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Gestational Age and Kindergarten School Readiness in a National Sample of Preterm Infants

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Abstract

Objective—To examine the association of gestational age with school readiness in kindergarten reading and math skills. We hypothesized that compared with infants born at 39–41 weeks, infants born at lower gestational ages would have poorer school readiness.

Study design—Sample included 5250 children from the Early Childhood Longitudinal Study, Birth Cohort (ECLS-B), assessed with specialized reading and math assessments at kindergarten. Poor school readiness was characterized by reading and math theta scores 1.5 standard deviation (SD) below the sample mean. The adjusted odds ratios (aOR) and 95% confidence intervals (CI) of poor school readiness were estimated using multivariate logistic regression, examining gestational age continuously and categorically (very preterm [VPT], moderate/late preterm [M/LPT], early term [ET], and term). Pairwise comparisons tested for differences by gestational age categories.

Results—There was an association between gestational age and poor school readiness for reading and math with suggestion of a threshold effect in children born 32 weeks gestation. In adjusted models, the odds of poor school readiness in VPT reading and math were aOR=2.58, 95% CI [1.29–5.15] and aOR=3.38, 95% CI [1.66–6.91], respectively. However, for infants born M/LPT and ET, the odds of poor school readiness in reading did not differ from children born full-term.

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Conclusions—Compared with term infants, the highest odds of poor school readiness in reading and math were seen in VPT infants, with lower odds of poor school readiness in children born 32 weeks gestation. Ongoing developmental surveillance prior to kindergarten is indicated for very preterm infants.

Keywords

Preterm infant; Gestational Age; Kindergarten; Reading, Math; School Readiness

In 1990, The US National Education Goals Panel articulated a vision that all children in America will start kindergarten “ready to learn.”(1). This led the American Academy of Pediatrics to define a set of competencies in the young child known as “school readiness”(2), characterized partially by foundational skills in reading and math(2-4). Poor school readiness is predictive of lesser future academic achievement(4, 5), educational attainment(6), and economic success(7), but can be remediated with interventions(8, 9). Identifying children at risk for poor school readiness may help target some for intervention.

Preterm birth, defined as birth prior to 37 weeks gestation (10), has been considered a potential risk factor for poor school readiness; however, we have only identified a handful of studies that have focused on school readiness in preterm infants(11-19), and these studies have some limitations. Several studies have focused on infants born extremely preterm(11, 12), very preterm(13, 14), or late preterm(15) without examining school readiness across the full range of gestation. Three studies have examined school readiness in non-US preterm samples(16-18), thereby limiting generalizability to the US population, and one study(19) combined prematurity with low birth weight status, thereby limiting interpretation about prematurity in school readiness.

In the United States, neonatal follow-up care is typically provided only to infants born extremely preterm(20), with most preterm infants not receiving any specialized developmental care prior to school entry. Identifying the risks for poor school readiness in preterm infants can help individualize pre-educational strategies for children across the full spectrum of prematurity. Using a nationally representative, population-based U.S. sample, this study examined the odds of poor school readiness in preterm infants. We hypothesized that there would be a dose-response association between gestational age and school readiness skills in kindergarten reading and math.

METHODS

Data were drawn from the Early Childhood Longitudinal Study, Birth Cohort (ECLS-B), a nationally representative, population-based longitudinal study sponsored by the US Department of Education's National Center for Education Statistics (NCES) in the Institute for Education Science. The ECLS-B is based on a nationally representative probability sample of children born in the United States in 2001 (inclusive), and data were collected from over 10,000 children and their parents at 9 months, with subsequent assessments at 24-month, preschool, and kindergarten time points, with over 77% of the sample included at the kindergarten 2006 time point. Data collection consisted of home visits with parent interview

and direct child assessments, and included information on children's development across multiple settings(21).

Because in most states, children must be five years of age to be eligible to enter kindergarten(22, 23), for this study we defined “kindergarten eligible” by child's age 60 months at the kindergarten time point. Our sample was thus restricted to children 60 months at the kindergarten time point, excluded children with congenital and chromosomal abnormalities, and including children born at 22-41 weeks gestation inclusive and utilizing data from 5 time points (birth, 9 months, 24 months, preschool, and kindergarten). This study was considered exempt by the Institutional Review Board because the research involved the use of a publicly available dataset, in which the participants were de-identified, and data could not be linked to the participants.

