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Are the adverse academic outcomes seen in preterm children attenuated from first to third grade? An investigation using a Georgia-born cohort

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2013

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Abstract

Introduction

Children born preterm are more susceptible to impaired cognitive function, potentially leading to impediment in school readiness, which can have a lasting impact on health and opportunity trajectory, and studies investigating whether or not children eventually "catch-up" are inconsistent and minimal. The objective of this study is to investigate whether the association of being born preterm with risk for adverse cognitive function is attenuated in third grade as compared to first grade.

Methods

The Georgia Birth to School Cohort, a retrospective cohort, consisting of singleton live births to Georgia resident mothers, deterministically linked these birth records, including the exposure of gestational age in weeks, to their respective Criterion-Referenced Competency Test (CRCT) data for first and third grade. CRCT linkage was considered as follow-up points, and the final dataset for analysis included 176,674 observations. Association between the outcome – change in first to third grade CRCT—and exposure were assessed using multinomial regression. A supplementary analysis using logistic regression was also performed, using third grade failure as the outcome of interest.

Results

Across all three outcome contrasts relative to pass-pass, extremely preterm births (compared to term births) had the strongest exposure-outcome relationships. Notably, the odds of failing, then passing the CRCT (i.e. catch-up) relative to passing in both first and third grades among extremely preterm births compared to term births across all components was: math [OR=1.9, 95% CI (1.3, 2.9)], ELA [OR= 2.0, 95% CI (1.5, 2.6)], and reading [OR= 2.2, 95% CI (1.7, 3.0)]. Extremely preterm births, relative to term births, had the highest odds of failing each third grade CRCT component – math [OR=2.1 95% CI (1.7, 2.6)], ELA [OR=1.9, 95% CI (1.4, 2.5)], and reading [OR=1.7, 95% CI (1.4, 2.2)]. First grade failure was also the strongest predictor of third grade failure for each component.

Conclusion

It is unknown if, or when, cognitive catch-up following preterm birth occurs. Generally speaking, there was an inverse dose-response relationship by the association of preterm status on CRCT outcome change and third grade outcome only.

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Literature Review

Introduction

Using a life course perspective, pregnancy is a sensitive period for a developing fetus, as exposures a mother may face have the potential to result in unalterable changes later in her child's life. For instance, literature suggests children born preterm are more susceptible to impaired motor, behavior and academic performance when compared to their term counterparts, and environmental factors may increase the intensity of these outcomes (1). This could lead to impediment in school readiness, which can have a lasting impact on health and opportunity trajectory. Furthermore, disparities in preterm birth rates persist. For example, African Americans have disproportionately higher rates of preterm birth compared to whites. And by age five, children born preterm show significantly lower academic achievement compared to their full-term peers, suggesting a need for interventions and educational supports for these children (2). Among children born preterm, gestational age has been shown to be predictive of academic ability in children, where a shorter gestational age is associated with poorer performance across all subjects (3). Poor achievement in school has been linked to a range of adverse health outcomes in adulthood, further supporting the importance of potential long-term effects due to early childhood academic deficits (4, 5).

Though the literature illustrating cognitive deficits in children born preterm are vast, evidence suggesting whether these children eventually catch up to their term counterparts is inconclusive (1). Failure to recognize these setbacks by the time a child enters schooling is common, and can potentially delay any intervention intended to alleviate negative outcomes that may be associated with preterm birth (6). As such, this

research will attempt to estimate the degree to which early elementary schooling can buffer the adverse cognitive effects of early life preterm birth, using outcomes from standardized tests in first and third grade. To date, studies measuring first grade outcomes tell us a deficit is apparent. What sets this analysis apart is the inclusion of third grade outcomes, which may determine whether adverse first grade outcomes are attenuated through third grade with traditional schooling.

Preterm Birth

Preterm birth is defined as birth occurring between 20 and 37 weeks gestation. This can be further parsed into late preterm (between 34 and 36 weeks gestation), moderately preterm (between 28 and 33 weeks gestation) and extremely preterm (between 20 and 27 weeks gestation). Term births occur between 37 and 40 weeks gestation, and post-term births occur at 41 weeks gestation or more. Babies born preterm face a higher risk of death during infancy when compared to their term birth counterparts, as preterm birth is one of the greatest contributors to infant death (7). In 2013, about 36% of infant deaths were attributed to preterm-related birth and 67% of infant deaths occurred to infants born preterm (8). Though advancements in medical technology, perinatal care and neonatal care have yielded improved survival rates in preterm infants, these surviving infants have a higher risk of facing adverse, long-term health outcomes when compared to their term counterparts, including: intellectual disabilities, cerebral palsy, breathing and respiratory problems, visual problems, hearing loss, language and learning problems, attention deficit hyperactivity disorder, and behavioral and socio-emotional difficulties (7, 9).

Preterm Birth Rates

Preliminary births data from 2014 indicate that preterm birth affects about 9.6% of infants born in the United States, a less than one percent decline from 2013 and down from 10.4% in 2007. Most preterm babies have a gestation period of 34 to 36 weeks – 6.8% of all births (10). For the 2014 rates, gestation was measured using the obstetric estimate of gestation at delivery, defined as "the best estimate of the infant's gestation in completed weeks based on the birth attendant's final estimate of gestation." According to the CDC, the estimate of gestation should be determined by ultrasound, preferably taken in early pregnancy. Introduced in 2003 by the National Centers for Health Statistics (NCHS), this measure is undergoing a transition into becoming the new standard for estimating the gestational age of a newborn, to eventually replace the current standard, which is based on the mother's last normal menses (11). Between 1981 and 2006, however, the preterm birth rate in the U.S. rose from about 9% of births to about 13% yielding an overall 36% increase, using an older measure of gestation (8, 12). Since the peak in 2006 to today, both measures of gestational age have shown a steady drop in preterm birth rates (11).

Social and Demographic Patterns in Preterm Birth

Race/Ethnicity

After stratifying U.S. preterm birth rates by race, a large disparity emerges. In 2014, the preterm birth rate was 8.9% for non-Hispanic white mothers, 13.2% for non-Hispanic black mothers, 9.0% for Hispanic mothers, 8.5% for Asian mothers, and 10.2% for American Indian/Alaska Native mothers. Despite an overall decline in preterm births

since 2006, this decline is slower among African American mothers, who have the highest preterm birth rate in the U.S. and are roughly 50% more likely to deliver a preterm baby compared to non-Hispanic white mothers and Hispanic mothers (10). Though this evidence may be reasonable for one to assume preterm birth risk has racial-ethnic undertones, evidence shows risk factors are largely related to social constructs.

Collins et al. discussed studies that have shown birth outcomes from mothers who are African immigrants are comparable to white, American women. The phenomenon at play here is that female children of African immigrants, once they age and give birth, have birth outcomes comparable to the U.S. African American population, questioning the notion of genetic predisposition (13). Furthermore, in many immigrant groups, the pattern seems to be with greater time spent in the U.S. comes a higher preterm birth rate (14).

Higher income and greater education are largely known for having protective effects against adverse health outcomes, but data shows larger disparities in preterm birth rates exist among college educated black mothers, compared to white mothers. In fact, the preterm birth rate among college educated black mothers is higher than the rate for white mothers without a high school education – 12.8% vs. 11.0% using NCHS data for U.S. birth cohorts from 1998 to 2000 (15). In a study exploring the association between race and preterm birth among women who have a lifelong residence in high-income Chicago neighborhoods, black mothers still had higher rates of preterm birth compared to white mothers (13).

Similarly, because cigarette smoking and drug use are associated with adverse pregnancy outcomes, including preterm birth, some explanations point to these as

maternal risk factors attributed to the racial disparity (15). However, a smaller proportion of African American women report smoking during pregnancy when compared to non-Hispanic white women and there appears to be no significant difference in the proportion of drug users during pregnancy in both groups (16, 17).

The effects of self-reported racial discrimination experiences are theorized to be a factor in the black-white preterm birth disparity. Stress, and psychological responses to stress, caused by external factors have been linked to biologic responses, which can have dire effects on one's health and well-being (18). Several studies show relationships between racism as a psychosocial stressor and gestational age at delivery, where shorter gestation is related to increased experiences of racism (9, 19). A popular theoretical framework in social epidemiology is the life course perspective, which, in this case, conceptualizes the outcome of preterm birth as the end product of not only pregnancy, but also the entire life course of the mother pre-pregnancy. Disparities in birth outcomes are, according to this approach, consequences of differential exposures before and during pregnancy (20). According to Lu et al, the cumulative pathways model collects stress throughout life; this "wear and tear", or allostatic load, can lead to a decline in health over time. This suggests African American women, as compared to non-Hispanic white women, may have higher rates of preterm birth due to increased stressful exposures in childhood and adulthood up to and including pregnancy that build on each other. This can translate into increased weathering, the concept of faster age-related deterioration of health, resulting in a larger allostatic load present before pregnancy occurs (20).

Maternal Age

Numerous studies have shown associations between young maternal age, less than 16 years in particular, and an increased risk for adverse pregnancy outcomes, including preterm birth (21). However, it should be noted that young maternal age may be a marker for one or more risk factors associated with preterm birth, such as poverty, minority status, deleterious social environment, or biological immaturity (22). Gynecologic age, calculated by subtracting age at menarche from age at conception has also been shown to be associated with adverse perinatal outcomes (23). One study, after adjusting for chronological age, found that among primigravidas between ages 12 to 29, a one-year increase in gynecologic age was associated with a 28% decline in preterm birth (24).

Numerous studies have also shown associations between delayed childbearing and preterm birth, but many studies also reveal null findings. In a meta-analysis by Newburn-Cook and Onyskiw, they found that there is, indeed, a maternal age effect on preterm birth, but it is unclear whether older maternal age acts as an independent variable or if it acts through age-dependent confounders, such as increased prevalence of pre-existing chronic conditions, leading to preterm birth. The meta-analysis also revealed inconsistencies in defining at what age "delayed childbearing" refers to; studies have referred to this age as mothers in their late 20s, over 30, over 35, and over 40 (25).

Researchers have yet to discover reasons attributed to the increased risk of preterm birth among younger and older mothers. Pooled data from the National Center for Health Statistics, using 1998 to 2000 birth cohorts revealed a similar U-shaped pattern of preterm birth risk by maternal age. This pattern is seen within racial/ethnic groups, but a closer look at the data show these risks-by-age are not consistent between black and

white mothers, as the risk increases for black mothers at a younger age (27 to 29 years) compared to white mothers (33 to 35 years) (15).

