HHS Public Access
Author manuscript
J Learn Disabil. Author manuscript; available in PMC 2016 May 01.

Published in final edited form as:
J Learn Disabil. 2016 May ; 49(3): 305–319. doi:10.1177/0022219414553849.

Who is At Risk for Persistent Mathematics Difficulties in the U.S?

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Abstract

We analyzed two nationally representative, longitudinal datasets of U.S. children to identify risk factors for persistent mathematics difficulties (PMD). Results indicated that children from low socioeconomic households were at elevated risk of PMD at 48 and 60 months of age, as were children with cognitive delays, identified developmental delays or disabilities, or those with vocabulary difficulties. In contrast, children attending preschool either in Head Start or non-Head Start classrooms are at initially lower risk of PMD. Kindergarten-aged children experiencing either low socioeconomic status or mathematics difficulties are at greatest risk for PMD across 3rd, 5th, and 8th grade. Also at risk for PMD between 3rd–8th grade are children displaying reading difficulties or inattention and other learning-related behaviors problems, children with identified disabilities, and those who are retained. Educationally relevant and potentially malleable factors for decreasing young children's risk for PMD may include increasing children's access to preschool, decreasing their risk of experiencing vocabulary or reading difficulties, and avoiding use of grade retention.

Young children experiencing learning difficulties in mathematics will likely continue experiencing these mathematics difficulties (MD) later in their school careers (Morgan, Farkas, & Wu, 2009). Continuing to experience MD by the end of high school increases children's likelihood of being unemployed as an adult, as well as of being unemployed for longer durations (e.g., Bynner, 1997). If employed, those with MD are less likely to be promoted or to hold higher-paying jobs (Hall & Farkas 2011). Experiencing MD also increases children's risk of experiencing clinically significant socio-emotional maladjustment (Auerback, Gross-Tsur, Manor, & Shalev, 2008; Morgan, Farkas, & Wu, 2011; Lin et al., 2013). Early identification and intervention for those most at risk for MD is

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therefore necessary as these children are likely to experience far fewer educational and societal opportunities as adults (Geary, 2011).

Persistent Mathematics Difficulties

Which children are most at risk for continuing to experience MD as they age? Theoretically, those at greatest risk should be those *persistently* experiencing learning difficulties in mathematics (Geary, 2011; Mazzocco & Myers, 2003). This is because persistent learning difficulties most likely result from underlying cognitive impairments, including learning disabilities (Fuchs et al., 2007; Geary, 2004; Geary, Hoard, & Hamson, 1999). Persistently struggling in mathematics is considered a defining characteristic of mathematics learning disabilities (Geary, 2011; Mazzocco & Myers, 2003). Specific cognitive processes associated with persistent mathematics difficulties (PMD) include deficits in working memory, information retrieval, and attention regulation (e.g., Compton, Fuchs, Fuchs, Lambert, & Hamlett, 2012; Fuchs et al., 2006). These cognitive deficits may be more difficult to remediate than low achievement resulting from more transitory causes (e.g., being taught by a less skilled teacher during a particular grade). Students with PMD are also likely to display more generalized cognitive deficits than students with transitory MD (Geary, Hamson, & Hoard, 2000), further complicating intervention efforts. Children displaying PMD, particularly over one or two years, are very likely to remain poorly skilled in mathematics even when compared to peers with prior but transitory histories of MD (Morgan et al., 2009).