Outcomes

Kindergarten School Readiness—Children were directly assessed at kindergarten age during a home visit by trained NCES staff using a specialized battery of tests developed for the ECLS-B to assess early reading and math skills. The reading assessment was formulated from existing instruments including the Peabody Picture Vocabulary Test, 3rd Edition, and Preschool Comprehensive Test of Phonological and Print Processing and measured markers of early literacy including basic reading skills (letter and word recognition, understanding letter-sound relationships, phonological awareness, sight word recognition, and understanding words in the context of simple sentences). The reliability of the early reading assessment is described by the item response theory (IRT) reliability coefficient, reported as 0.92 at kindergarten. Scores provide ability estimates in a particular domain and were reported as normally distributed theta scores which demonstrated a range of -2.11 to 3.09 (mean= 0.33, SD= 0.86) at kindergarten(22). The ECLS-B mathematics assessment incorporated items to test the following content areas: number sense, geometry, counting numerical operations, and pattern recognition. The item response theory reliability coefficient for the early mathematics assessment was also 0.92 at kindergarten. The mathematics theta scores demonstrated a range of -2.42 to 3.12 (mean= 0.38, SD= 0.80) at kindergarten(22). Because a performance of 1 or 1.5 standard deviations below the mean for age on standardized, norm-referenced tests in a specific area of development has been used previously as a threshold to identify children in need of educational services(24, 25), we defined “poor school readiness” by kindergarten reading and math theta scores falling 1.5 standard deviations below the mean.

Predictor

Gestational age was ascertained from birth certificate data from the ECLS-B restricted use data set(26). We examined the association between gestational age and poor school readiness using gestational age as a continuous variable, and also by gestational age categories as defined by clinical convention(27-29). We created a 4-group gestational age category, with infants characterized as being very preterm (<32 weeks), moderate/late preterm (32-36 weeks), early term (37-38 weeks), or full term (39-41 weeks), following gestational age categories as previously described(29).

Covariates

Maternal and infant characteristics associated with suboptimal development(30-33) were chosen *a priori* as covariates after a review of the literature. The following maternal characteristics were ascertained from the restricted ECLS-B birth certificate data: maternal age, race/ethnicity, marital status (married/ unmarried), history of prenatal smoking, duration of breastfeeding, and plurality (singleton, twin, multiple gestation). Included also were measures of maternal education (< high school; high school graduate; > high school) and poverty (<185% federal poverty level; 185% federal poverty level), which were incorporated into a single composite measure of household socioeconomic status (SES) created by ECLS-B at 9 months(34).

Because the ECLS-B did not contain a composite measure of neonatal morbidity, we included the following neonatal risks ascertained from birth certificate data, as indicators of infant medical risk: birth weight, fetal growth characterized as small for gestational age (SGA:<10%); appropriate for gestational age (AGA: 10-90%); large for gestational age (LGA: >90%); 5-minute Apgar scores (dichotomized as 7 versus >7) and days of hospitalization (0-1 days; 2-7 days; 8-14 days; 15-30 days; >30 days).

At the kindergarten assessment, although all children were kindergarten eligible, a notable percentage of children were identified as attending preschool, at the kindergarten time point. We accounted for this variability in kindergarten experience by including a 4- category variable indicating grade level and month of school at time of kindergarten assessment (Preschool; Kindergarten: August-October; Kindergarten: November- January; Kindergarten: February- June), and we adjusted for the age of the child at kindergarten assessment. Enrollment in Early Intervention, determined from 9- and 24-month parent questionnaires, Head Start, or any preschool program at preschool-age, and child sex were also included as covariates.