Maternal Education

Several studies illustrate education level as a significant protective factor against preterm birth. The trend appears to be that as a mother's years of education increase, rates of preterm birth decrease for all races, yet the rate of preterm birth for black mothers decreases at a slower rate compared to white mothers (15). The elevated risk of preterm birth among lower educated women may be attributable to the relationship between low education and pregnancy risk factors such as poor psychosocial well-being and poor lifestyle habits – e.g. increased incidences of smoking, drug usage and alcohol consumption (26). However, a second study by El-Sayed et al. found a decreased protective effect of maternal education on preterm birth. Using the aforementioned Michigan cohort, the odds of preterm birth among women with less than 12 years of education (and no GED) was 73% greater than the odds of preterm birth among women with a college degree or greater, after adjusting for race, age, and parity. By 2006, the relative gap decreased to 31% (27).

Marital Status and Cohabitation

Pregnancy outside of marriage has been associated with an increased risk of preterm birth, possibly acting as a moderator for increased access to prenatal care, financial security, and social support (28). The protective effects of marriage, however, are not consistent when stratifying on race/ethnicity, as African American women experience the least protection (15, 28). This gap between married and unmarried women, however, appears to be narrowing. In a study using records from nearly 2.4

million births between 1989 and 2006 in the state of Michigan, El-Sayed et al. found that marriage was less protective against preterm birth, even after adjusting for race/ethnicity, previous live birth(s), age, and education, and appear to be consistent with the increasing trend in cohabitation among unmarried couples (29). Cohabitation may bring lower levels of emotional stress, increased social support and increased financial support when compared to non-cohabiting, single mothers (29, 30).

Occupational and Behavioral Stress

An increasing number of women continue to work their jobs relatively late into their pregnancy (31). In a systematic review examining studies that have explored associations between preterm delivery and indicators of occupational stress – including: working long hours, having inconvenient work schedules, standing for prolonged periods, lifting heavy loads or psychosocial work-related stress – results were inconsistent; prospective study designs yielded more significant associations when compared to retrospective and case-control (32). Occupational stress may also be related to low SES, assuming having an occupation that allows for time off during pregnancy is not a typical characteristic of this group.

Other Socio-Demographic Patterns

Other factors associated with preterm birth include male infant gender, a previous preterm delivery, multiple gestation, low maternal BMI, and delayed or inadequate use of prenatal care (14, 33-35). Regarding the latter, African American women tend to have higher incidences of delayed, inadequate, or lack of prenatal care when compared to white women. However, there is little evidence to show the effectiveness of prenatal care for preventing preterm birth, despite the increased use of adequate prenatal care among

African American women over the past decade (15, 36). This may suggest access to prenatal care may be a proxy for health-seeking behaviors, or other factors including SES, drug usage, and parity, resulting in a confounding relationship (37).

Geographic Patterns

The preterm birth rate varies by geographic region of the U.S. Data from 2003 showed the highest rates were in the southern states, decreasing as one moves toward the west and the north, generally speaking. New England and the west coast states had the lowest preterm birth rates, followed by the Midwest states (9). The March of Dimes ranks Georgia 27th out of 50 by percentage of births that are preterm, and the city of Atlanta carries a higher percentage than the state – 11.5% vs. 10.7% in 2013 – according to their 2015 report card (38). Additionally, compared to other developed countries, the preterm birth rate in the U.S. is among the higher rates, but this may be due to differences in gestational age measurement and varying cutoffs for preterm birth. As such, international comparisons should be made with caution (9).

Education and Health

There is a large body of literature linking education with health. Notably, in a study examining educational differentials in adult mortality in the United States using the National Longitudinal Mortality Study, a large follow up study conducted between March 1979 and March 1981 linking death records from 1979 to 1985, researchers found that the death rate among 24 to 64 year olds and 65 to 89 year olds diminished as years of education increased. Furthermore, they suggested a 7.7% and 7.3% reduction of mortality per one-year increase in education for males and females, respectively, aged 35 to 54 (4).

A positive association exists between education and health, as more years of education have been associated with lower rates of morbidity in the most common acute and chronic diseases, including: heart conditions, stroke and hypertension, high cholesterol, obesity, and diabetes (39). Cutler and Lleras-Muney also note this education gradient is found for not only health status, but also health behaviors, suggesting that increasing levels of education yield different thinking and decision-making patterns, thus interventions impacting educational attainment could have a meaningful effect on population health.

Early childhood exposures can shape cognitive and brain function during this critical development period, potentially making individuals susceptible or resistant to health outcomes during adulthood. Researchers suggest children who enter pre-schooling between ages two and three have the greatest academic benefit (40). Carneiro et al. found that attendance in the Head Start program, a federal U.S. pre-schooling program for children ages 3 to 5 years, yields significant impacts on health and criminal behavior in adolescents and young adults. Head Start participants, when compared to non-participants, were shown to be less likely to be obese at 12 to 13 years of age, less likely show depression symptoms at 16 to 17 years of age, and less likely to be convicted of a crime leading to serving time at a correctional facility at 20 to 21 years of age (41).

Achievement Gaps in Education

Segregation in the U.S. until 1954 and de facto segregation that occurs today account for differences in quantity and quality of schooling between races by place of residence, at both a local and regional levels, and parental SES (42). Using a reproductionist perspective, schooling may better serve those at the top of the social

ladder, maintaining class-based division of labor and perpetuating inequalities in the larger social order (43). Schools serving low SES students may stress qualities to prepare them for low-wage jobs – e.g. memorization, punctuality, obedience (44). Downey et al. also noted explanations for the achievement gap between low and high SES children have been attributed to disparate non-school environments, yet the black-white achievement gap in children is less clear.

Preterm Birth on Childhood Education

Several studies have documented significant differences in cognitive development using preterm birth as a primary exposure (2, 3, 45-51). Children born preterm are more likely to perform poorer on cognitive and academic assessments in all subjects, experience poorer academic performance in school, require more educational assistance and individual attention in the classroom, and have an increased incidence of attention deficit hyperactivity disorder (ADHD) when compared to children born at term (3, 50, 51). Often, the intelligence quotient (IQ) is used in studies as a measure of cognitive ability. Behrman et al. note children born preterm with normal IQ scores tend to have increased difficulty with sustained attention, executive function, spatial skills, and fine and gross motor function when compared to term, normal birthweight controls. However, in using the IQ when assessing cognitive ability in individuals born preterm, this may not capture the full range of cognitive deficits seen in a population; children born preterm may have a scatter in their cognitive abilities, excelling in some areas and performing poorly in others, which contribute to difficulties in school and at home (47, 50).

Cognitive Ability during Early Childhood

Differential cognitive, educational, and behavioral outcomes between preterm and term children have been witnessed at as young as age two, and persist through kindergarten and early childhood (2, 6, 51, 52). Neonatal risk factors, neurodevelopment impairment at 20 months, and SES have been associated with learning problems within early preterm children[6]. And among preterm children, gestational age has been shown to be proportional to their mean cognitive scores – e.g. moderately preterm children tend to outperform very preterm children (51).

Reading, an element of cognition, can be divided in to two components: comprehension and single-word reading (or decoding). Literature yields inconsistencies in examining reading performance in preterm children. One meta-analysis attributes these inconsistencies to differences in environmental factors, such as SES, and that many of these studies do not differentiate between reading comprehension and decoding, which are independent components (49). Kovatchy et al. concluded that children born preterm are more likely to have worse performance in reading comprehension and decoding, and that gestational age is proportional to performance in both components of reading.

Children born preterm may also display nonverbal learning disabilities over time, translating into deficits in visuomotor integrative abilities, visual perception, mathematics, spatial skills, fine motor speed, verbal abstracting, reading comprehension, written output, and social skills Furthermore, among children of very low birthweight, evidence suggests a smaller proportion from high SES backgrounds in special education classrooms than children of low SES backgrounds, suggesting effect modification due to environmental factors. This may also be true for the exposure of preterm birth (53).

Cognitive Ability beyond Early Childhood

Though there are ample studies examining cognitive ability in preterm children at school age, many focus on deficits in cognition during kindergarten and between the ages of five and eight; few explore whether these differences are attenuated over time, throughout adolescence and/or in adulthood. As such, longitudinal studies assessing the impact of preterm birth on academic outcomes in early childhood through adolescence, especially in the U.S., are minimal and inconsistent.

One longitudinal study conducted in Sweden sought to examine individual cognitive patterns and developmental trajectories in children born preterm from age five to 18 years, as one of the few studies investigating cognitive development of preterm children from early childhood through adolescence. They found that cognitive ability at age five was predictive of cognitive ability at age 18 – those who performed below average at age five continued to perform below average at age 18, those who performed average at age five continued to perform average or better at age 18, and those who performed above average at age five continued to perform above average (48).

In contrast, some studies conclude most preterm children adjust well, regarding cognitive function, by adulthood (46). In a study comparing cognitive, achievement, socio-emotional, and behavioral outcomes between healthy late-preterm infants and full-term counterparts from age four through 15 years, researchers concluded no consistent significant differences between the groups. It should be noted, however, that they followed 1,298 children, including 53 late preterm cases, indicating a potential selection bias (54).

The "Catch-up" Period

Katz et al. conclude "catch-up" on tasks that require sustained attention may occur between ages six to eight years (55, 56). However, Mulder et al. note that it is unknown whether the underperformance of children born preterm is due to one or more of the following three hypotheses: an early delay in cognitive function followed by a catch-up period, increasing delay over time, or a continued delay with age[(56)]. Furthermore, if a catch-up period does occur in preterm children, it may differ by age and at different rates perhaps due to varying environmental factors, including SES (56, 57).

Research Aims

There are many gaps in the literature on preterm birth and its subsequent effects on a child's cognitive ability. Typically, documentation of academic difficulties in children, regardless of preterm or term status, are based on teacher observations or cognitive assessments at early school age, and research in this area rarely seeks to find predictors leading to poor cognitive ability (6). Numerous studies looking at outcomes related to preterm birth use birthweight as one of the criteria for study participant selection, rather than gestational age at delivery; the conventional low birthweight cutoff of 2,500 grams may capture not only preterm infants, but also small for gestational age term infants (50). Children born preterm are often followed for short periods of time, limiting the assessment of any attenuation of adverse cognitive outcomes (1). Longitudinal studies aiming to determine if there is a catch-up period are inconsistent. And finally, environmental risk factors must be considered, as preterm birth and academic performance have been shown to be related to SES.