A Limited Knowledge Base about Persistent Mathematics Difficulties

Currently, researchers, policymakers, and practitioners know very little about which children are likely to experience PMD. The extant research mostly reports on risk factors for the occurrence of MD by a single time point (Murphy, Mazzocco, Hanich, & Early, 2007). Yet children identified as having MD at a single time point, which itself is often operationalized as scoring below a low cut off score on a single administration of an achievement measure, often do not display MD when subsequently re-assessed (Mazzocco & Myers, 2003; Murphy et al., 2007). Specifically, one-third to one-half of students who display MD at one time point do not display MD at a later time point (Mazzocco & Myers; Shalev, Manor, Auerbach, & Gross-Tsur, 1998; Silver, Pennett, Black, Fair, & Balise, 1999; Stock, Desoete, & Roeyers, 2010). These children’s observed MD may instead be the result of natural fluctuation in the growth of their mathematical knowledge, as well as measurement error (Fletcher, Denton, & Francis, 2005). Consequently, analyses based on MD measured at a single time point may not have accurately identified those children most at risk.. Identifying risk factors for PMD requires multi-year longitudinal studies in which PMD is operationalized as MD that occurs over more than one grade (Geary, 2011; Mazzocco & Myers, 2003).

Yet this type of longitudinal research on PMD is exceedingly rare. Although groundbreaking in many respects, the few available studies also have methodological and substantive limitations. Of those few studies available, most advance the field’s limited knowledge base by reporting on specific academic and cognitive deficits characterizing PMD (e.g., Stock, Desoete, & Roeyers, 2010; Toll, Van der Ven, Kroesbergen, & Van Luit, 2011). For example, Mazzocco and Myers (2003) reported that students with PMD were more likely to display reading disabilities. However, the full range of risk factors for PMD remains largely unknown. In part this is because the available studies have almost entirely relied on convenience samples. These samples likely do not generalize to the heterogeneous population of preschool- or school-aged children in the U.S. For example, Vukovic and Siegel's (2010) analyses were based on 99 Canadian students, only 26 of whom later displayed PMD, while Toll et al.'s (2011) analyses were based on 209 Dutch students, only 21 of whom later displayed PMD. Badian's (1999) data were collected from within a single school district and included relatively few children with PMD. Stock et al.'s (2010) analyses were based on a larger analytical sample of 464 students, but these students were all Dutch speaking and living in Belgium. Mazzocco and Myers' (2003) study were based on students in the U.S., but included only 22 students with PMD.

Consequently, generalization to the heterogeneous population of students attending preschools, elementary and middle schools in the U.S. is currently constrained. The extent to which a wide range of factors including those that are educationally policy-relevant (e.g., access to preschool, use of retention) and potentially malleable by practitioners (e.g., reading difficulties, inattention and other learning-related behavior problems) increases children's risk of PMD remains to be systematically investigated. Also largely unknown is whether particular population subgroups (e.g., racial/ethnic minorities, those from low socio-economic status [SES] families) may be at higher risk for later experiencing PMD. Prior work has sometimes (e.g., Jordan, Kaplan, Nabors Oláh, & Locuniak, 2006; Jordan, Kaplan, & Hanich, 2002), and sometimes not (e.g., Badian, 1999; Lachance & Mazzocco, 2006; Shalev et al., 2005) found that specific population subgroups are at increased risk of displaying lower mathematics achievement generally, or MD or PMD specifically. For example, prior work has sometimes reported that females are at greater risk for lower mathematics achievement or MD (e.g., Fryer & Levitt, 2010; Jordan et al., 2006). Yet Lachance and Mazzocco's (2006) analyses indicated that gender difference in mathematics are "minimal or nonexistent" (p. 195). Still other work finds that males are initially more likely to have mathematics disabilities, but that this relation is then explained by other factors (Geary et al., 2009). Whether females may be at risk for PMD has not been conclusively established. Statistical control for potential confounding factors has also been limited, resulting in inconclusive estimates of the risk attributable to any given factor (Badian, 1999).