Statistical Analyses

Maternal and child characteristics were examined using descriptive statistics. Multivariate logistic regression utilizing the SURVEYLOGISTIC procedure in SAS was used to examine the association between gestational age and poor school readiness in reading and math at kindergarten using gestational age as a continuous variable in linear and non-linear models. We adjusted for covariates that were related to both gestational age and the outcome to account for potential confounding. The logistic model, using the log of gestational age as the predictor, fit our data best, thereby providing additional support for examining gestational age categorically. Adjusted post hoc tests examined pairwise differences between preterm and term gestational age categories at a significance level of $p<.05$.

We also examined whether the association between gestational age and poor school readiness was moderated by select infant, maternal and sociodemographic factors. Because poor school readiness has been associated with male sex, maternal sociodemographic factors(33) and fetal growth status(31), and because risk for poor school readiness can be obviated by the receipt of early educational experiences(35), we examined whether the associations between gestational age and school readiness in reading or math were

moderated by the following factors: maternal age (<28 years, ≥28 years); maternal race/ethnicity (Black/White/Hispanic); maternal education (<high school/high school graduate/>high school); poverty status (<185% below federal poverty level/≥185% federal poverty level); infant sex (male/female), fetal growth status (SGA/AGA/LGA), enrollment in early intervention at 9 or 24 months (yes/no); enrollment in Head Start (yes/no), and enrollment in any preschool program prior to kindergarten assessment (yes/no).

All analyses were conducted using SAS 9.4(36) (SAS Institute Inc., Cary, NC). Because of the complex sample design, sample weights and the Jackknife method were utilized to account for stratification, clustering and unit non-response, thereby allowing the weighted results to be generalized to the population of U.S. children born in 2001. In accord with the NCES requirements for ECLS-B data usage, reported numbers were rounded to the nearest 50.

RESULTS

There were 6300 children born between 22-41 weeks with complete reading or mathematics assessments at the kindergarten assessment time point. At the kindergarten time point, children were either enrolled in kindergarten, preschool, or had unspecified school placement. Because the level of school at kindergarten was an important predictor of school readiness, children with unspecified school placement were unable to be included in the analyses due to missing data (n= 550); 500 children were excluded because their age was less than 60 months, and they did not meet the age requirements for kindergarten eligibility. The final unweighted sample included 5250 infants, comprised of 550 very preterm (<32 weeks), 950 moderate/late preterm (32-36 weeks), 1400 early term (37-38 weeks), and 2350 term (39-41 weeks). After applying sample weights, the maternal and infant characteristics were generalizable to the US population in 2001, and are shown in Table I.

We compared children included in our analytic sample with children excluded due to attrition on demographic characteristics at the 9-month time point. Children included in our analyzed sample did not differ from children lost to attrition on most neonatal and maternal characteristics; however, children in the sample were characterized by a higher level of SES, greater percentage of minority race, older mothers, higher maternal education, higher percentage of multiples, lower percentage of prenatal smoking, and higher percentage of mothers who breastfed longer.

Gestational Age and School Readiness

In our adjusted logistic models, a relationship between log gestational age and poor school readiness at kindergarten was demonstrated for both reading ($\beta = -2.65$, $\chi^2 = 12.03$, $p < .001$) and math ($\beta = -3.84$, $\chi^2 = 14.80$, $p < .001$).

Using gestational age as a categorical variable (very preterm; moderate/late preterm; early term; term), we found a similar relationship between lower gestational age categories and poorer kindergarten school readiness in reading ($\chi^2 = 10.14$, $df=3$, $p=.017$) and math ($\chi^2 = 14.98$, $df=3$, $p=.002$). The percentage of infants with poor school readiness in reading and math ranged from 3.3- 8.3% and 4.1-12.8% respectively, but our data also suggested the

presence of a gestational age threshold for poor school readiness. Compared with infants born full term, very preterm infants demonstrated the highest percentage of poor school readiness in reading and math, but the risk for poor school readiness dropped and gradually plateaued in infants born at or above 32 weeks gestation (Figure).