Given these gaps, this research will investigate whether the association between being born preterm and adverse educational outcomes is attenuated in third grade as compared to first grade based on the change in a child's Criterion-Referenced Competency Tests (CRCT) score from first to third grade. Previous research has shown an association between preterm birth, low maternal education and an increased risk of first grade CRCT failure (58). Additionally, this research will investigate the effect of first grade CRCT outcomes on third grade outcomes CRCT. This research could potentially determine whether or not schools, specifically public schools in the state of Georgia, may serve as a buffer, attenuating adverse academic outcomes preterm children may face in first grade. This research also tests the hypothesis Katz et al. propose on the catch-up period preterm children may encounter between six to eight years, as first through third grade falls within this age range. As of 2015, 60.1% of Georgia public school students qualify for free/reduced lunch, often used as a marker for poverty (59). As such, this research has implications for future development of interventions focused on low resource populations.

Results from this research has the potential to impact the effectiveness of future school interventions through mechanisms to target and identify children born preterm. It could also have impacts in identifying poor cognition prior to entry into the first year of school, and developing interventions in order to help facilitate catch-up among this population. Most studies comparing cognitive abilities of individuals born preterm to those born term use small sample sizes, focus on early or middle childhood, and rarely follow up to assess possible changes. Though substantial strides have been made in decreasing the preterm birth rate, there are no definitive ways to prevent it and no

definitive ways to close the gaps in disparities. Infants born preterm lose critical development time in the womb, followed by a decline in neurological development, translating into poor academic achievement, leading to a trajectory of poor health outcomes in adulthood and a perpetuation of this cycle for future generations.

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Abstract

Introduction
Children born preterm are more susceptible to impaired cognitive function, potentially leading to impediment in school readiness, which can have a lasting impact on health and opportunity trajectory, and studies investigating whether or not children eventually "catch-up" are inconsistent and minimal. The objective of this study is to investigate whether the association of being born preterm with risk for adverse cognitive function is attenuated in third grade as compared to first grade.

Methods
The Georgia Birth to School Cohort, a retrospective cohort, consisting of singleton live births to Georgia resident mothers, deterministically linked these birth records, including the exposure of gestational age in weeks, to their respective Criterion-Referenced Competency Test (CRCT) data for first and third grade. CRCT linkage was considered as follow-up points, and the final dataset for analysis included 176,674 observations. Association between the outcome – change in first to third grade CRCT—and exposure were assessed using multinomial regression. A supplementary analysis using logistic regression was also performed, using third grade failure as the outcome of interest.

Results
Across all three outcome contrasts relative to pass-pass, extremely preterm births (compared to term births) had the strongest exposure-outcome relationships. Notably, the odds of failing, then passing the CRCT (i.e. catch-up) relative to passing in both first and third grades among extremely preterm births compared to term births across all components was: math [OR=1.9, 95% CI (1.3, 2.9)], ELA [OR= 2.0, 95% CI (1.5, 2.6)], and reading [OR= 2.2, 95% CI (1.7, 3.0)]. Extremely preterm births, relative to term births, had the highest odds of failing each third grade CRCT component – math [OR=2.1 95% CI (1.7, 2.6)], ELA [OR=1.9, 95% CI (1.4, 2.5)], and reading [OR=1.7, 95% CI (1.4, 2.2)]. First grade failure was also the strongest predictor of third grade failure for each component.

Conclusion
It is unknown if, or when, cognitive catch-up following preterm birth occurs. Generally speaking, there was an inverse dose-response relationship by the association of preterm status on CRCT outcome change and third grade outcome only.

Introduction

Pregnancy is a sensitive period for a developing fetus – exposures a mother may face have the potential to result in unalterable changes in her child's life. For instance, literature suggests children born preterm (less than 32 weeks gestation) are more susceptible to impaired motor, behavior and academic performance when compared to their term counterparts, and environmental factors may increase the intensity of these outcomes (1). This could lead to impediment in school readiness, which can have a lasting impact on health and opportunity trajectory.

Poor achievement in school has been linked to a range of adverse health outcomes in adulthood, further supporting the importance of potential long-term effects due to early childhood academic deficits (4, 5). Several studies have documented significant differences in cognitive development using preterm birth as a primary exposure (2, 3, 45-51). Children born preterm are more likely to perform poorer on cognitive and academic assessments in all subjects, experience poorer academic performance in school, require more educational assistance and individual attention in the classroom, and have an increased incidence of attention deficit hyperactivity disorder (ADHD) when compared to children born at term (3, 50, 51). Failure to recognize these setbacks by the time a child enters schooling is common, and can potentially delay any intervention intended to alleviate negative outcomes that may be associated with preterm birth (6).

Though the extant literature illustrating cognitive deficits in children born preterm are vast, evidence suggesting whether these children eventually catch-up to their term counterparts is inconclusive (1, 56). For instance, Katz et al. conclude "catch-up" on tasks that require sustained attention may occur between ages six to eight years (55, 56).

However, Mulder et al. note that it is unknown whether the underperformance of children born preterm is due to one or more of the following three hypotheses: an early delay in cognitive function followed by a catch-up period, increasing delay over time, or a continued delay with age (56). As such, the objective of this study is to investigate whether the association of being born preterm with risk for adverse cognitive function is attenuated in third grade as compared to first grade, in an attempt to test the Katz et al. hypothesis. To date, studies measuring first grade outcomes tell us a deficit is apparent; what sets this analysis apart is the inclusion of third grade outcomes. Results from this research also has the potential to impact the effectiveness of future pre-school and in-school interventions through mechanisms to target and identify children born preterm.

Methods

Data

The Georgia Birth to School Cohort is a retrospective cohort, consisting of singleton live births to Georgia resident mothers, deterministically linking these births to their respective Criterion-Referenced Competency Test (CRCT) data provided by the Georgia Professional Standards Association. The CRCT, implemented in 2000, was a Georgia State Department of Education standardized exam designed to measure students' competency in state standards in reading, English/language arts, mathematics, science and social studies. Every year, students in grades one through eight were required to take the exam in reading, English/language arts, and mathematics. Students in grades three through eight were also assessed science and social studies. Students in grades 3, 5 and 8 were required to pass the CRCT before promotion to the next grade. This exam was

retired after the 2013-14 academic year. Further information on the CRCT can be found on the Georgia State Department of Education website (60). Birth records, provided through the Office of Health Indicators for Planning of the Georgia Department of Public Health, came from Georgia live births from 1998 to 2002, and test data came from first and third grade attendees of Georgia public schools from 2004 to 2009. For this analysis, data was restricted to include children who have both first and third grade CRCT scores reported. After exclusions, the final sample consisted of 176,674 observations.

Exposure

Preterm birth by gestational age in weeks was estimated using the mother's last menstrual period, reported on birth certificate data. Preterm birth was categorized to five levels, using clinically-based cut-points by the American College of Obstetricians and Gynecologists – extremely preterm (between 20 and 27 weeks gestation inclusive), moderate preterm (between 28 and 33 weeks gestation inclusive), late preterm (between 34 and 36 weeks gestation inclusive), term (reference; between 37 and 40 weeks gestation inclusive), and post-term (between 41 and 43 weeks gestation inclusive).

Outcome

The CRCT is a multiple choice exam, where students are scored as "meets standards," "exceeds standards," or "does not meet standards." The outcome measured, serving as a proxy for cognitive development in first and third grade, was the change in a child's dichotomized (pass or fail) CRCT score from first to third grade for the components of Math, English/Language Arts (ELA), and Reading. "Meets standards" and "exceeds standards" were coded as pass, and "does not meet standards" was coded as fail. Each outcome variable had four levels representing the change from first to third grade

CRCT scores: failing both first and third (fail-fail), failing first and passing third (fail-pass), and passing first and failing third (pass-fail). As a proxy for cognitive ability, this measure has the potential to test the hypothesis Katz et. al propose that a catch-up period among preterm children may occur between six to eight years, suggesting traditional public schooling may buffer against adverse cognitive effects preterm birth causes.

Covariates

Covariates were included to control for demographic and social characteristics. Maternal race/ethnicity was categorized as Non-Hispanic white (reference), Non-Hispanic black, Hispanic, and other. Maternal age at birth was treated as an eight-level categorical variable, using the following age groups: 11 to 14 years, 15 to 17 years, 18 to 19 years, 20 to 24 years, 25 to 29 years (reference), 30 to 34 years, 35 to 39 years, and 40 years or older. Marital status of the mother at the time of birth was included, dichotomized as married (reference) or unmarried. Smoking status of the mother at the time of birth was also included, dichotomized as smoking or nonsmoking (reference).

Socioeconomic status at the time of birth was controlled for via maternal education at birth and payor of medical costs associated with birth as proxy measures. Maternal education at birth was categorized into the following four ordinal categories: did not compete high school, completed high school, completed one to three years post-secondary education, and completed four or more years post-secondary education (reference). Payor of medical costs was categorized as Medicaid or unknown (reference).

Child demographic information was also controlled for in the analysis. Child's race/ethnicity was categorized in the same manner as maternal race/ethnicity – Non-Hispanic white (reference), Non-Hispanic black, Hispanic, and other – child's sex

(female - reference), child's categorical year of birth (1998 - reference) and small for gestational age (no - reference), were included. A school-related variable controlled for was years between first and third grade (one to three years; two years - reference), obtained from the school year the CRCT was taken in those two grades. Due to potential non-independence issues, first grade CRCT year and third grade CRCT year were excluded from analysis, which ranged from 2004 to 2008 and 2006 to 2009, respectively.

Data Analysis

Descriptive statistics were generated for outcome variables, exposure variables, and covariates using PROC FREQ in SAS 9.3 (Cary, NC) for observations containing both first and third grade (linked) observations. Using PROC LOGISTIC, bivariate analyses were conducted to determine possible associations between preterm birth as the primary exposure, as well as each predictor variable, on each level of the outcome for each of the three CRCT components. Multinomial logistic regression was chosen as the analysis based on the categorization of the outcome, using pass-pass as the reference. Thus, each model yielded three regression expressions for each CRCT component. Ratios of "odds like" expressions, herein referred to as odds ratios (OR), were obtained, yielding three contrasts – fail-fail vs. pass-pass, fail-pass vs. pass-pass, and pass-fail vs. pass-pass. The general form for the OR can be expressed as:

$$\mathrm{OR}_g = \exp(\alpha_g + \sum_{i=1}^{k} \beta_{gi} X_i)$$

where α_g is an intercept constant, β_{gi} are regression (beta) coefficients, and X_i are the predictor values associated with each coefficient for levels g = 1, 2, 3 – representing each level of the outcome relative to pass-pass for i = 1 to k predictors.

