 25th percentile SGA. These unadjusted associations were more negative than in the sample including all singleton births, consistent with more adverse characteristics of families with siblings in our study cohorts (eg, lower maternal education; **Table I**, column 1 vs **Table II** column 1). In the adjusted analyses, including family fixed effects, the associations declined to −0.078 SD (95% CI −0.095 to −0.062) and −0.040 SD (95% CI −0.047 to −0.033) at 3rd and 25th percentile, respectively. The difference between these 2 estimates was 0.038 SD or 1/26th of a SD.

Table I. Descriptive statistics: all singleton births

	(1)	(2)	(3)	(4)	(5)	(6)
	All singletons			Singletons with 3rd grade scores		
	All	10th percentile SGA		All	10th percentile SGA	
Characteristics		No	Yes		No	Yes
African American	342 404 (21.9)	293 023 (20.7)	49 381 (33.4)	258 438 (24.9)	220 883 (23.6)	37 555 (37.0)
Hispanic	374 142 (23.9)	339 671 (24.0)	34 471 (23.3)	257 571 (24.8)	234 029 (25.0)	23 542 (23.2)
Immigrant	375 318 (24.0)	339 548 (24.0)	35 770 (24.2)	246 251 (23.8)	222 925 (23.8)	23 326 (23.0)
Mother high school dropout	315 820 (20.2)	275 406 (19.5)	40 414 (27.4)	232 762 (22.5)	202 936 (21.7)	29 826 (29.4)
Mother high school graduate	916 402 (58.6)	831 344 (58.7)	85 058 (57.6)	629 083 (60.7)	569 581 (60.9)	59 502 (58.7)
Mother college graduate	331 304 (21.2)	309 035 (21.8)	22 269 (15.1)	174 684 (16.9)	162 603 (17.4)	12 081 (11.9)
Married	1 017 323 (65.1)	939 722 (66.4)	77 601 (52.5)	634 914 (61.3)	585 344 (62.6)	49 570 (48.9)
Age at birth, y	27.2 (6.2)	27.3 (6.2)	26.1 (6.5)	26.8 (6.2)	26.9 (6.2)	25.8 (6.5)
# previous births	1.0 (1.2)	1.0 (1.2)	0.9 (1.2)	1.0 (1.2)	1.0 (1.2)	0.9 (1.2)
Female	762 928 (48.8)	689 638 (48.7)	73 290 (49.6)	513 275 (49.5)	462 015 (49.4)	51 260 (50.5)
N	1 563 526	1 415 785	147 741	1 036 529	935 120	101 409

Columns (1) to (3) include all singleton Florida births between 1994 and 2002 at 23 to 41 weeks of gestation. Columns (4) to (6) include a subset of individuals for whom we observe third grade test scores. Counts or averages (% of sample values or SDs).

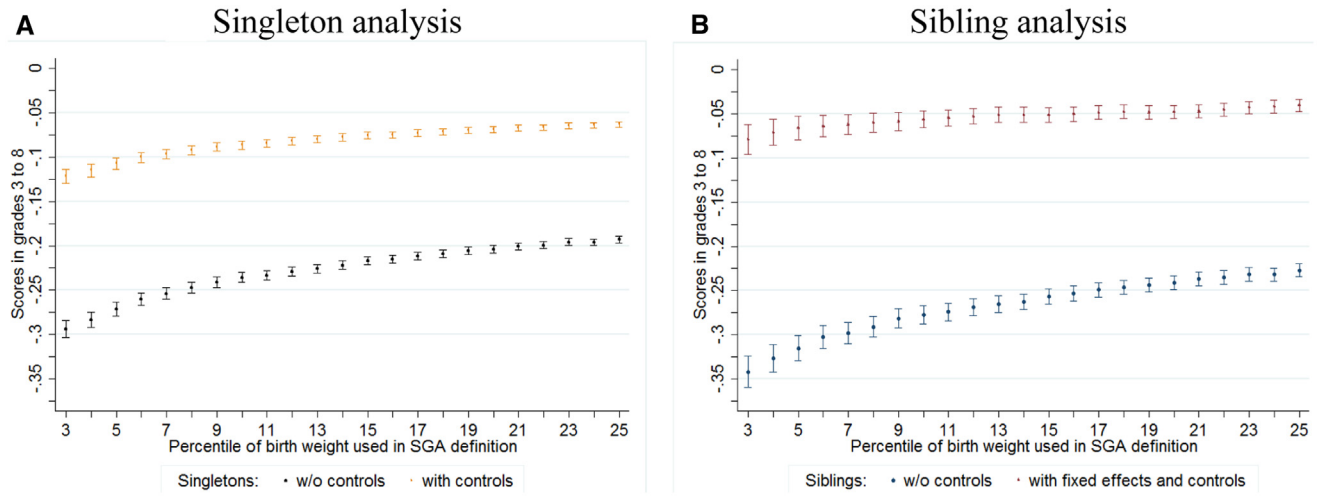

Figure 7. Association between SGA and FCAT test scores. Point estimates with robust SEs (clustered at **A,** individual and **B,** family level) used to calculate 95% CIs. **A** uses all singleton births and **B** restricts the sample to siblings born between 1994 and 2002 to the same mother.