Infants born very preterm demonstrated the highest odds of poor school readiness in reading and math (aOR= 2.58, 95% CI [1.29-5.15], and aOR= 3.38, 95% CI [1.66-6.91] respectively), with lower odds of poor school readiness for children born 32 weeks gestation. Although our findings suggested that M/LPT and ET appear to have higher odds of poor school readiness compared with full term infants, the pairwise comparisons indicated that the differences were not statistically significant (Table II). Poor school readiness in reading was also associated with low SES ($p < .001$), younger age of child ($p < .001$), child's level of school ($p < .001$), race ($p < .001$), male sex ($p = .003$) and no previous preschool experience ($p < .001$). Poor school readiness in math was associated with low SES ($p < .001$), younger age ($p < .001$), child's level of school ($p = .002$), male sex ($p < .001$), SGA status ($p = .02$), no early intervention at 24-months ($p = .02$), and no previous preschool experience ($p < .001$).

When we examined the association between gestational age and poor school readiness without restricting our sample to age 60 months, the associations between gestational age and poor school readiness were similar (though slightly attenuated), compared with the age-restricted sample. The associations with the non age-restricted sample were only marginally significant for reading ($p = .08$), but remained significant for math ($p < .001$). In our non age-restricted sample, the aforementioned sociodemographic risks continued to be associated with poor school readiness.

Moderators of School Readiness in Preterm Infants—We examined whether the association between gestational age and poor school readiness was moderated by maternal and socio-demographic factors chosen *a priori*, and by the significant predictors in our multivariate model. The association between gestational age and poor school readiness in reading and math was not moderated by maternal race/ethnicity, maternal education, infant sex, fetal growth, poverty, or by attendance in early intervention, Head Start or any preschool program. All interaction terms were non-significant.

DISCUSSION

We have examined the odds of poor school readiness at kindergarten in preterm infants across the full range of gestational age using a nationally representative, population-based sample from the United States. Similar to other studies focused on school readiness in preterm infants born at earlier gestational ages (11-14), we also found that infants born very preterm (<32 weeks) demonstrated the greatest odds of poor school readiness in reading and math, compared with infants born full term. However, in contrast to studies with both US (37) and non-US samples (16, 17), we did not find evidence of a linear dose-response relationship between gestational age and poor school readiness. Rather, we found the suggestion of a threshold effect, wherein compared with full-term infants, the odds of poor school readiness are markedly lower and then gradually plateau after 32 weeks gestation. In

our multivariate models, higher odds of poor school readiness were associated with socio-demographic characteristics including minority race, lower SES, lower level of school experience, younger age at the kindergarten time point, and lack of early developmental and educational experiences, suggesting that there are a multiplicity of factors that are associated with poor school readiness, beyond variations in gestational age.

We did not find that the association between gestational age and poor school readiness was moderated by maternal race/ethnicity, maternal education, infant sex, fetal growth, or poverty. This suggests that the association of degrees of prematurity with poor school readiness do not differ across these socio-demographic risks and infant characteristics. Our findings are similar to other studies of developmental delay in preterm infants which have found that the degree of prematurity and socio-demographic risks are separate risk factors associated with suboptimal development in the period prior to kindergarten(16, 32). Similarly, we found that receipt of early intervention services at 9 and 24 months, Head Start Enrollment, or previous preschool experience did not moderate the relationship between prematurity and poor school readiness, suggesting that compared with full-term infants, preterm infants do not differentially benefit from these interventions, and that these interventions do not moderate the effects of preterm birth on school readiness. Similar to previous research(18), we found that early preschool experience was independently related to school readiness, suggesting that although developmental interventions may not mitigate the effects of preterm birth, these interventions may help foster school readiness in children across the full spectrum of gestational age.