Substantively, PMD (and MD generally) has mostly been investigated during only the elementary school grades (e.g., Jordan, Hanich, & Kaplan, 2003; Jordan et al., 2002; Stock et al., 2010; Vukovic & Siegel, 2010). Thus, risk factors for PMD across children's larger life course are unknown. One critical but currently unexplored developmental period is the time prior to kindergarten entry when young children's opportunities to acquire foundational mathematical knowledge (e.g., counting, number sense, adding small sums) are mostly provided through interactions with parents, siblings, and childcare providers (Galindo & Sheldon, 2012; LeFevre, Skwarchuk, Smith-Chant, Fast, Kamawar, & Bisanz, 2009). Yet children raised in low SES families may be especially likely to initially fail to acquire foundational mathematical knowledge as a result of being less likely to be provided with informal learning opportunities (Jordan & Levine, 2009). Whether and to what extent low SES and the attending lack of early informal learning opportunities increase very young children's risk for PMD by kindergarten entry is not well understood. For example, Badian (1999) reported that preschool children's SES was not significantly related to whether they later experienced PMD, although SES was related to their mathematics achievement more generally.

A second unexplored developmental period is the time between the later elementary grades and middle school. During this period, children are increasingly provided with formal learning opportunities involving algebra, geometry, and other types of precalculus mathematical skills. Mastering these "gateway" skills should allow for more advanced learning through high school instruction (e.g., National Mathematics Advisory Panel, 2008). Yet both are critically unexplored developmental time periods because, for either period, studies of risk factors for PMD, particularly using population-based, multivariate, longitudinal samples of U.S. children, have yet to be conducted. As a result, researchers, policymakers, and practitioners presently do not know what factors uniquely increase children's risk of experiencing PMD during either of these two developmental time periods. The field's capacity to prevent or remediate PMD would be substantially advanced if risk factors for PMD—particularly those that might be policy relevant and potentially malleable by educational systems—were identified through concurrent analyses of multi-year longitudinal, contextually rich, population-based datasets. Such analyses should better guide critical preschool- and school-based intervention efforts for children who may be at risk for PMD.

Educationally Relevant, Potentially Malleable Risk or Protective Factors for PMD

Factors hypothesized or reported to increase children's risk of PMD or MD include socio-demographic (e.g., low SES, race/ethnicity, gender), gestational (e.g., smoking or drinking during pregnancy) and birth (e.g., prematurity, low birthweight) characteristics (e.g., Aunola, Leskinen, Lerkkanen, & Nurmi, 2004; Badian, 1999; Lachance & Mazzocco, 2006; Taylor, Espy, & Anderson, 2009). Additional, policy relevant and potentially malleable risk factors include vocabulary difficulties prior to school entry, reading difficulties following school entry, inattention and other learning-related behavioral difficulties across both developmental periods, access to preschool, and use of retention

Difficulties in vocabulary acquisition during infancy and toddlerhood have been theorized to be a primary impediment to the acquisition of early mathematical concepts (Carey, 2004), including basic arithmetic retrieval (Geary, 1993). Yet other researchers consider vocabulary and other language difficulties as having a relatively secondary relation to MD (Gelman & Butterworth, 2005; Landerl, Bevan, & Butterworth, 2004). The limited empirical work suggests that vocabulary difficulties may increase children's risk of MD (Fuchs et al., 2006; Jordan, Levine, and Huttenlocher, 1995). Yet most of this work is based on a sample of relatively older (i.e., primary- and middle elementary-grade) students. It may be that the relation between vocabulary difficulties and mathematics difficulties emerges prior to school entry (Pappas & Ginsberg, 2003). For example, Purpura, Hume, Sims, and Lonigan (2011) reported that preschool-aged children's oral vocabularies uniquely predicted their mathematics achievement one year later, following extensive statistical control. In contrast, Badian (1999) reported that preschool children's language abilities were not significantly related to whether they later displayed PMD. Researchers have also theorized that reading difficulties (RD) should interfere with older children's learning of mathematics over time, especially when, in the later grades, such learning involves increasingly greater listening and reading comprehension demands, including listening to longer and more complicated verbal explanations by teachers and reading multi-step word problems in worksheets or textbooks (Geary, 2011; Grimm, 2008). Yet a relation between MD and RD has been observed in some (Mazzocco & Murphy, 2003; Jordan et al., 2002) but not other (Andersson, 2010) longitudinal studies. Barbaresi, Katusic, Colligan, Weaver, and Jacobsen (2005) reported that substantial percentages of children with mathematics disabilities did not display comorbid reading disabilities (i.e., 35–57%, depending on the identification method).