SGA birth and the probability of disability classified at school were also related (Figure 8). The unadjusted effect sizes were 23.0% (95% CI 20.8%-25.2%) and 21.0% (95% CI 17.2%-24.8%) at the 3rd percentile SGA and 8.7% (95% CI 7.9%-9.5%) and 9.1% (95% CI 7.7%-10.5%) at the 25th percentile SGA for the singletons and siblings cohorts, respectively. These relationships declined after including covariates, which in the singleton cohort (Figure 8, A) resulted in a 3rd percentile SGA estimate of 12.1% (95% CI 10.0%-14.1%) and 25th percentile SGA estimate of 3.4% (95% CI 2.6%-4.2%), a range of 8.7 percentage points. The estimates were similar in the sibling sample (Figure 8, B).

Figure 9 presents the relationship between SGA and FCAT scores (Figure 9, A) and disability (Figure 9, B) for 5 gestational age groups. Within each gestational age stratum, associations between FCAT score and SGA were most negative for the 3rd percentile SGA definition and least negative for the 25th percentile SGA definition. Conversely, the adjusted effect sizes of disability classification were most positive for the 3rd percentile and diminished through 25th percentile SGA definition. When considering children born ≥32 weeks of gestation, test score associations for each percentile definition were similar across the gestational age strata. For infants born <32 weeks of gestation, the estimates were smaller for test scores and larger for disability for each percentile SGA definition. However, because of the smaller sample sizes (n = 11 318 in total; n = 278 SGA at 3rd percentile), we could not conduct credible statistical inferences for this group.

The relationships between SGA and FCAT scores were similar in the sample of healthier pregnancies and associations with disabilities were modestly smaller (Figure 1 and Figure 2). For both outcomes, restricting the sample to families with the same mothers and fathers did not change the results (Figure 3). Associations were more negative for mathematics scores than for reading scores (Figure 4 and Figure 5) but were similar across grades 3-8 in a 6-year panel analysis (Figure 6). In the panel analysis, for each SGA definition, there was a gradient of decreasing associations from grade 3 to grade 8 (minimum of 0.007 SD and maximum of 0.010 SD in Figure 6, A), but the estimates were not statistically different between these 2 grades.

Discussion

We found that SGA birth was significantly associated with lower test scores and higher likelihood of disability classification in school. The findings were present across the spectrum of birth weight-based definitions of SGA (3rd through 25th percentile). For test scores, the small but negative and persistent relationship ranged from −0.08 SD at the 3rd percentile SGA definition to −0.04 SD at the 25th percentile SGA definition, even in the most rigorous estimation specification (sibling fixed effects with controls). The association between SGA and disability was larger and ranged from 12.1% at the 3rd percentile to 3.4% at the 25th percentile. We did not detect any policy-relevant inflection in the studied relationships.

We compared our SGA results with other frequently studied disparities in test scores and disability: racial black-white gaps and gaps by maternal education.[20] Analyzing the black-white test score gap within this same Florida dataset, we found a difference of 0.58 SD and a test score gap between children of high school dropout vs college graduate mothers of 1.01 SD. Disability rates of children with high school

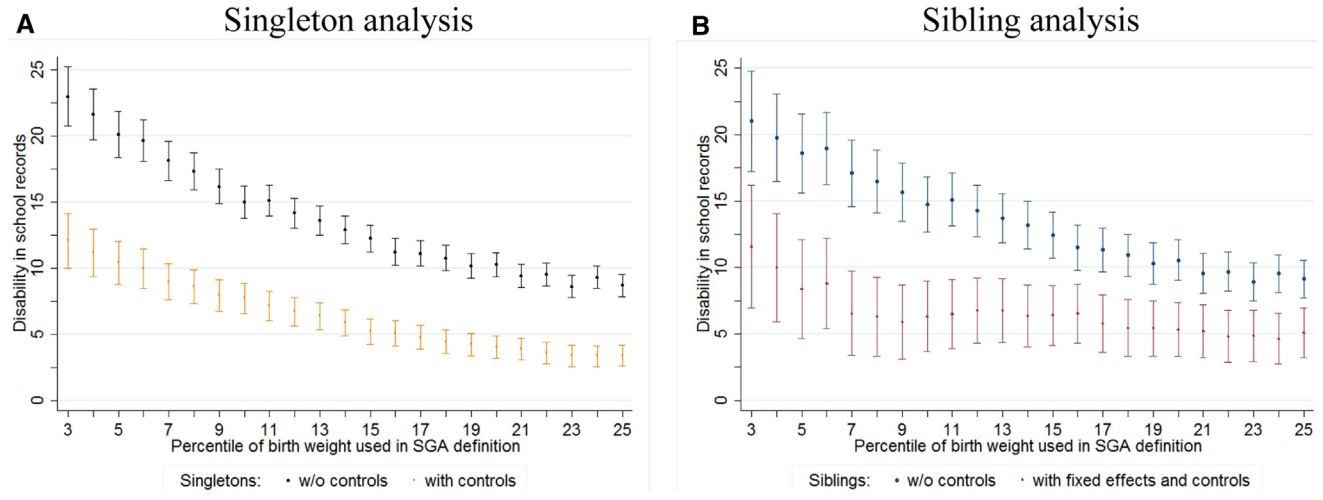

Figure 8. Association between SGA and disability in school records. Effect sizes (point estimate divided by mean of Y and multiplied by 100) with robust SEs (**A,** heteroscedasticity robust and **B,** clustered at family level) used to calculate 95% CIs. **A,** singleton sample and **B,** sibling sample.