Our findings differ from prior studies regarding which gestational age categories are at risk, and whether there is a dose-response association between gestational age and suboptimal development across the full spectrum of prematurity. Although other studies using large, nationally representative databases have identified moderate and late preterm infants as having poorer school readiness(15, 18), our results found no significant differences between the odds of poor school readiness in M/LPT infants and children born full term. There are some potential explanations for these disparate findings. One study(18) identifying M/LPT as having poorer school readiness, assessed children at a different time period (between 4-5 years), and defined school readiness by performance on a nonverbal assessment. The verbal assessment scores of the M/LPT infants in this study did not differ from term-born infants, which is similar to the findings we reported for school readiness in reading. Of greater interest is that our findings differ from similar research using the ECLS-B, which examined the neurodevelopmental outcomes of late preterm infants at kindergarten(15). Even though previous research using the same database identified late preterm infants as having poorer neurodevelopmental outcomes at kindergarten, we found no differences in the odds of school readiness between M/LPT and full-term children. We believe that the difference between our two studies may be related to our observation that 14% of the children assessed at the kindergarten time point were identified as attending preschool, rather than kindergarten, although all children in our sample were kindergarten eligible based on age. When we did not account for school experience (preschool versus kindergarten enrollment at the kindergarten time point), we also found evidence that late preterm children had lower school readiness scores compared with full-term infants. After controlling for school experience in our multivariate models, we did not find an increased risk for poor school

readiness for infants born late preterm. In addition, although previous studies have identified a dose-response association between gestational age and poor school readiness across the full spectrum of prematurity(16, 17), our results suggest a threshold such that there is no significant effect of gestational age on school readiness for children born ≥ 32 weeks, compared with infants born full term. Using data from the Millenium Cohort Study (MCS), both studies found a dose-response association between gestational age and pre-academic skills at age 5.

Similar to our findings, school readiness was associated with child's age and month of school(16). However, in contrast to our study, it is not clear whether all children assessed at 5 years of age in the MCS were in the same grade. In our sample, children who were enrolled in preschool at the kindergarten time point had the greatest odds of poor school readiness, which may account for why these children were chosen to delay kindergarten entry. Of note, although previous studies have identified cognitive differences in moderate and late preterm infants, compared with full term infants(17, 38), the effect sizes are small, and the threshold of -1.5 SD below the mean we chose for this study may be too stringent to identify developmental differences between late preterm and full term infants. Furthermore, our non-significant group differences may also be related to insufficient power to detect small effect sizes between M/LPT and full term groups. Finally, as new cognitive processes start to develop over the lifespan, learning problems may emerge later in life which were not present early in life (39), which may explain the gestational-age differences in educational attainment observed later in life(40).

The association between lower gestational age and poor school readiness in kindergarten seen in very preterm infants may be related to biological differences in early brain development, associated with preterm birth. The third trimester of pregnancy is a period of rapid fetal brain development characterized by growth of gray matter(41), increased myelination(42) and increased synaptogenesis and neural connectivity(43). Compared with the full term infants, the underdevelopment of the preterm brain has been associated with poorer educational performance and lower intellectual abilities(44, 45), with these differences are most pronounced in children born at earlier gestational ages.

Our study has several implications for the pediatric primary care provider. Infants born <32 weeks of age demonstrate the greatest risks for poor school readiness in reading and math, and could benefit from more targeted developmental surveillance in early literacy and numeracy prior to kindergarten. Independent of gestational age, the risks for poor school readiness include low SES, history of being SGA, male sex, and race. Because receipt of early intervention and preschool-age preschool experiences were associated with school readiness, pediatricians should provide anticipatory guidance at the preschool health-supervision visit about the potential benefits of preschool for all children with school readiness risk factors, but especially for those born very preterm, in whom the odds of poor school readiness are the highest. Finally, because children with the poorest school readiness were reported as attending preschool instead of kindergarten, it may be appropriate to consider postponing kindergarten entry to foster school readiness.

Our study had several strengths and limitations. The study includes a nationally representative sample, the results of which generalize to the population, and longitudinal assessments of child development from infancy through kindergarten. In addition, in contrast to other studies that have used parent-report questionnaires to assess development(32), the ECLS-B administered direct child assessments to measure development, thus minimizing biases that can be associated with parent-report measures. One of the limitations of the study relates to the limited health and neonatal risk information in the ECLS-B: there is no information about illnesses and hospitalizations in the neonatal period, which may be related to subsequent developmental outcomes of preterm infants. The ECLS-B has generalized measures of neonatal risk (eg, gestational age, birth weight, presence of major malformations), but does not contain specific details regarding the medical morbidities associated with preterm birth that may be associated with suboptimal developmental outcomes(46). In addition, there are no data on maternal intelligence quotient, or family history of learning difficulties, which can be associated with school readiness in early childhood.