Inattention and other learning-related behavioral difficulties (e.g., task persistence, organization) may also impede children's learning of mathematics. This is because these behaviors may constrain children's information processing, listening comprehension during both informal and formal learning opportunities, and retrieval of numerical representations when completing a range of mathematics work (Diperna, Lei, & Reid, 2007; Geary et al., 1999). Fuchs et al. (2006) reported that 3rd grade children's learning-related behavioral difficulties were uniquely associated with lower performance in arithmetic, computation, and word problem solving. Geary, Hoard, Nugent, and Bailey (2012) found that elementary school-aged children with PMD were more likely to display learning-related behavioral difficulties than children without PMD. Yet Aunola et al. (2004) hypothesized these types of behaviors may be particularly important to mathematical learning during children's early years, "when basic skills are to be learned and automatized, but less so in the later phases, when the processes of problem solving have become automatized" (p. 709; also see Geary, 2013). Still others have hypothesized that the observed relation between learning-related behavioral difficulties and learning difficulties in mathematics may itself be spurious and instead result from a third, unmeasured factor, including lower general cognitive functioning (Conway et al., 2002, but see see Geary, Hoard, & Nugent, 2012). Identifying whether these behaviors, like vocabulary difficulties and RD, are risk factors for PMD is important because they are potentially malleable to early intervention efforts (Rabiner, Murray, Skinner, & Malone, 2010).

Attending childcare or preschool may increase children's mathematics achievement, and so decrease their later risk for PMD. This may occur because they may provide children raised in lower SES households or other at-risk environments with greater informal opportunities to learn mathematics than they may experience in their homes (Geoffroy et al., 2010). Children from lower-income families who are provided with informal learning opportunities at their childcare centers or preschools can then display the same learning gains as those from middle-income families (Ramani & Siegler, 2011). Melhuish et al. (2008) estimated an adjusted effect size of .26 on the mathematics achievement of children 10 years later if they had attended a higher quality preschool in the U.K. However, research in the U.S. sometimes indicates that preschool's long-term impact may be limited. Geoffroy et al. did not find that childcare attendance predicted greater mathematics achievement in 1st grade generally, although it did predict greater reading achievement (p=.02) and, marginally, greater mathematics achievement (p=.06) for those children raised by mothers with low levels of education. The recent Head Start evaluation yielded effect sizes of zero on at-risk children's 3rd grade mathematics achievement (Puma et al., 2012; Table 4.2). Yet these studies have yet to evaluate whether childcare or preschool attendance decreases the risk of PMD specifically.

Retention is sometimes believed to increase children's knowledge about basic skills, resulting in greater academic achievement over time (Tomchin & Impara, 1992). Yet existing research generally indicates that retention lowers academic achievement (Jimerson, 2001). Children retained in kindergarten have been reported to subsequently display lower mathematics achievement in the later primary grades (Hong & Raudenbush, 2005). However, whether and to what extent these negative effects maintain over time is unclear. For example, Hong and Yu (2007) reported that children who had been retained in kindergarten displayed the same level of mathematics achievement in 5th grade as peers who had not been retained.