dropout mothers were 26.9% and those with college graduate mothers were 18.2%, or a difference of 39% when compared with the mean of 22.5% for the entire sample. In light of such comparisons, the adverse but independently attributable risk due to even a 3rd percentile SGA (−0.08 SD for FCAT and +12.1% for disabilities) are comparatively small and reflect reassuring middle school performance for test scores.

This study demonstrates the advantage of linking health and education data sources to create tools for research with public health applications. With a high-rate of follow-up over 13-14 years, our retrospective analyses produced policy-relevant relationships that would have taken significant funds and time to complete prospectively. Sibling linkage, for example, requires large-scale administrative data to provide credible statistical inference. Furthermore, our results can be used by clinicians/providers to counsel parents who experience SGA birth and who may be asking what long-term educational outcomes are anticipated.

This study has certain limitations. Our findings are associations and do not imply causality. Though our follow-up rate was high, it does not exclude the possibility that SGA infants who were not tested or went to private schools were systematically different from those in public schools. In addition, our initial sample was selected because we required an infant to survive at least to age 1 year. The Center for Disease Control and Prevention linked birth-death cohort data for Florida for 1995-2002 births suggest that 1-year mortality rates are as high as 2.7%, 1.5%, and 1.0% among those born

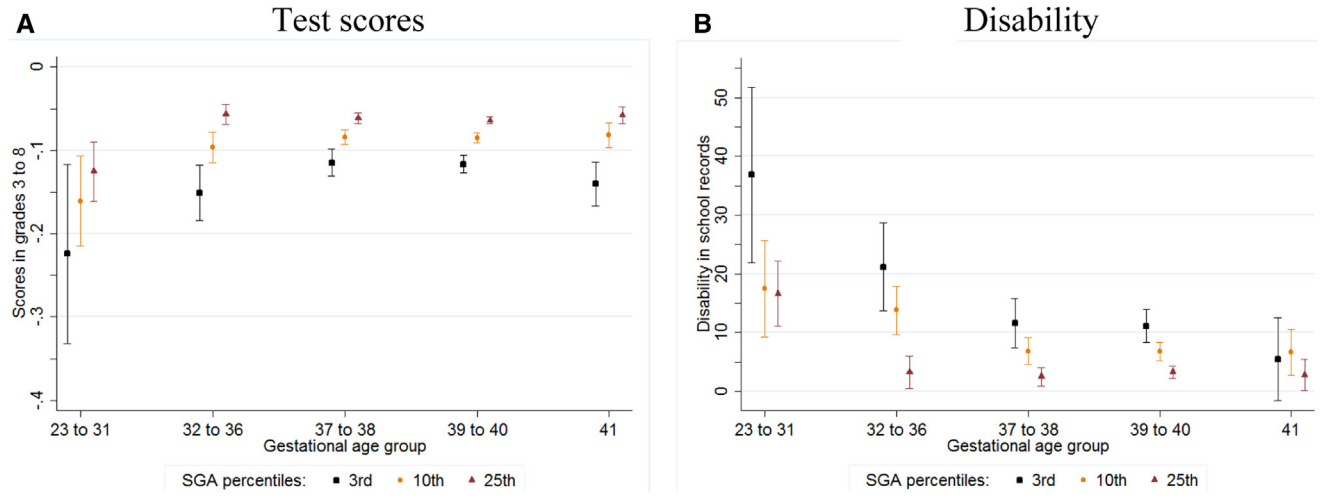

Figure 9. SGA associations by percentiles and gestational age strata. Estimates (based on analyses akin to **A,** Figure 7 and **A,** Figure 8) and robust SEs (clustered at **A,** individual level and **B,** heteroscedasticity robust) used to calculate 95% CIs.

SGA at 3rd, 10th, and 25th percentiles, respectively.[21] In our sibling analyses, some infants had siblings who were not born between 1994 and 2002; however, unless correlated with SGA status of observed siblings, this lacuna should not bias the estimates.

Unknown and unmeasured factors (eg, incidence of bronchopulmonary dysplasia, intraventricular hemorrhage, caffeine or corticosteroid use, etc.) may have modified the observed associations.[22-24] To the extent that these can vary within families and across children born to the same parents, even our most stringent empirical comparisons (sibling fixed effects) were unable to account for these unobserved factors. Likewise, we cannot discern if the quantitatively small associations are due to a weak causal relationship between SGA and our outcomes or because the postnatal care that these infants receive is so effective (eg, developmental follow-up clinics, early intervention services, or medical follow up) that it overcomes fetal growth problems. Distinguishing which factors are driving the association is a fruitful avenue of future research and potential policy refinements.