Our findings suggest that very preterm infants would continue to benefit from developmental monitoring beyond 2 years of age, in the period prior to school entry. In addition, all children with risk factors for poor school readiness, regardless of gestational age should be targeted for interventions prior to kindergarten entry, with consideration of preschool enrollment prior to kindergarten age as potential way to foster school readiness.

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Superscripts a, b and c that differ from one another denote significant differences ($p < .05$) between very preterm, moderate/late preterm, early term, and term infants.

Figure 1.
Percentages of Poor School Readiness in Kindergarten Reading and Math by Gestational Age Groups

Table 1**Maternal and Infant Characteristics for Weighted Sample**

Maternal Characteristics	Mean, SD (Range) or Weighted (%)
Age (years)	27.4, 4.8 (15-50)
Race/ ethnicity	
White / Non-Hispanic	57.4%
Black / Non-Hispanic	13.7%
Hispanic	22.6%
Asian	3.5%
Other	2.7%
Marital Status	
Married	68.2%
Unmarried	31.8%
History of Prenatal Smoking	
No	89.0%
Yes	11.0%
Duration of Breastfeeding	
< 1 months	37.5%
1-2 months	28.2%
>2 months	34.3%
Plurality	
Singleton	96.6%
Twin	3.1%
Multiple (> twin)	0.2%
Socioeconomic indicators calculated from measures of education and income at 9-months:	
Maternal Education	
Less than high school	18.2%
High graduate	29.0%
> High School	52.8%
Below poverty threshold (<185% federal poverty line)	44.2%
At or above poverty threshold (≥ 185% federal poverty line)	55.8%
Child Characteristics	Mean, SD (Range) or Weighted (%)
Gestational Age (weeks)	38.4, 2.7 (22-41)
Gestational Age Categories	
Very Preterm (< 32 weeks)	2.1%
Moderate /Late Preterm (32-36 weeks)	10.5%
Early Term (37-38 weeks)	28.4%
Term (39-41 weeks)	59.0%
Sex	
Male	50.5%
Female	49.5%
Birthweight (grams)	3309.9, 567.3 (602-5443)

Child Characteristics	Mean, SD (Range) or Weighted (%)
Fetal Growth	
Small for gestational age (<10%)	10.6%
Appropriate for gestational age (10-90%)	78.4%
Large for Gestational age (>90%)	11.0%
5-Minute Apgar	
>7	97.1%
7	2.9%
Days of Hospitalization	
0-1 Days	89.0%
2-7 Days	5.8%
8-14 Days	1.8%
15-30 days	1.4%
>30 days	1.2%
Enrollment in Early Intervention at 9 months	
No	97.6%
Yes	2.4%
Enrollment in Early Intervention at 24 months	
No	97.6%
Yes	2.4%
Enrollment in Head Start	
No	83.4%
Yes	16.6%
Enrollment in Preschool at Preschool timepoint	
No	58.6%
Yes	41.4%
Age at Kindergarten Assessment (months)	65.7, 4.2 (60-74.5)
Level of School at time of Kindergarten Assessment	
Enrolled in Preschool	13.7%
Kindergarten: August-October	36.2%
Kindergarten: November – January	41.8%
Kindergarten: February - June	8.4%

Table 2
Adjusted Odds Ratios of Poor School Readiness in Reading and Math by Gestational Age Categories

	READING		MATH	
	aOR	(95% CI)	aOR	(95% CI)
Very Preterm (<32 weeks)	2.58	[1.29-5.15]	3.38	[1.66-6.91]
Moderate /Late Preterm (32-36 weeks)	1.44	[0.96-2.16]	1.44	[0.91-2.26]
Early Term (37-38 weeks)	1.25	[0.87-1.78]	1.55	[1.07-2.24]
Term (39-41 weeks)				

-----Reference-----

Adjusted analyses included the following covariates: maternal race/ethnicity, socioeconomic status at kindergarten, infant gender, age at assessment and month of school.