Study's Purpose

We sought to identify who is at risk for PMD in the U.S. We addressed the extant work's methodological and substantive limitations by analyzing two multi-year longitudinal, contextually rich, population-based datasets of children. Analyses of these two datasets allowed us to investigate risk factors for PMD across two critical developmental periods—one representing young children's initial opportunities to learn mathematics (that is, prior to formally receiving instruction in schools) and the other period representing subsequent opportunities to learn mathematics while attending elementary and middle school. Because of each dataset's very large sample size, we were able to identify unusually large numbers of students ($n \approx 900$) displaying PMD. We were particularly interested in identifying how a range of socio-demographic, gestational, and birth characteristics (e.g., gender, racial/ethnic minority status, low SES, low birthweight) predicted children's likelihood of later experiencing PMD. Additionally, and by controlling for these and other potential strong confounds (e.g., a prior history of cognitive delay or MD), we investigated whether and to what extent specific and potentially malleable learner characteristics (e.g., a prior history of vocabulary difficulties, RD, or inattention and other learning-related behavioral difficulties) and policy-relevant factors (e.g., attendance in Head Start or other center-based care, use of retention) increase children's risk of experiencing PMD and so might be targeted by educational practitioners and policymakers.

General Method

Overview

For Study 1, we examined the predicted effects of 24-month old children's socio-demographics, gestational and birth characteristics, access to preschool, and prior histories of cognitive delays, vocabulary difficulties, and learning-related behavioral difficulties on their risk for PMD at both 48 and 60 months. For Study 2, we examined the predicted effects of kindergarten children's socio-demographics, birth and gestational characteristics, attendance in Head Start or other center-based care, prior history of learning difficulties in reading and mathematics, prior history of inattention and other learning-related behavioral difficulties, and grade retention, as measured in the spring of kindergarten, on their risk of displaying PMD in 3rd, 5th, and 8th grade. Both Study 1's and Study 2's datasets (i.e., the Early Childhood Longitudinal Study-Birth 2001 and -Kindergarten 1998–1999 Cohort, or ECLS-B and ECLS-K, respectively) are maintained by the U.S. Department of Education's National Center for Education Statistics (NCES).

Persistent mathematics difficulties—Children in Study 1 were identified as displaying PMD if they scored approximately in the bottom 25% of both the 48- and 60-month administrations of the ECSL-B Mathematics Test. Children in Study 2 were identified as displaying PMD if they scored approximately in the bottom 25% in the springs of 3rd, 5th, and 8th grade administrations of the ECLS-K Mathematics Test. About 16% of Study 1's and, separately, Study 2's analytical sample were classified as having PMD. A 25% cut off is a widely used single-year criterion for identifying students as MD (for a review, see Murphy et al., 2007).[1]

Missing Data

We used multiple imputation to account for missing data in both the ECLS-B and -K. Specifically, and for each analytical dataset, we imputed 5 (complete) data sets, estimating models separately for each completed data set, and then combining these estimates into a single set of estimates using mathematically-derived formulas (Little & Rubin, 2002). Only observations with missing independent (predictor) variables had those values imputed; cases with missing outcome variables were deleted.

Data Analysis

We used logistic regression to identify early risk factors for later PMD. The criterion variable in Study 1 was PMD at both 48 and 60 months; for Study 2 it was PMD at 3rd, 5th, and 8th grade. Predictor variables in Study 1 were measured by 24 months; in Study 2 these were measured in the spring semester of kindergarten. Logistic regression produces odds ratios (*OR*s) as effect sizes.

Study 1

Database and Analytical Sample

Study 1 analyzed data from the ECLS-B. The ECLS-B is a cohort of children born in the year 2001.[2] Children participating in the ECLS-B include those from diverse socioeconomic and racial/ethnic backgrounds, oversamples of Asian and Pacific Islanders, Native Americans and Alaska Natives, those born with low- (1,500–2,500 g) and very-low-birthweight (< 1,500 g), and those who were twins or of multiple births. The ECLS-B

[1]To further examine the robustness of our results, we predicted PMD using an alternative cutoff of 10% and the NCES-constructed 5-factor (occupations and education levels of the child's parents, family income). Results (available from the study's first author) were highly consistent with those reported here.