Backwards elimination approach was used as the variable selection method, with a cut-off p-value of 0.05. Additionally, all two-way interactions between exposure and covariates were assessed for each CRCT component, also using backwards elimination approach. A visual inspection of the predicted probabilities for the outcome by candidate interaction covariates, stratified by exposure category, was performed using an EFFECTPLOT statement. As a result, one model for each level of the outcome was obtained to estimate the association between preterm birth and change in CRCT score. This final model adjusts for maternal race/ethnicity, maternal age, marital status, maternal education, payor status, smoking status, child's race/ethnicity, child's sex, child's year of birth, small for gestational age status, and years between first and third grade.

In a secondary analysis, binary logistic regression was performed, also using PROC LOGISTIC. In this case, for each component (math, ELA, and reading), the dependent variable was failure of third grade test; failure of each corresponding first grade CRCT was used as covariate. Correlation between each of the three first grade CRCTs was considered. Backwards elimination approach was used as the variable selection method, with a cut-off p-value of 0.05. One regression expression was generated for each CRCT component. In a no-interaction model, bivariate and multivariate analyses were performed.

Results

There were 176,674 observations assessed in the analysis. The entire birth cohort included 628,115 live births in the state of Georgia from 1998 to 2003. There were 286,136 births excluded because they did not link with first grade data. There were an

additional 10,292 observations excluded due to the following reasons: 458 observations with birth weight less than 500 grams or greater than 5,000 grams, 989 observations with weeks gestation less than 20 or greater than 43, five observations with fetal alcohol syndrome, and 8,840 non-singleton observations. The analysis used births with both first and third grade linked data, excluding 154,940 observations without third grade data. Five observations with implausible years CRCT was taken were excluded, and 47 were excluded if years between first and third grade exceeded three years. Finally, due to sparse data, 21 observations born in 2001 through 2003 were excluded.

Descriptive statistics for linked observations are presented in Table 1. The majority of births were term (75.4%), followed by 14.7% post-term births. Consistent with the literature, approximately 10% of births were preterm – 0.3% extremely, 1.9% moderate, and 7.7% late. Observations with non-Hispanic black mothers had higher proportions of all levels of preterm birth – 0.6% extremely, 2.8% moderate, and 9.3% late. Observations with the youngest mothers, ages 11 to 14, also had higher proportions of preterm birth – 0.7% extremely, 3.5% moderate, and 12.4% late. Observations with mothers without a high school diploma also saw higher proportions of preterm birth – 0.4% extremely, 2.2% moderate, and 8.7% late.

Tables 2, 3, and 4 report crude OR estimates and their associated 95% confidence intervals (CI) from multinomial logistic regression by CRCT component– math (Table 2), ELA (Table 3), and reading (Table 4) – for each of the three contrasts. Taken independently, main effects obtained for preterm birth category, maternal race/ethnicity, maternal age, marital status, maternal education, payor status, smoking status, child's race/ethnicity, child's sex, child's year of birth, small for gestational age status, and years

between first and third grade were significant across all components. Maternal education and years between first and third grade were the strongest risk factors for failing first and/or third grade CRCT across all components. Following an inverse dose-response relationship, preterm birth was associated with an increased probability of belonging to any of the three outcome contrasts compared to pass-pass, generally speaking.

A significance level of $\alpha = 0.05$ was used in assessing interaction. For the subject of math, results of interaction assessment found significant two-way exposure-covariate interaction between preterm birth and the covariates maternal education ($p = 0.0492$) and child sex ($p = 0.0343$). However, upon further investigation of stratum-specific ORs, heterogeneity was deemed not meaningful enough for consideration in a final model, despite statistical significance. No significant interaction was present for either ELA or reading. The analysis produced a model for each outcome contrast, yet produced one overall p-value for each interaction, for each CRCT component. A visual inspection of the interactions yielded no meaningful differences in predicted probabilities of the outcome by candidate interaction covariate, stratified by preterm birth category.

All covariates assessed in crude analyses were significant in the final adjusted model. Table 5 and Figure 1 report adjusted ORs and their associated 95% CIs by CRCT component (math, ELA, and reading, respectively) for this final adjusted model. The odds of fail-pass (i.e. catch-up) compared to pass-pass was highest in extremely preterm births compared to term births across all components – math [OR=1.9, 95% CI (1.3, 2.9)], ELA [OR= 2.0, 95% CI (1.5, 2.6)], and reading [OR= 2.2, 95% CI (1.7, 3.0)]. Compared to term births, moderate preterm births were also associated with increased odds of fail-pass, followed by late preterm in math and ELA. The association among

moderate preterm births was null for the subject of reading, but significant among late preterm. Associations among post-term were null. The odds of fail-fail (i.e. continued delay) compared to pass-pass was highest in extremely preterm births compared to term births across all components – math [OR=3.5, 95% CI (2.7, 4.7)], ELA [OR=3.8, 95% CI (2.8, 5.2)], and reading [OR= 3.5, 95% CI (2.6, 4.7)]. Compared to term births, moderate preterm births were also associated with increased odds of fail-fail, followed by late preterm in math and reading. The association among moderate preterm births was also significant for the subject of ELA, but null among late preterm. Associations among post-term were null. Finally, the odds of pass-fail compared to pass-pass was highest in extremely preterm births compared to term births across all components – math [OR=2.2, 95% CI (1.7, 2.8)], ELA [OR=1.8, 95% CI (1.2, 2.7)], and reading [OR=1.9, 95% CI (1.4, 2.6)]. Compared to term births, moderate preterm births were also associated with increased odds of pass-fail, followed by late preterm and post-term in math. The association among moderate preterm births was also significant for the subjects of ELA and reading, but null among late preterm and post-term.

A supplementary analysis using logistic regression was performed, to determine the effect of preterm birth (exposure) and first grade failure of CRCT components (mediator) on third grade CRCT components (outcome). Existent literature using the Georgia Birth to School Cohort reveals an association between preterm birth and first grade CRCT failure(58). In this scenario, the value added of public schooling, or the question of catch-up, may come from the direct effect of preterm birth on third grade CRCT results, conditional on first grade CRCT results, illustrated in Figure 2.

Taken independently, main effects obtained for preterm birth category, maternal race/ethnicity, maternal age, marital status, maternal education, payor status, smoking status, child's race/ethnicity, child's sex, child's year of birth, small for gestational age status, and years between first and third grade were also significant across all components. Tetrachoric correlation coefficients for failure of first grade math, ELA, and reading CRCTs are presented in Table 6. These variables were considered highly correlated with each other; subsequently each model included its corresponding first grade outcome and excluded the other first grade outcomes.

Three regression expressions were generated – one for each third grade CRCT component. Crude OR estimates are presented in Table 7. The inverse dose-response of preterm birth remained present across all three third grade CRCT components. First grade failure was the strongest predictor of third grade failure for each corresponding component. Analogous to results from the multinomial method, maternal age, followed by a three-year gap between first and third grade were also strong predictors.

Adjusted OR estimates are presented in Table 8. Extremely preterm births, relative to term births, had the highest odds of failing each third grade CRCT component – math [OR=2.1 95% CI (1.7, 2.6)], ELA [OR=1.9, 95% CI (1.4, 2.5)], and reading [OR=1.7, 95% CI (1.4, 2.2)]. Failure of first grade math CRCT was the strongest predictor for failure of third grade math CRCT [OR=8.2, 95% CI (7.8, 8.5)]. The same follows for ELA [OR=8.6, 95% CI (8.2, 9.0)] and reading [OR=9.1, 95% CI (8.7, 9.5)].

Discussion

Across all three outcome contrasts relative to pass-pass, extremely preterm births (compared to term births) had the strongest exposure-outcome relationships. Generally speaking, there was also an inverse dose-response relationship by the association of preterm status on CRCT outcome change and third grade outcome only, which is not surprising. Mulder et al. provide three hypotheses on the path by which cognitive catch up may (or may not) occur with age among children born preterm (56). If using this as a basis for interpreting the results, this analysis attempts to depict two of the three hypotheses with the following two outcome contrasts relative to pass-pass: early delay followed by catch up, illustrated by "fail-pass," and continued delay over time, illustrated by "fail-fail." The outcome contrast of "pass-fail" was less intuitive to compare using Mulder's hypotheses, but it may indicate increased difficulty in achieving academic outcomes. These results illustrate children born extremely preterm have the highest odds of catching up, the highest odds of experiencing continued delay over time, and the highest odds of increased difficulty in achieving academic outcomes, relative to their term counterparts. Children born extremely preterm also have the highest odds of failing third grade CRCTs, given their first grade results within corresponding components, relative to their term counterparts.

In the multivariable multinomial regression model, the strongest risk factors for each outcome contrast across all components were maternal education, consistent with previous research (58), and having a three-year gap between the first and third grade CRCT. Children of mothers with no high school education at the time of birth had the highest probability, which decreased as maternal education increased. In the

multivariable binary logistic regression model, for the subject of math, first grade math outcome was most significantly associated with the corresponding third grade outcome in extremely preterm births. The same pattern follows for the subjects of ELA and reading in their respective first grade outcomes.

The unmeasured effects of traditional schooling may not be enough to attenuate adverse academic outcomes, possibly indicating the need for additional interventions for at-risk children. The analysis also adds to the abundance of literature suggesting children born between 20 and 27 weeks gestation are more likely to continue to academically perform worse than children born after a longer gestation period, possibly suggesting a retention of the adverse cognitive effects of preterm birth from first to third grade in select observations, in this case. However, misclassification of outcome is a potential issue and should be considered. If one were to consider the two CRCTs as a validation check for classification of the outcome, rather than the tests being two distinct measures, one could consider observations discordant in the outcome (e.g. fail-pass and pass-fail) as true failures. Then, the research question becomes, "Is academic achievement by preterm status significantly different using first and third grade exams as markers?" In this case, yes, being born preterm yields significantly lower performance on the CRCT.

Strengths and Limitations

Due to the limited research on the attenuation of cognitive ability effects, especially looking at U.S.-based populations, this analysis contributes to the extant literature using a cohort of Georgia children, with data collected at three time points – birth, first grade, and third grade. It also follows observations into middle childhood; many studies on preterm birth as an exposure focus on outcomes in infancy and/or early

childhood. Additionally, the large sample size this cohort yields indicates high statistical power. This analysis also has strength in its selection of variables, through attempting to consider demographic, as well as socioeconomic contributors to the association of preterm birth and CRCT outcome change. It also attempts to measure SES through the inclusion of maternal education and payor (Medicaid) status at the time of birth. Finally, the outcome was measured using a criterion-referenced test, assessing how well students acquire, learn, and accomplish Georgia-based standards, as opposed to norm-referenced tests which use national instructional standards that may not be generalizable at the state level (60).