Finally, the births and birth weights observed in the state of Florida may differ from nationwide averages.[16] Other investigators have applied more restricted definitions of SGA[12] that may be more tightly related to standardized testing scores. Though FCAT scores are objective measures based on standardized assessment instruments, disability classification includes by law parental input at the individual, classroom, or school level.

In this linked birth certificate and school-based dataset, SGA birth appears to have an independent and persistent but small negative association with educational performance and larger positive association with disability in school-age children. These associations are less prominent when accounting for maternal, infant, and familial factors and are relatively constant across a range of SGA definitions from 3rd to 25th percentile. Our findings suggest that educational and disability outcomes are affected in a minor way except at the most stringent definitions of SGA and among those born <32 weeks of gestation. From a clinical and public health perspective, our findings may help clinicians counsel families who have had an SGA birth. ■

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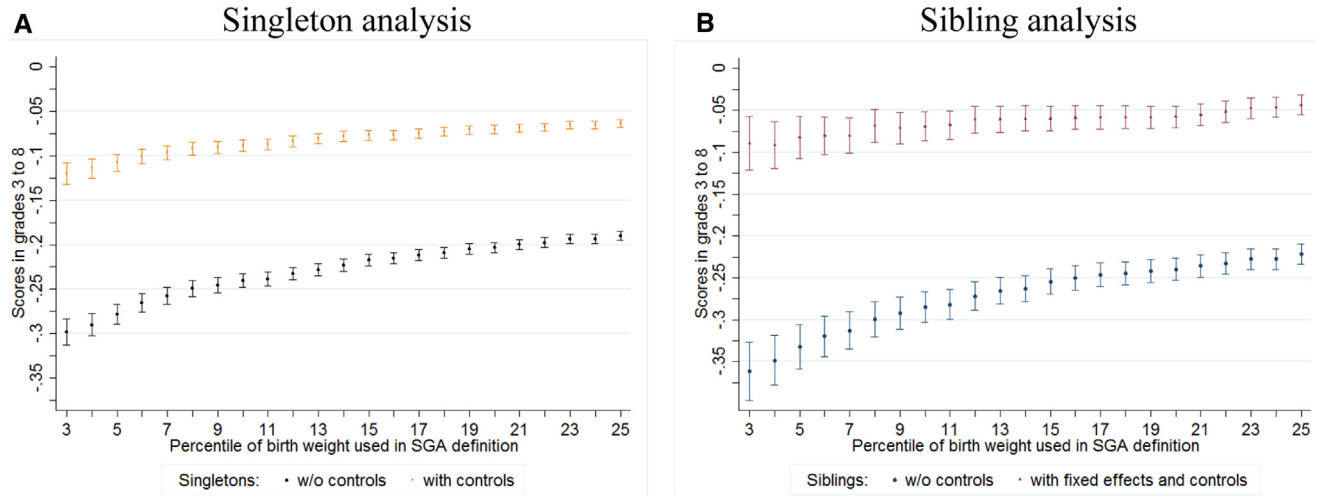

Figure 1. Association between SGA and FCAT test scores. Estimates for "healthier" pregnancies. Sample is based on singleton births from 1994 to 2002 and restricted to "healthier pregnancies" defined as one without maternal health problems, child congenital anomalies or abnormal conditions at birth, older mothers (age at birth of 36 years or above), or those who do not speak Spanish or English; it further includes only pregnancies where prenatal care started in the first trimester. Multivariable linear regressions in both panels. Robust SEs used to calculate 95% CIs. SEs are clustered at **A,** individual level and at **B,** family level. Each scatterplot series presents estimates from 23 separate regressions where the independent variable of interests is an indicator for SGA defined at a given percentile of birth weight (3rd-25th). Outcome is pooled grades 3-8 test scores that are averaged across reading and mathematics for each individual in each grade. **A,** uses all singleton births; **B,** restricts the sample to siblings born between 1994 and 2002 to the same mother. We required at least 2 births to the mother between 1994 and 2002 to be included in the sample used in panel **B**. Black squares (**A**) and navy diamonds (**B**) present unadjusted relationship between an indicator for SGA birth and test scores. Orange circles (**A**) and maroon triangles (**B**) present adjusted relationship where the conditioning variables include gestational age, sex, race, nativity, ethnicity, marriage, month of birth, year of birth, maternal education (high school dropout, high school graduate, college graduate), maternal age (19 or below, 20-29, 30-35, 36 years and above), number of previous births, age at the time of testing in third grade, congenital anomalies, abnormal conditions at birth, maternal medical problems, prenatal care started in first trimester, language spoken at home (non-English and non-Spanish), zip code of residence (2079 variables), and birth paid by Medicaid indicators. Adjusted analysis in panel **B** further includes sibling fixed effects.