[2]All sample sizes reported for the ECLS-B data have been rounded to the nearest 50, as specified by ECLS-B data confidentiality requirements (see http://nces.ed.gov/ecls/birthdatainformation.asp).

includes direct measures of children's early cognitive, academic, behavioral, and physical functioning, as well as indirect interviews with family members their children's cognitive, academic, and behavioral functioning, care, and education from birth through kindergarten entry. Table 1 displays this analytical sample's (*N*=5,950) background characteristics (with *M*s but not *SD*s weighted). We used the NCES-constructed sample weight w4c0 to obtain nationally representative estimates.

Measures

Persistent Mathematic Difficulties—Preschool-aged children were identified as displaying PMD based on their scores on the ECLS-B Mathematics Test (i.e., a score in the bottom 25% the distribution at both the 48 and 60 month survey waves). The content of the ECLS-B Mathematics Test used frameworks established by Brush, Salinger, Sussman, and Kirshstein (2003). The 60-month version of the ECLS-B Mathematics Test was based on the ECLS-K Mathematics Test (described below). Measured mathematics constructs included (a) number sense, properties, and operations, (b) measurement, (c) geometry and spatial sense, (d) data analysis, statistics, and probability, and (e) patterns, algebra, and functions. Items measuring these five constructs were either selected from published instruments (e.g., Test of Early Mathematical Ability-3, or TEMA-3; Ginsburg & Baroody, 2003), or from the ECLS-K, or were developed specifically for the ECLS-B. Correlations between the ECLS-B Mathematics Test and the Bracken Basic Concept Scale-Revised were moderate but supportive given their dissimiliar content allocations (range = .54–.75). Both the 48- and 60-month tests were individually administered, untimed, and adaptive. Routing procedures and item response theory (IRT) methods were used to build a vertical scale so that scores from the 48- and 60-month administrations of the Mathematics Test could be calibrated on the same metric (NCES, 2010). The internal consistency reliability of the 48- and 60-month IRT-based scores was .89 and .92, respectively.

Cognitive Delay—We used children's mental scale scores on the 24-month administration of the Bayley Short Form-Research Edition (BSF-R), a modified version of the Bayley Scales of Infant Development, Second Edition (BSID-II; Bayley, 1993), to identify children displaying delays in general cognitive functioning. The R^2 between BSF-R and BSID-II scores was .99. The mental scale of BSF-R is an individually-administered measure of children's age-appropriate cognitive functioning as manifested in memory, habituation, preverbal communication, problem-solving and concept attainment. The ECLS-B field staff rated children as they completed specific tasks measuring their general cognitive functioning (e.g., "look for contents of a box," "put three cubes in a cup"). The IRT reliability coefficient for the BSF-R mental scale at 24 months was .88 (NCES, 2007). We identified those children who scored in the lowest 25% of the score distribution at the age of 24 months as having low general cognitive functioning, and thus of displaying cognitive delay (e.g., Hillemeier et al., 2009).

Vocabulary Difficulties—We used children's word scores on a modified version of the MacArthur Communication Development Inventory (M-CDI, Fenson et al., 1994), which was included in the parent interview during the ECLS-B home visit at 24 months, to identify those displaying delayed vocabulary knowledge. The modified M-CDI selected a representative sample of 50 words typically known and said by children in the target age range (e.g., "meow," "shoe," "mommy," "chase"). Parents were asked whether their children could say the targeted vocabulary words (NCES, 2007). The modified M-CDI was recently reported to classify children into language status groups with 97% accuracy (Skarakis-Doyle, Campbell, & Dempsey, 2009). Children who had a total score in the lowest 25% of the word score distribution were categorized as having low word scores, and thus displaying vocabulary difficulties (e.g., Sauer, Levine, & Goldin-Meadow, 2010; Thal, 1991).