However, several limitations do exist. Covariate misclassification is of concern, as all maternal variables were collected at the time of birth, and the outcome was measured roughly eight years later for most observations, questioning their validity. Mothers with low levels of education at the time of birth, for instance, could have achieved higher levels by the time the outcome occurred. For similar reasons, this kind of misclassification is plausible for marital status, and payor status. Measuring SES via maternal education and payor status is also flawed, as SES is a complex construct, composed of education, income, wealth, and occupation. Regarding the outcome, using dichotomized pass/fail test scores, rather than continuous scores, may result in more conservative effect sizes. However, it could be argued that observing significant effects could indicate robustness. Further, the three CRCT components were created as measures of meeting state standards, not a measure of cognitive function.

Data linkage and selection bias are also of concern. Previous usage of the Georgia Birth to School Cohort report 53% of the entire birth to school cohort linked to their first

grade standardized test scores, and there are several possible sources of loss to follow up(58). First, observations could have moved out of Georgia before entering first grade. Second, because only public schools are mandated to implement the CRCT, children who attend private schools or are homeschooled will not be linked. Third, a small number of observations may have died before entering first grade. And finally, errors in the data could have prevented successful linkage. Though selection bias is of concern, previous research has shown those successfully linked to have similar demographics compared to those who did not link. In this analysis, the linkage rate dropped to 28%. This may also be attributed to the possible aforementioned sources of loss to follow up.

Finally, the Atlanta Public School System (APS) cheating scandal is worth noting. In 2011, special investigators reported of the 56 APS schools they examined, 44 schools were found to have cheated on the 2009 CRCT, and cheating within the district dates back as far as 2001. Investigators identified 178 educators responsible, and 82 of these confessed. Using erasure analysis, of the roughly 1,800 non-APS elementary and middle schools in Georgia where the CRCT was administered in 2009, 54 schools were flagged with greater than 20% of classes having greater than three standard deviations outside the state average of wrong-to-right erasures. Notably, of the 90 APS elementary and middle schools, 52 schools – over half – were flagged with greater than 20% of classes having greater than three standard deviations outside the state average of wrong-to-right erasures (61). Because educator misconduct dates back to 2001, this indicates that there may be more true failures than reported among observations across all study years (2004-2009). Consequentially, this misclassification of the outcome may have resulted in bias toward the null, or underestimation of the exposure-outcome relationship.

Conclusion

Though numerous studies illustrate an association between preterm birth, especially extremely preterm, and significantly lower cognitive ability when compared to term counterparts, few explore whether these effects are attenuated over time. Further, few studies explore additional risk factors leading to cognitive debilitation of those born preterm, or extremely preterm. This analysis attempted to reveal if schooling alone would aid in attenuation of adverse cognitive effects attributed to preterm birth and highlight possible risk factors for failing first and/or third grade among a cohort of Georgia-born children. Overall, these results align more with the Mulder et al. hypothesis, that it is unknown if, or when, cognitive catch up occurs, which may occur at different ages and for different skills, contrasting the Katz et al. hypothesis, that cognitive catch up occurs between ages six and eight; grades one and three capture ages six and eight, respectively.

Tables

Table 1. Descriptive statistics of retrospective birth to school cohort

	Total Births	Extremely Preterm		Moderate Preterm		Late Preterm		Term		Post-term	
		n	%	n	%	n	%	n	%	n	%
Total	176,674	576	0.3	3,313	1.9	13,552	7.7	133,187	75.4	26,046	14.7
Outcome											
Math											
Pass-Pass	130,861	288	0.2	2,085	1.6	9,440	7.2	99,525	76.1	19,523	14.9
Fail-Pass	5,626	26	0.5	148	2.6	487	8.7	4,166	74.0	799	14.2
Fail-Fail	8,024	71	0.9	240	3.0	703	8.8	5,890	73.4	1,120	14.0
Pass-Fail	17,358	95	0.5	418	2.4	1,528	8.8	12,744	73.4	2,573	14.8
First Grade Math CRCT											
Fail	19,737	156	0.8	595	3.0	1,800	9.1	14,445	73.2	2,741	13.9
Pass	156,740	420	0.3	2,714	1.7	11,733	7.5	118,605	75.7	23,268	14.8
Third Grade Math CRCT											
Fail	25,418	166	0.7	658	2.6	2,233	8.8	18,661	73.4	3,700	14.6
Pass	136,615	314	0.2	2,237	1.6	9,940	7.3	103,782	76.0	20,342	14.9
ELA											
Pass-Pass	136,707	335	0.2	2,283	1.7	9,990	7.3	103,685	75.8	20,414	14.9
Fail-Pass	13,440	63	0.5	321	2.4	1,159	8.6	9,971	74.2	1,926	14.3
Fail-Fail	5,966	56	0.9	151	2.5	519	8.7	4,374	73.3	866	14.5
Pass-Fail	5,789	26	0.4	138	2.4	494	8.5	4,315	74.5	816	14.1
First Grade ELA CRCT											

Fail	27,652	181	0.7	716	2.6	2,491	9.0	20,346	73.6	3,918	14.2
Pass	148,856	395	0.3	2,595	1.7	11,050	7.4	112,721	75.7	22,095	14.8
Third Grade ELA CRCT											
Fail	11,779	82	0.7	290	2.5	1,014	8.6	8,709	73.9	1,684	14.3
Pass	150,256	398	0.3	2,605	1.7	11,157	7.4	113,738	75.7	22,358	14.9
Reading											
Pass-Pass	152,932	408	0.3	2,690	1.8	11,431	7.5	115,797	75.7	22,606	14.8
Fail-Pass	9,840	62	0.6	225	2.3	869	8.8	7,253	73.7	1,431	14.5
Fail-Fail	5,754	60	1.0	183	3.2	534	9.3	4,173	72.5	804	14.0
Pass-Fail	7,967	45	0.6	210	2.6	709	8.9	5,830	73.2	1,173	14.7
First Grade Reading CRCT											
Fail	15,623	122	0.8	409	2.6	1,405	9.0	11,448	73.3	2,239	14.3
Pass	160,929	454	0.3	2,900	1.8	12,142	7.5	121,650	75.6	23,783	14.8
Third Grade Reading CRCT											
Fail	13,754	105	0.8	395	2.9	1,244	9.0	10,025	72.9	1,985	14.4
Pass	162,860	470	0.3	2,917	1.8	12,304	7.6	123,116	75.6	24,053	14.8
Characteristics											
Maternal Race/Ethnicity											
Non-Hispanic White	95,972	164	0.2	1,279	1.3	6,630	6.9	72,719	75.8	15,180	15.8
Non-Hispanic Black	63,180	385	0.6	1,797	2.8	5,849	9.3	46,961	74.3	8,188	13.0
Hispanic	13,384	21	0.2	184	1.4	792	5.9	10,277	76.8	2,110	15.8
Other	4,138	6	0.1	53	1.3	281	6.8	3,230	78.1	568	13.7
Maternal Age at Birth											
11 to 14 years	691	5	0.7	24	3.5	86	12.4	485	70.2	91	13.2
15 to 17 years	9,694	47	0.5	234	2.4	926	9.6	7,016	72.4	1,471	15.2
18 to 19 years	17,320	71	0.4	389	2.2	1,447	8.4	12,665	73.1	2,748	15.9
20 to 24 years	49,599	148	0.3	880	1.8	3,872	7.8	37,014	74.6	7,685	15.5
25 to 29 years	48,033	136	0.3	813	1.7	3,323	6.9	36,616	76.2	7,145	14.9

30 to 34 years	33,584	110	0.3	569	1.7	2,420	7.2	25,861	77.0	4,624	13.8
35 to 39 years	15,143	52	0.3	336	2.2	1,235	8.2	11,529	76.1	1,991	13.1
40+ years	2,610	7	0.3	68	2.6	243	9.3	2,001	76.7	291	11.1
Marital Status at Birth											
Married	110,504	241	0.2	1,604	1.5	7,629	6.9	84,497	76.5	16,533	15.0
Unmarried	66,153	335	0.5	1,708	2.6	5,923	9.0	48,679	73.6	9,508	14.4
Smoked during pregnancy											
Yes	16,602	53	0.3	392	2.4	1,543	9.3	12,061	72.6	2,553	15.4
No	158,960	517	0.3	2,883	1.8	11,924	7.5	120,304	75.7	23,332	14.7
Maternal Education at Birth											
No high school	42,436	151	0.4	934	2.2	3,691	8.7	31,247	73.6	6,413	15.1
High school graduate	62,454	217	0.3	1,199	1.9	4,863	7.8	47,180	75.5	8,995	14.4
1-3 years postsecondary	34,938	117	0.3	685	2.0	2,611	7.5	26,598	76.1	4,927	14.1
4+ years postsecondary	33,715	79	0.2	442	1.3	2,192	6.5	25,801	76.5	5,201	15.4
Payor Status											
Medicaid	78,705	288	0.4	1,689	2.1	6,531	8.3	58,668	74.5	11,529	14.6
Unknown	97,969	288	0.3	1,624	1.7	7,021	7.2	74,519	76.1	14,517	14.8
Child's Race/Ethnicity											
Non-Hispanic White	89,904	135	0.2	1,175	1.3	6,187	6.9	68,184	75.8	14,223	15.8
Non-Hispanic Black	63,038	388	0.6	1,792	2.8	5,858	9.3	46,836	74.3	8,164	13.0
Hispanic	15,157	31	0.2	211	1.4	929	6.1	11,622	76.7	2,364	15.6
Other	8,575	22	0.3	135	1.6	578	6.7	6,545	76.3	1,295	15.1
Child's Sex											
Male	88,698	274	0.3	1,704	1.9	7,162	8.1	66,825	75.3	12,733	14.4
Female	87,976	302	0.3	1,609	1.8	6,390	7.3	66,362	75.4	13,313	15.1
Small for Gestational Age											
Yes	20,077	12	0.1	354	1.8	1,653	8.2	15,252	76.0	2,806	14.0
No	156,597	564	0.4	2,959	1.9	11,899	7.6	117,935	75.3	23,240	14.8

Child's Year of Birth											
1998	67,845	213	0.3	1,296	1.9	5,133	7.6	50,673	74.7	10,530	15.5
1999	67,609	230	0.3	1,270	1.9	5,315	7.9	51,175	75.7	9,619	14.2
2000	41,220	133	0.3	747	1.8	3,104	7.5	31,339	76.0	5,897	14.3
Years between 1st and 3rd grades											
1	94	1	1.1	0	0.0	5	5.3	70	74.5	18	19.1
2	170,420	541	0.3	3,146	1.8	12,974	7.6	128,619	75.5	25,140	14.8
3	6,160	34	0.6	167	2.7	573	9.3	4,498	73.0	888	14.4