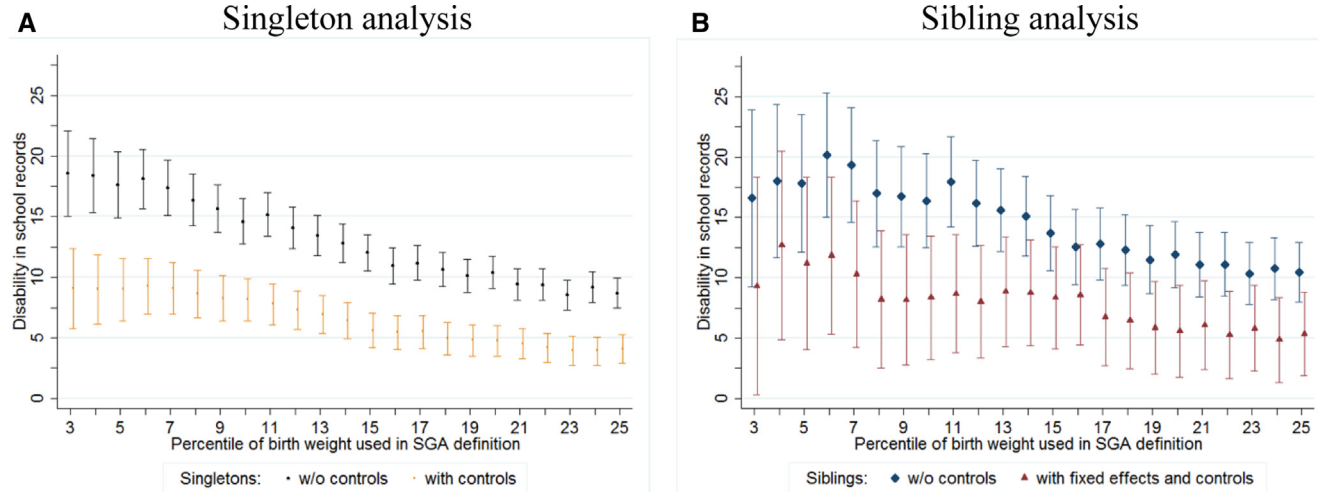

Figure 2. Association between SGA and disability in school records. Estimates for "healthier" pregnancies. Sample is based on singleton births from 1994 to 2002 birth cohorts and restricted to "healthier pregnancies" defined as one without maternal health problems, child congenital anomalies or abnormal conditions at birth, older mothers (age at birth of 36 years or above), or those who do not speak Spanish or English; it further includes only pregnancies where prenatal care started in the first trimester. Multivariable linear regressions in both panels. Robust SEs used to calculate 95% CIs. SEs are **A,** heteroscedasticity robust and **B,** clustered at family level. Each scatterplot series presents estimates from 23 separate regressions where the independent variable of interests is an indicator for SGA defined at a given percentile of birth weight (3rd-25th). Outcome is an indicator variable for having disability based on school records. Plots present effect sizes that mean that each point estimate is scaled by the mean of the dependent variable, and multiplied by 100 to provide percent effect size. **A,** all singleton births; **B,** restricts the sample to siblings born between 1994 and 2002 to the same mother. We required at least 2 births to the mother between 1994 and 2002 to be included in the sample used in panel **B**. Black squares (**A**) and navy diamonds (**B**) present unadjusted relationship between an indicator for SGA birth and disability. Orange circles (**A**) and maroon triangles (**B**) present adjusted relationship where the conditioning variables include gestational age, sex, race, nativity, ethnicity, marriage, month of birth, year of birth, maternal education (high school dropout, high school graduate, college graduate), maternal age (19 or below, 20-29, 30-35, 36 years and above), number of previous births, age at the time of testing in third grade, congenital anomalies, abnormal conditions at birth, maternal medical problems, prenatal care started in first trimester, language spoken at home (non-English and non-Spanish), zip code of residence (2079 variables), and birth paid by Medicaid indicators. Adjusted analysis in panel **B** further includes sibling fixed effects.