ELA = English/Language Arts

CRCT = Criterion Referenced Competency Test

Pass-Pass = Passing both first and third grade CRCTs

Fail-Pass = Failing first grade CRCT and passing third grade CRCT

Fail-Fail = Failing both first and third grade CRCTs

Pass-Fail = Passing first grade CRCT and failing third grade CRCT

Table 2. Crude multinomial logistic regression odds ratio (OR) estimates and 95% confidence intervals (CI) of exposure and selected characteristics with change of the CRCT math component from first to third grade

	Fail-Pass (n = 5,626)			Fail-Fail (n = 8,024)			Pass-Fail (n = 17,358)		
	OR	95% CI		OR	95% CI		OR	95% CI	
Exposure									
Gestational Age									
Extremely preterm	2.2	1.4	3.2	4.2	3.2	5.4	2.6	2.0	3.3
Moderate preterm	1.7	1.4	2.0	1.9	1.7	2.2	1.6	1.4	1.7
Late preterm	1.2	1.1	1.4	1.3	1.2	1.4	1.3	1.2	1.3
Term	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Post-term	1.0	0.9	1.1	1.0	0.9	1.0	1.0	1.0	1.1
Characteristics									
Maternal Race/Ethnicity									
Non-Hispanic White	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Non-Hispanic Black	2.8	2.6	3.0	3.6	3.4	3.8	2.5	2.4	2.5
Hispanic	3.6	3.4	4.0	3.0	2.8	3.2	1.4	1.3	1.5
Other	0.9	0.7	1.1	0.6	0.5	0.7	0.4	0.3	0.5
Maternal Age at Birth									
11 to 14 years	2.8	2.0	3.9	2.8	2.1	3.8	2.4	2.0	3.0
15 to 17 years	2.0	1.8	2.3	2.4	2.2	2.6	2.0	1.8	2.1
18 to 19 years	1.9	1.7	2.1	2.0	1.8	2.1	1.8	1.7	1.9
20 to 24 years	1.6	1.5	1.7	1.6	1.5	1.7	1.5	1.4	1.6
25 to 29 years	1.00	(ref)		1.00	(ref)		1.00	(ref)	
30 to 34 years	0.8	0.7	0.9	0.7	0.7	0.8	0.7	0.7	0.8
35 to 39 years	0.7	0.6	0.8	0.8	0.7	0.8	0.8	0.7	0.8
40+ years	1.2	0.9	1.5	0.9	0.7	1.1	0.7	0.6	0.9
Marital Status at Birth									
Married	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Unmarried	2.4	2.3	2.6	3.1	2.9	3.2	2.5	2.4	2.6
Smoked during pregnancy									
Yes	1.2	1.1	1.3	1.3	1.2	1.4	1.4	1.3	1.5
No	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Maternal Education at Birth									
No high school	8.0	7.1	9.0	11.2	10.0	12.5	5.7	5.3	6.0
High school graduate	4.7	4.2	5.3	6.1	5.4	6.8	3.8	3.6	4.1
1-3 years postsecondary	2.9	2.5	3.3	3.4	3.0	3.8	2.5	2.4	2.7
4+ years postsecondary	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Payor Status									
Medicaid	2.3	2.2	2.4	2.8	2.7	2.9	2.2	2.2	2.3
Unknown	1.00	(ref)		1.00	(ref)		1.00	(ref)	

Child's Race/Ethnicity									
Non-Hispanic White	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Non-Hispanic Black	3.0	2.9	3.2	3.9	3.7	4.1	2.6	2.5	2.7
Hispanic	3.7	3.4	4.1	3.2	2.9	3.4	1.5	1.4	1.6
Other	1.4	1.2	1.6	1.0	0.8	1.1	1.0	0.9	1.1
Child's Sex									
Male	1.1	1.1	1.2	1.1	1.1	1.2	1.0	1.0	1.0
Female	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Child's Year of Birth									
1998	1.00	(ref)		1.00	(ref)		1.00	(ref)	
1999	0.7	0.6	0.7	1.1	1.1	1.2	1.5	1.5	1.6
2000	1.3	1.2	1.3	1.3	1.2	1.3	0.9	0.8	0.9
Small for Gestational Age									
Yes	1.7	1.5	1.8	1.8	1.7	1.9	1.6	1.5	1.6
No	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Years between 1st and 3rd grades									
1	0.3	0.05	2.4	1.6	0.8	3.5	0.6	0.3	1.3
2	1.00	(ref)		1.00	(ref)		1.00	(ref)	
3	11.1	10.2	12.1	10.8	10.0	11.7	2.9	2.7	3.2

The models use the referent Pass-Pass and have a total of n=161,869 observations

CRCT = Criterion Referenced Competency Test

Pass-Pass = Passing both first and third grade CRCTs

Fail-Pass = Failing first grade CRCT and passing third grade CRCT

Fail-Fail = Failing both first and third grade CRCTs

Pass-Fail = Passing first grade CRCT and failing third grade CRCT

Table 3. Crude multinomial logistic regression odds ratio (OR) estimates and 95% confidence intervals (CI) of exposure and selected characteristics with change of the CRCT English/Language Arts (ELA) component from first to third grade

	Fail-Pass (n = 13,440)			Fail-Fail (n = 5,966)			Pass-Fail (n = 5,789)		
	OR	95% CI		OR	95% CI		OR	95% CI	
Exposure									
Gestational Age									
Extremely preterm	2.0	1.5	2.6	4.0	3.0	5.3	1.9	1.3	2.8
Moderate preterm	1.5	1.3	1.6	1.6	1.3	1.9	1.5	1.2	1.7
Late preterm	1.2	1.1	1.3	1.2	1.1	1.4	1.2	1.1	1.3
Term	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Post-term	1.0	0.9	1.0	1.0	0.9	1.1	1.0	0.9	1.0
Characteristics									
Maternal Race/Ethnicity									
Non-Hispanic White	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Non-Hispanic Black	1.9	1.8	1.9	2.3	2.2	2.4	1.9	1.8	2.0
Hispanic	3.7	3.5	3.9	2.6	2.4	2.9	1.3	1.1	1.4
Other	1.0	0.8	1.1	0.5	0.4	0.7	0.3	0.3	0.5
Maternal Age at Birth									
11 to 14 years	2.5	2.0	3.1	2.6	1.8	3.6	3.8	2.8	5.1
15 to 17 years	2.0	1.8	2.1	2.1	1.9	2.4	2.1	1.9	2.3
18 to 19 years	1.7	1.6	1.8	1.9	1.7	2.1	1.9	1.7	2.1
20 to 24 years	1.5	1.4	1.6	1.6	1.5	1.7	1.6	1.5	1.8
25 to 29 years	1.00	(ref)		1.00	(ref)		1.00	(ref)	
30 to 34 years	0.8	0.7	0.8	0.7	0.6	0.8	0.8	0.7	0.9
35 to 39 years	0.7	0.7	0.8	0.8	0.7	0.8	0.7	0.6	0.8
40+ years	0.9	0.7	1.0	0.8	0.6	1.0	0.7	0.5	0.9
Marital Status at Birth									
Married	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Unmarried	2.0	1.9	2.1	2.6	2.4	2.7	2.3	2.2	2.4
Smoked during pregnancy									
Yes	1.2	1.2	1.3	1.7	1.5	1.8	1.2	1.2	1.3
No	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Maternal Education at Birth									
No high school	6.9	6.4	7.4	12.5	11.0	14.3	7.5	6.7	8.4
High school graduate	3.9	3.6	4.1	6.3	5.6	7.3	4.6	4.1	5.2
1-3 years postsecondary	2.5	2.3	2.7	3.4	2.9	3.9	2.9	2.6	3.3
4+ years postsecondary	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Payor Status									
Medicaid	2.0	2.0	2.1	2.6	2.5	2.7	2.3	2.2	2.4
Unknown	1.00	(ref)		1.00	(ref)		1.00	(ref)	

Child's Race/Ethnicity									
Non-Hispanic White	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Non-Hispanic Black	2.0	1.9	2.0	2.5	2.3	2.6	2.0	1.9	2.1
Hispanic	3.7	3.5	3.9	2.8	2.6	3.1	1.3	1.2	1.5
Other	1.2	1.1	1.3	0.9	0.8	1.1	0.9	0.8	1.1
Child's Sex									
Male	1.6	1.5	1.6	2.1	2.0	2.2	1.7	1.6	1.7
Female	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Child's Year of Birth									
1998	1.00	(ref)		1.00	(ref)		1.00	(ref)	
1999	1.1	1.1	1.2	0.6	0.6	0.7	0.6	0.5	0.6
2000	0.8	0.8	0.8	0.5	0.4	0.5	0.5	0.5	0.6
Small for Gestational Age									
Yes	1.5	1.4	1.5	1.6	1.5	1.8	1.5	1.4	1.6
No	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Years between 1st and 3rd grades									
1	0.4	0.1	1.4	1.2	0.4	3.3	1.2	0.4	3.2
2	1.00	(ref)		1.00	(ref)		1.00	(ref)	
3	19.0	17.8	20.4	10.7	9.7	11.8	2.4	2.0	2.9

The models use the referent Pass-Pass and have a total of n=161,902 observations
CRCT = Criterion Referenced Competency Test
Pass-Pass = Passing both first and third grade CRCTs
Fail-Pass = Failing first grade CRCT and passing third grade CRCT
Fail-Fail = Failing both first and third grade CRCTs
Pass-Fail = Passing first grade CRCT and failing third grade CRCT

Table 4. Crude multinomial logistic regression odds ratio (OR) estimates and 95% confidence intervals (CI) of exposure and selected characteristics with change of the CRCT reading component from first to third grade