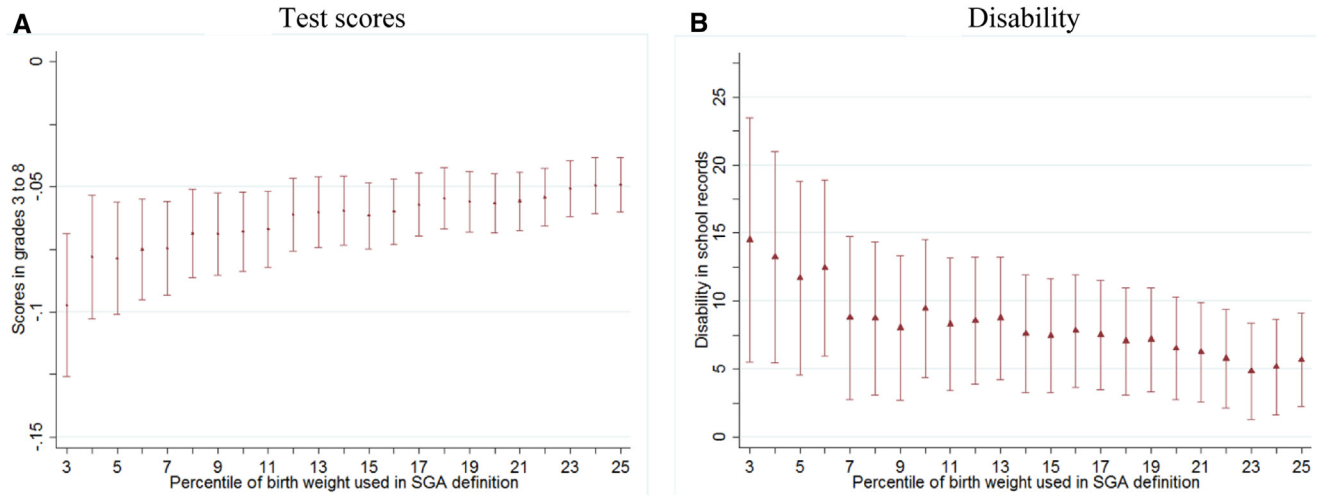

Figure 3. Association between SGA and outcomes when mother and father are the same. Sample is based on singleton births from 1994 to 2002 birth cohorts. Multivariable linear regressions in both panels restricted to sample of siblings born between 1994 and 2002 to the same mother and father. We required at least 2 births to the mother between 1994 and 2002 to be included in the sample, and we further required paternal information to be present on birth certificate and for the father to be the same across multiple births observed to the same mother. Outcomes are **A,** test scores and **B,** disability as indicated by school records. Robust standard errors used to calculate 95% CIs. SEs are clustered at family level in both panels. Each scatterplot series presents estimates from 23 separate regressions where the independent variable of interest is an indicator for SGA defined at a given percentile of birth weight (3rd-25th). All analyses are adjusted by covariates and include sibling fixed effects. These covariates include gestational age, sex, marriage, month of birth, year of birth, maternal education (high school dropout, high school graduate, college graduate), maternal age (19 or below, 20-29, 30-35, 36 years and above), age at the time of testing in third grade, congenital anomalies, abnormal conditions at birth, maternal medical problems, prenatal care started in first trimester, zip code of residence (2079 variables), and birth paid by Medicaid indicators.

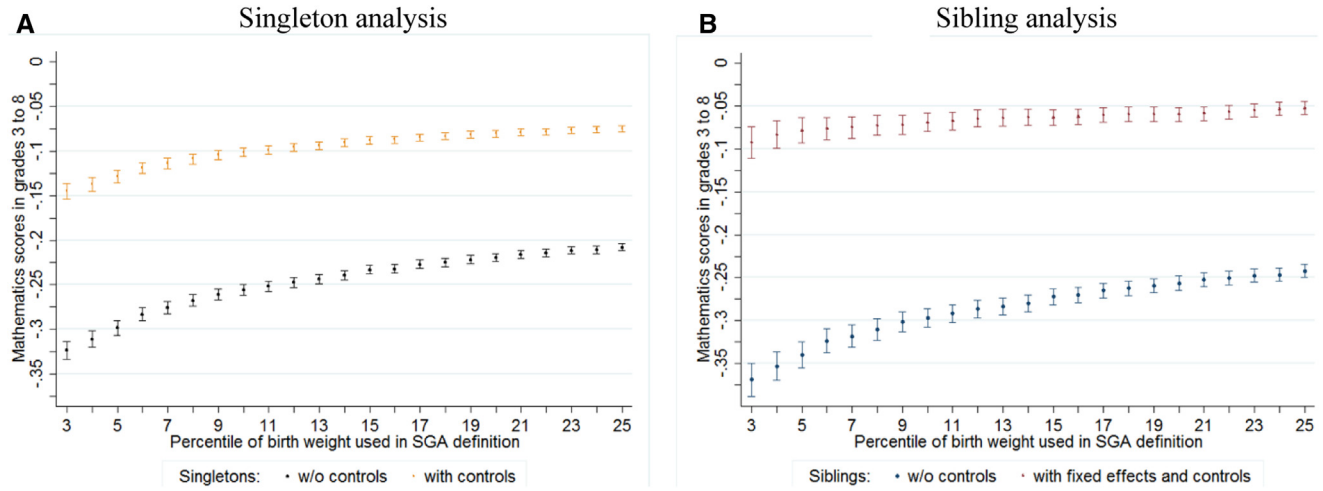

Figure 4. Association between SGA and mathematics FCAT test scores. Sample is based on singleton births from 1994 to 2002 birth cohorts. Multivariable linear regressions in both panels. Robust SEs used to calculate 95% CIs. SEs are clustered at **A,** individual level and at **B,** family level. Each scatterplot series presents estimates from 23 separate regressions where the independent variable of interests is an indicator for SGA defined at a given percentile of birth weight (3rd-25th). Outcome is pooled grades 3-8 test scores in mathematics. **A,** uses all singleton births; **B,** restricts the sample to siblings born between 1994 and 2002 to the same mother. We required at least 2 births to the mother between 1994 and 2002 to be included in the sample used in panel **B**. Black squares (**A**) and navy diamonds (**B**) present unadjusted relationship between an indicator for SGA birth and test scores. Orange circles (**A**) and maroon triangles (**B**) present adjusted relationship where the conditioning variables include gestational age, sex, race, nativity, ethnicity, marriage, month of birth, year of birth, maternal education (high school dropout, high school graduate, college graduate), maternal age (19 or below, 20-29, 30-35, 36 years and above), number of previous births, age at the time of testing in third grade, congenital anomalies, abnormal conditions at birth, maternal medical problems, prenatal care started in first trimester, language spoken at home (non-English and non-Spanish), zip code of residence (2079 variables), and birth paid by Medicaid indicators. Adjusted analysis in panel **B** further includes sibling fixed effects.

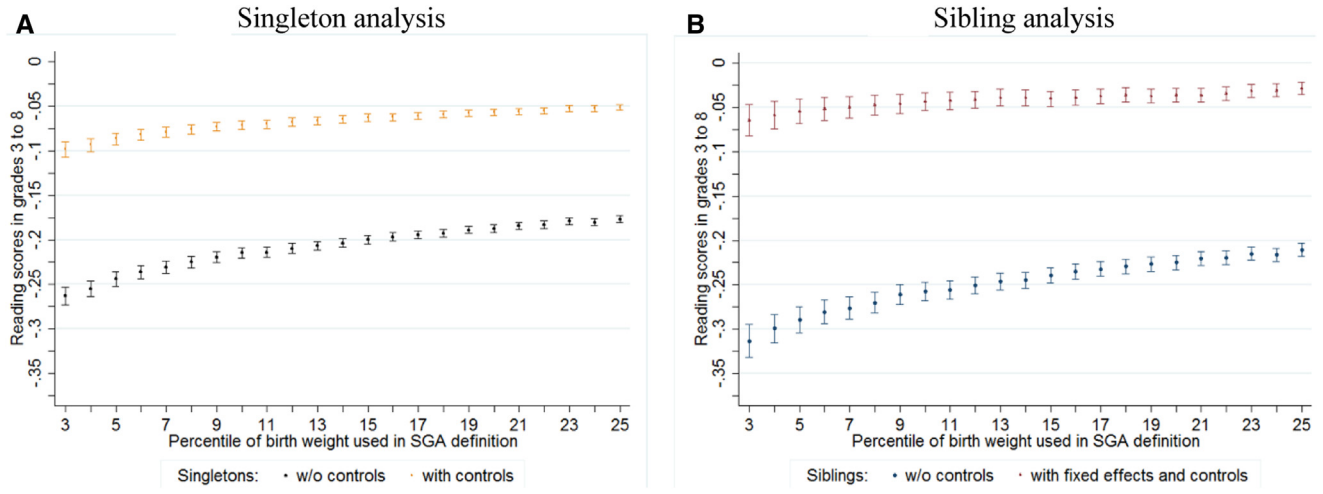

Figure 5. Association between SGA and reading FCAT test scores. Sample is based on singleton births from 1994 to 2002 birth cohorts. Multivariable linear regressions in both panels. Robust SEs used to calculate 95% CIs. SEs are clustered at **A,** individual level and at **B,** family level. Each scatterplot series presents estimates from 23 separate regressions where the independent variable of interests is an indicator for SGA defined at a given percentile of birth weight (3rd-25th). Outcome is pooled grades 3-8 test scores in reading. **A,** uses all singleton births; **B,** restricts the sample to siblings born between 1994 and 2002 to the same mother. We required at least 2 births to the mother between 1994 and 2002 to be included in the sample used in panel **B**. Black squares (**A**) and navy diamonds (**B**) present unadjusted relationship between an indicator for SGA birth and test scores. Orange circles (**A**) and maroon triangles (**B**) present adjusted relationship where the conditioning variables include gestational age, sex, race, nativity, ethnicity, marriage, month of birth, year of birth, maternal education (high school dropout, high school graduate, college graduate), maternal age (19 or below, 20-29, 30-35, 36 years and above), number of previous births, age at the time of testing in third grade, congenital anomalies, abnormal conditions at birth, maternal medical problems, prenatal care started in first trimester, language spoken at home (non-English and non-Spanish), zip code of residence (2079 variables), and birth paid by Medicaid indicators. Adjusted analysis in panel **B** further includes sibling fixed effects.