	Fail-Pass (n = 9,840)			Fail-Fail (n = 5,754)			Pass-Fail (n = 7,967)		
	OR	95% CI		OR	95% CI		OR	95% CI	
Exposure									
Gestational Age									
Extremely preterm	2.4	1.9	3.2	4.1	3.1	5.4	2.2	1.6	3.0
Moderate preterm	1.3	1.2	1.5	1.9	1.6	2.2	1.6	1.3	1.8
Late preterm	1.2	1.1	1.3	1.3	1.2	1.4	1.2	1.1	1.3
Term	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Post-term	1.0	1.0	1.1	1.0	0.9	1.1	1.0	1.0	1.1
Characteristics									
Maternal Race/Ethnicity									
Non-Hispanic White	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Non-Hispanic Black	2.2	2.1	2.3	3.6	3.4	3.8	2.9	2.8	3.1
Hispanic	3.7	3.5	3.9	3.4	3.1	3.7	1.7	1.6	1.9
Other	1.1	1.0	1.3	0.8	0.6	1.0	0.5	0.4	0.6
Maternal Age at Birth									
11 to 14 years	2.0	1.5	2.6	3.9	3.0	5.1	2.7	2.0	3.5
15 to 17 years	2.0	1.8	2.2	2.2	2.0	2.5	2.1	2.0	2.3
18 to 19 years	1.7	1.6	1.8	1.9	1.7	2.0	1.9	1.7	2.0
20 to 24 years	1.5	1.4	1.6	1.7	1.6	1.9	1.7	1.6	1.8
25 to 29 years	1.00	(ref)		1.00	(ref)		1.00	(ref)	
30 to 34 years	0.8	0.7	0.8	0.7	0.7	0.8	0.7	0.7	0.8
35 to 39 years	0.7	0.7	0.8	0.7	0.6	0.8	0.7	0.6	0.7
40+ years	0.9	0.7	1.1	0.9	0.7	1.2	0.6	0.5	0.8
Marital Status at Birth									
Married	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Unmarried	2.1	2.0	2.2	3.1	3.0	3.3	2.8	2.7	2.9
Smoked during pregnancy									
Yes	1.3	1.2	1.4	1.4	1.3	1.5	1.4	1.3	1.5
No	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Maternal Education at Birth									
No high school	9.0	8.2	9.9	12.4	10.8	14.3	9.2	8.2	10.2
High school graduate	5.0	4.5	5.5	6.2	5.4	7.2	5.6	5.0	6.3
1-3 years postsecondary	3.0	2.7	3.3	3.1	2.6	3.6	3.1	2.8	3.5
4+ years postsecondary	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Payor Status									
Medicaid	2.1	2.0	2.2	2.7	2.6	2.9	2.6	2.5	2.8
Unknown	1.00	(ref)		1.00	(ref)		1.00	(ref)	

Child's Race/Ethnicity									
Non-Hispanic White	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Non-Hispanic Black	2.4	2.3	2.5	3.9	3.7	4.2	3.1	2.9	3.2
Hispanic	3.8	3.5	4.0	3.6	3.3	4.0	1.8	1.7	2.0
Other	1.2	1.1	1.3	1.2	1.0	1.4	1.1	1.0	1.3
Child's Sex									
Male	1.7	1.7	1.8	2.0	1.9	2.1	1.5	1.5	1.6
Female	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Child's Year of Birth									
1998	1.00	(ref)		1.00	(ref)		1.00	(ref)	
1999	1.2	1.1	1.2	0.8	0.8	0.9	0.4	0.4	0.4
2000	0.8	0.7	0.8	0.5	0.5	0.5	0.4	0.4	0.4
Small for Gestational Age									
Yes	1.5	1.4	1.6	1.9	1.8	2.1	1.5	1.4	1.6
No	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Years between 1st and 3rd grades									
1	0.7	0.2	2.2	1.7	0.7	4.3	0.7	0.2	2.2
2	1.00	(ref)		1.00	(ref)		1.00	(ref)	
3	16.6	15.6	17.6	8.2	7.5	8.9	1.9	1.7	2.1

The models use the referent Pass-Pass and have a total of n=176,493 observations

CRCT = Criterion Referenced Competency Test

Pass-Pass = Passing both first and third grade CRCTs

Fail-Pass = Failing first grade CRCT and passing third grade CRCT

Fail-Fail = Failing both first and third grade CRCTs

Pass-Fail = Passing first grade CRCT and failing third grade CRCT

Table 5. Adjusted multinomial logistic regression odds ratio (OR) estimates and 95% confidence intervals (CI) of exposure with change of CRCT components from first to third grade

	Fail-Pass						Fail-Fail						Pass-Fail					
	n	%	OR	95% CI		p-value	n	%	OR	95% CI		p-value	n	%	OR	95% CI		p-value
Math																		
Gestational Age																		
Extremely preterm	26	0.0	1.9	1.3	2.9	0.002	71	0.0	3.5	2.7	4.7	<0.001	95	0.1	2.2	1.7	2.8	<0.001
Moderate preterm	148	0.1	1.4	1.2	1.7	< 0.001	240	0.2	1.6	1.4	1.8	<0.001	418	0.3	1.3	1.2	1.5	<0.001
Late preterm	487	0.3	1.1	1.0	1.2	0.018	703	0.4	1.1	1.0	1.2	0.021	1,528	1.0	1.1	1.1	1.2	<0.001
Term	4,166	2.6	1.00	(ref)			5,890	3.7	1.00	(ref)			12,744	8.1	1.00	(ref)		
Post-term	799	0.5	1.0	0.9	1.1	0.964	1,120	0.7	1.0	0.9	1.1	0.814	2,573	1.6	1.1	1.0	1.1	0.012
ELA																		
Gestational Age																		
Extremely preterm	63	0.0	2.0	1.5	2.6	< 0.001	56	0.0	3.8	2.8	5.2	< 0.001	26	0.0	1.8	1.2	2.7	0.006
Moderate preterm	321	0.2	1.3	1.1	1.4	< 0.001	151	0.1	1.3	1.1	1.6	0.003	138	0.1	1.2	1.0	1.5	0.029
Late preterm	1,159	0.7	1.1	1.0	1.2	0.001	519	0.3	1.1	1.0	1.2	0.058	494	0.3	1.1	1.0	1.2	0.168
Term	9,971	6.3	1.0	(ref)			4,374	2.8	1.0	(ref)			4,315	2.7	1.0	(ref)		
Post-term	1,926	1.2	1.0	0.9	1.0	0.609	866	0.5	1.0	0.9	1.1	0.661	816	0.5	1.0	0.9	1.0	0.372
Reading																		
Gestational Age																		
Extremely preterm	62	0.0	2.2	1.7	3.0	< 0.001	60	0.0	3.5	2.6	4.7	< 0.001	45	0.0	1.9	1.4	2.6	< 0.001
Moderate preterm	225	0.1	1.1	0.9	1.3	0.224	183	0.1	1.5	1.3	1.8	< 0.001	210	0.1	1.2	1.0	1.4	0.015
Late preterm	869	0.5	1.1	1.0	1.2	0.024	534	0.3	1.1	1.0	1.2	0.036	709	0.4	1.1	1.0	1.2	0.083
Term	7,253	4.2	1.00	(ref)			4,173	2.4	1.00	(ref)			5,830	3.4	1.00	(ref)		
Post-term	1,431	0.8	1.0	1.0	1.1	0.241	804	0.5	1.0	0.9	1.1	0.618	1,173	0.7	1.0	1.0	1.1	0.288

Each model uses the referent Pass-Pass

Wald Chi-square p-value

Models adjusted for maternal race/ethnicity, maternal age, marital status, maternal education, payor status, smoking status, child's race/ethnicity, child's sex, child's birth year, small for gestational age status, and years between first and third grade

CRCT = Criterion Referenced Competency Test
ELA = English/Language Arts
Pass-Pass = Passing both first and third grade CRCTs
Fail-Pass = Failing first grade CRCT and passing third grade CRCT
Fail-Fail = Failing both first and third grade CRCTs
Pass-Fail = Passing first grade CRCT and failing third grade CRCT
Math n = 158,124
ELA n = 158,160
Reading n = 172,356

Table 6. Tetrachoric correlation coefficients for first grade CRCT components

	First Grade Math CRCT	First Grade ELA CRCT	First Grade Reading CRCT
First Grade Math CRCT	1.00		
First Grade ELA CRCT	0.82	1.00	
First Grade Reading CRCT	0.78	0.86	1.00

Table 7. Crude logistic regression odds ratio (OR) estimates and 95% confidence intervals (CI) of failure of third grade math, English/Language Arts (ELA), and reading components of the CRCT for selected characteristics

	Math			ELA			Reading		
	OR	95% CI		OR	95% CI		OR	95% CI	
Exposure									
Gestational Age									
Extremely preterm	2.9	2.4	3.6	2.7	2.1	3.4	2.7	2.2	3.4
Moderate preterm	1.6	1.5	1.8	1.5	1.3	1.6	1.7	1.5	1.9
Late preterm	1.2	1.2	1.3	1.2	1.1	1.3	1.2	1.2	1.3
Term	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Post-term	1.0	1.0	1.1	1.0	0.9	1.0	1.0	1.0	1.1
Characteristics									
Fail First Grade Math CRCT	10.8	10.4	11.2	--	--	--	--	--	--
Fail First Grade ELA CRCT	--	--	--	10.5	10.1	10.9	--	--	--
Fail First Grade Reading CRCT	--	--	--	--	--	--	11.2	10.8	11.7
Maternal Race/Ethnicity									
Non-Hispanic White	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Non-Hispanic Black	2.6	2.6	2.7	2.0	1.9	2.1	3.0	2.9	3.1
Hispanic	1.7	1.6	1.8	1.6	1.5	1.7	2.1	2.0	2.3
Other	0.4	0.4	0.5	0.4	0.4	0.5	0.6	0.5	0.7
Maternal Age at Birth									
11 to 14 years	2.4	2.0	2.9	2.8	2.2	3.5	3.0	2.5	3.7
15 to 17 years	2.0	1.9	2.1	2.0	1.8	2.1	2.1	1.9	2.2
18 to 19 years	1.8	1.7	1.9	1.8	1.7	1.9	1.8	1.7	1.9
20 to 24 years	1.5	1.5	1.6	1.5	1.5	1.6	1.6	1.6	1.7
25 to 29 years	1.00	(ref)		1.00	(ref)		1.00	(ref)	
30 to 34 years	0.7	0.7	0.8	0.8	0.7	0.8	0.7	0.7	0.8
35 to 39 years	0.8	0.7	0.8	0.7	0.7	0.8	0.7	0.6	0.8
40+ years	0.8	0.7	0.9	0.8	0.6	0.9	0.7	0.6	0.9
Marital Status at Birth									