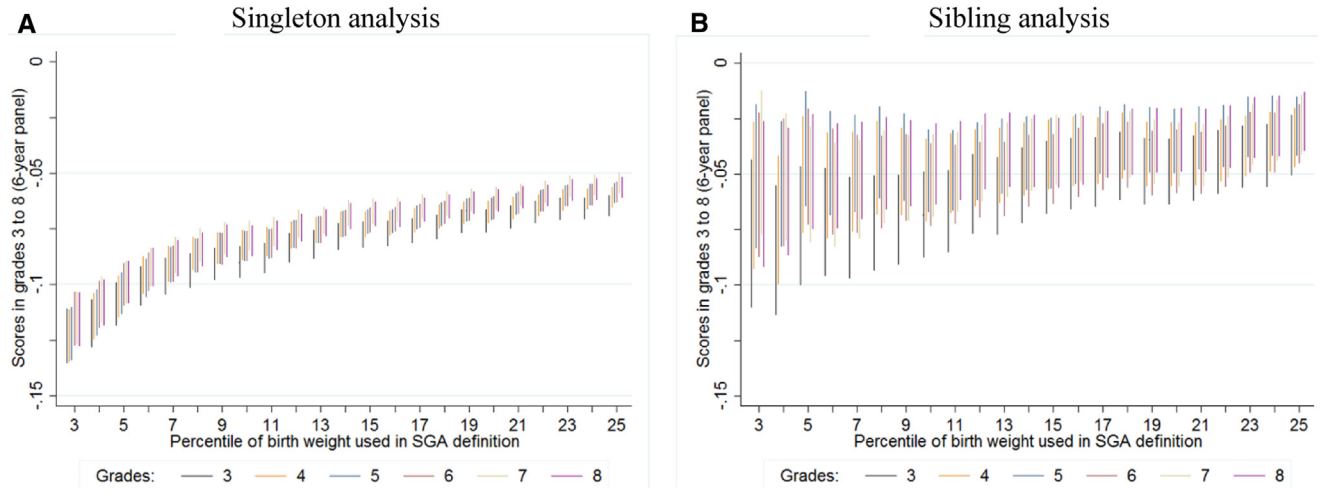

Figure 6. Association between SGA and FCAT test scores over grades in 6-year panel. Sample is based on singleton births from 1994 to 1999 birth cohorts who are observed in school records in grades 3-8 (6 panel observations). Multivariable linear regressions in both panels. Robust SEs used to calculate 95% CIs. SEs are clustered at **A,** individual level in and at **B,** family level. Each spike series presents estimates from 23 separate regressions where the independent variable of interests is an indicator for SGA defined at a given percentile of birth weight (3rd-25th). Outcomes are test scores in grades 3-8 that are averaged across reading and mathematics for each individual in each grade. **A,** uses all singleton births; **B,** restricts the sample to siblings born between 1994 and 1999 to the same mother. We required at least 2 births to the mother between 1994 and 1999 to be included in the sample used in panel **B**. All regressions are adjusted by covariates. Conditioning variables include gestational age, sex, race, nativity, ethnicity, marriage, month of birth, year of birth, maternal education (high school dropout, high school graduate, college graduate), maternal age (19 or below, 20-29, 30-35, 36 years and above), number of previous births, age at the time of testing in third grade, congenital anomalies, abnormal conditions at birth, maternal medical problems, prenatal care started in first trimester, language spoken at home (non-English and non-Spanish), zip code of residence (2079 variables), and birth paid by Medicaid indicators. Adjusted analysis in panel **B** further includes sibling fixed effects. Following colors of spikes denote grades: grade 3 (*black*), grade 4 (*orange*), grade 5 (*navy*), grade 6 (*maroon*), grade 7 (*khaki*), and grade 8 (*purple*).

Table II. Descriptive statistics: siblings sample

	(1)	(2)	(3)	(4)	(5)	(6)
	All siblings			Siblings with 3rd grade scores		
	All	10th percentile SGA		All	10th percentile SGA	
Characteristics		No	Yes		No	Yes
African American	133 876 (28.7)	115 071 (27.2)	18 805 (43.4)	110 014 (29.5)	94 663 (28.0)	15 351 (44.4)
Hispanic	101 281 (21.7)	92 596 (21.9)	8685 (20.0)	82 678 (22.2)	75 678 (22.3)	7000 (20.3)
Immigrant	88 382 (18.9)	80 540 (19.0)	7842 (18.1)	72 140 (19.3)	65 772 (19.4)	6368 (18.4)
Mother high school dropout	102 846 (22.0)	89 485 (21.1)	13 361 (30.8)	84 216 (22.6)	73 360 (21.7)	10 856 (31.4)
Mother high school graduate	275 588 (59.0)	251 033 (59.3)	24 555 (56.7)	221 166 (59.3)	201 574 (59.5)	19 592 (56.7)
Mother college graduate	88 452 (18.9)	83 036 (19.6)	5416 (12.5)	67 831 (18.2)	63 720 (18.8)	4111 (11.9)
Married	293 895 (62.9)	272,956 (64.4)	20 939 (48.3)	231 323 (62.0)	214 987 (63.5)	16 336 (47.3)
Age at birth, y	26.3 (5.9)	26.4 (5.8)	24.9 (5.9)	26.2 (5.9)	26.4 (5.8)	24.8 (5.9)
Number previous births	1.2 (1.2)	1.2 (1.2)	1.1 (1.3)	1.2 (1.2)	1.2 (1.2)	1.1 (1.3)
Female	228 827 (49.0)	207 139 (48.9)	21 688 (50.1)	184 462 (49.4)	167 043 (49.3)	17 419 (50.4)
N	466 886	423 554	43 332	373 213	338 654	34 559

Columns (1) to (3) present sample of singleton births that we can link as having the same mother (siblings) while columns (4) to (6) present subset of this population where individuals are observed with third grade test scores. Columns (2) and (5) present statistics for children who are not deemed as SGA while columns (3) and (6) present statistics for children who are deemed as SGA based on the 10th percentile definition. Counts or averages (% of sample values or SDs).