Married	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Unmarried	2.5	2.5	2.6	2.3	2.2	2.4	2.8	2.7	2.9
Smoked during pregnancy									
Yes	1.4	1.3	1.4	1.7	1.6	1.8	1.4	1.3	1.5
No	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Maternal Education at Birth									
No high school	6.4	6.1	6.8	8.3	7.6	9.0	9.4	8.6	10.2
High school graduate	4.2	3.9	4.4	5.0	4.6	5.4	5.5	5.1	6.1
1-3 years postsecondary	2.7	2.5	2.8	3.0	2.7	3.3	3.0	2.8	3.4
4+ years postsecondary	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Payor Status									
Medicaid	2.3	2.3	2.4	2.3	2.2	2.4	2.6	2.5	2.7
Unknown	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Child's Race/Ethnicity									
Non-Hispanic White	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Non-Hispanic Black	2.8	2.7	2.9	2.1	2.0	2.2	3.2	3.1	3.4
Hispanic	1.8	1.7	1.9	1.7	1.6	1.9	2.3	2.1	2.4
Other	1.0	0.9	1.1	0.9	0.8	1.0	1.1	1.0	1.3
Child's Sex									
Male	1.0	1.0	1.1	1.8	1.7	1.9	1.7	1.6	1.7
Female	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Child's Year of Birth									
1998	1.00	(ref)		1.00	(ref)		1.00	(ref)	
1999	1.4	1.4	1.5	0.6	0.6	0.6	0.6	0.5	0.6
2000	1.0	0.9	1.0	0.5	0.5	0.5	0.4	0.4	0.5
Small for Gestational Age									
Yes	1.6	1.5	1.7	1.5	1.4	1.6	1.6	1.6	1.7
No	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Years between 1st and 3rd grades									
1	0.9	0.5	1.7	1.3	0.6	2.7	1.2	0.6	2.4
2	1.00	(ref)		1.00	(ref)		1.00	(ref)	
3	3.8	3.6	4.1	2.7	2.5	2.9	2.5	2.3	2.7

CRCT = Criterion Referenced Competency Test

ELA = English/Language Arts

Table 8. Adjusted logistic regression odds ratio (OR) estimates and 95% confidence intervals (CI) of failure of third grade math, English/Language Arts (ELA), and reading components of the CRCT for selected characteristics

	Math[1] (n=158,124)				ELA[2] (n=158,160)				Reading[3] (n=172,356)			
	OR	95% CI		p-value	OR	95% CI		p-value	OR	95% CI		p-value
Exposure												
Gestational Age												
Extremely preterm	2.1	1.7	2.6	<0.001	1.9	1.4	2.5	<0.001	1.7	1.4	2.2	<0.001
Moderate preterm	1.3	1.1	1.4	<0.001	1.1	1.0	1.3	0.074	1.3	1.1	1.4	<0.001
Late preterm	1.1	1.1	1.2	<0.001	1.0	1.0	1.1	0.353	1.1	1.0	1.1	0.143
Term	1.00	(ref)			1.00	(ref)			1.00	(ref)		
Post-term	1.1	1.0	1.1	0.019	1.0	0.9	1.0	0.700	1.0	1.0	1.1	0.434
Characteristics												
First Grade Math CRCT												
Fail	8.2	7.8	8.5	<0.001	--	--	--		--	--	--	
Pass	1.00	(ref)			--	--	--		--	--	--	
First Grade ELA CRCT												
Fail	--	--	--		8.6	8.2	9.0	<0.001	--	--	--	
Pass	--	--	--		1.00	(ref)			--	--	--	
First Grade Reading CRCT												
Fail	--	--	--		--	--	--		9.1	8.7	9.5	<0.001
Pass	--	--	--		--	--	--		1.00	(ref)		

Wald Chi-square p-values
CRCT = Criterion Referenced Competency Test
ELA = English/Language Arts

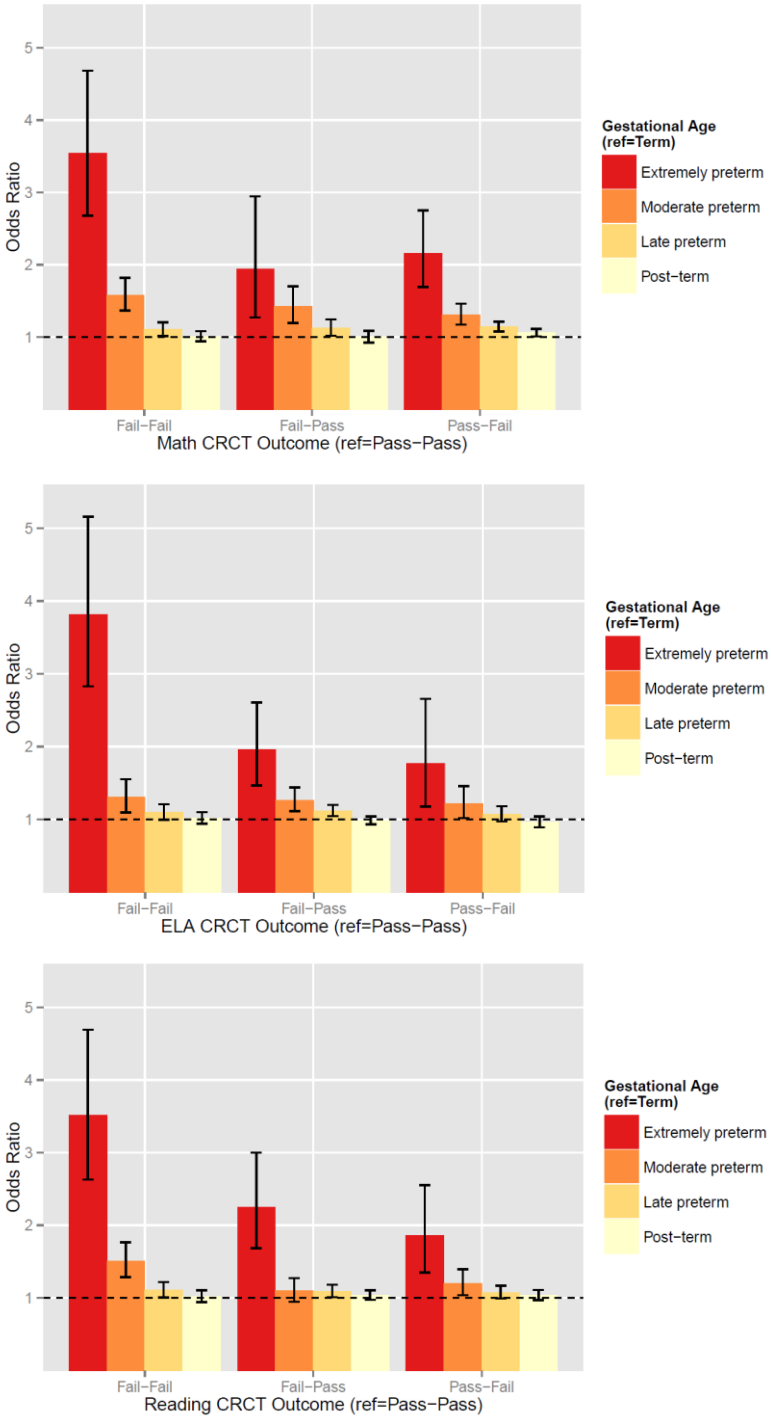
1. Adjusted for failure of first grade math CRCT, maternal race/ethnicity, maternal age, marital status, maternal education, payor status, smoking status, child's race/ethnicity, child's sex, small for gestational age status, and years between first and third grade

2. Adjusted for failure of first grade ELA CRCT, maternal race/ethnicity, maternal age, marital status, maternal education, payor status, smoking status, child's race/ethnicity, child's sex, small for gestational age status, and years between first and third grade

3. Adjusted failure of first grade reading CRCT, maternal race/ethnicity, maternal age, marital status, maternal education, payor status, smoking status, child's race/ethnicity, child's sex, small for gestational age status, and years between first and third grade

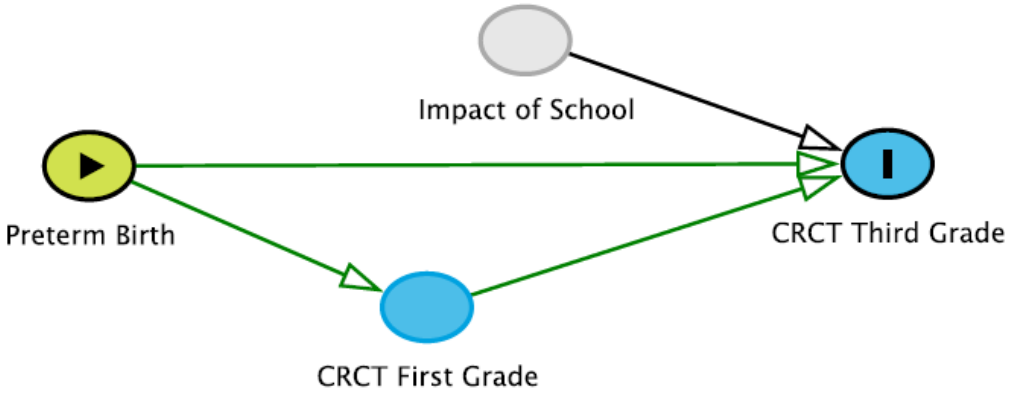
Figures

Figure 1. Adjusted multinomial logistic regression odds ratio (OR) estimates and 95% confidence intervals (CI) of exposure with change of math CRCT components – math (top), ELA (middle), and reading (bottom) – from first to third grade



CRCT = Criterion Referenced Competency Test; ELA = English/Language Arts; Pass-Pass = Passing both first and third grade CRCTs; Fail-Pass = Failing first grade CRCT and passing third grade CRCT; Fail-Fail = Failing both first and third grade CRCTs; Pass-Fail = Passing first grade CRCT and failing third grade CRCT

Figure 2. Directed acyclic graph for the relationship between preterm birth and third grade CRCT results, conditional on first grade CRCT results, considering the unmeasured impact of schooling



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Future Directions

This analysis depicts the potential impact a shorter gestation period, by a matter of weeks, may have on cognitive function into middle childhood (grades 1-3), as it is well documented that education has lasting impacts on health and well-being in adulthood. This analysis highlights the importance of including preterm status as a factor in determining which children may need more adult attention or other appropriate pre-school or in-school intervention. Children born preterm with significant deficits in cognitive ability (compared to term counterparts) may have a higher odds of facing continued delay over time, than a period of early delay followed by catch up, when compared to no deficit – which could vary based on home environment, among other unmeasured factors. Efforts should be made in schools to identify which of these categories preterm children fall into, fostering the creation of appropriate interventions.

The analysis also found that the greatest risk factor for a child to fail at any point (first, third, or both) was maternal education. This implies investments in education should be met at all levels, not only at the early/middle childhood level. Finally, if the children of women with low education are failing in schools, this follows a potential path of continued low education and cumulative stress, putting these females at a higher risk for delivering preterm babies, and a perpetuation of the cycle, as low education tends to be correlated with poverty and consequently, low access to resources. These results call for investments in not only childhood education, but also in women's perinatal health.