Learning-related Behavioral Difficulties—We used ECLS-B field staff's ratings of the children's self-regulation on the Behavior Rating Scale-Research Edition (BRS-R) to identify 24-month-olds displaying learning-related behavioral difficulties. The BRS-R was adapted from the Behavior Rating Scale (BRS, Bayley, 1993) and included 11 interviewer-rated items from the full BRS at the 24 month ECLS-B assessment. These items measured developmentally appropriate behaviors for 24-month-old children (NCES, 2006a) including attention to task, persistence, cooperation with an examiner, interest in the testing materials, and frustration. Raikes et al. (2007) reported a Cronbach's alpha of .92 for the BRS's self-regulatory items. Scores on the BRS were also found to moderately-to-highly correlate with scores on other measures of young children's socio-emotional adjustment (Buck, 1997). Field staff rated children on each of the behaviors in the BRS-R using a 5-point frequency scale (e.g., 1 = "constantly off task," 5 = "constantly attends") while the children completed the BSF-R's cognitive and physical tasks. In these analysis, we summed scores on the specific behaviors of "attention to task", "persistence", and "interest in the testing materials." Children with scores in the lowest 25% of the score distribution of the summed score were coded as frequently displaying learning-related behavioral difficulties.

Socio-demographic, Gestational and Birth Characteristics—Socio-demographic data were collected through parental surveys and children's birth certificates. Age in months was included to control for variations in actual age at the assessment administrations. For child's gender, we used female as the reference category. For race/ethnicity, we used non-Hispanic White as the reference group, and compared this group to non-Hispanic Black, Hispanic, and children of other racial and ethnic backgrounds. We also used indicators of the mother's marital status (mother married vs. unmarried at child's birth), age at child's birth (under 18 years old, 18–35 years old, or greater than 35 years old), and an index of household SES stratified by quintile (with, for this variable, the reference group being the highest quintile), estimated using parental surveys of parental education, occupation, and household income.

We analyzed data collected on children's gestational and birth characteristics from their birth certificates. Birthweight was indicated by dichotomous variables for very low birthweight (≤1500 grams) and moderately low birthweight (1,501–2,500 grams), contrasted with birthweight >2,500 grams. Birth certificate records also provided data on medical risk factors during pregnancy (quantified as a count of problems present including incompetent cervix, acute or chronic lung disease, chronic hypertension, pregnancy-induced hypertension, eclampsia, diabetes, hemoglobinopathy, cardiac disease, anemia, renal disease, genital herpes, oligohydramnios, uterine bleeding, Rh sensitization, previous birth weighing

4,000+g, or previous preterm birth), behavioral risk factors during pregnancy (alcohol and tobacco use during pregnancy, coded as 1 if present and summed to form a scale that ranged from 0 to 2), obstetrical procedures (measured as a count of procedures including induction of labor, stimulation of labor, tocolysis, amniocentesis, and cesarean section), labor complications (measured as a count of complications including abruption placenta, anesthetic complications, dysfunctional labor, breech/malpresentation, cephalopelvic disproportion, cord prolapsed, fetal distress, excessive bleeding, fever of > 100°F, moderate/heavy meconium, precipitous labor (< 3 h), prolonged labor (> 24 h), placental previa, or seizures during labor), and presence of any congenital anomaly.

Early Child Care and Preschool Attendance, Disability Status—We included parent-reported information in our analyses about whether or not children (a) had attended Head Start or other center-based childcare or preschool at 48 months, or (b) had an identified delay or disability, as indicated by parent survey of service receipt through an Individual Family Services Plan (IFSP) or Individualized Education Program (IEP) at 48 months.

Analytical Strategy

Children's socio-demographics, gestational and birth characteristics, as well as prior histories of delays in general cognitive functioning, vocabulary, or learning-related behavioral functioning were entered into four regression models sequentially so that their unique contributions above and beyond the other predictors could be estimated. Study 1's (and Study 2's) analyses included predictors that have been previously identified as early risk factors for later MD (e.g., Aunola et al., 2004; Hagen, Palta, Albanese, & Sadek-Badawi, 2006; Jordan, Kaplan, Locuniak, & Ramineni, 2007; McClelland, Acock, & Morrison, 2006; Taylor et al., 2009). The final model (i.e., Model 4) helps identify to what extent these additional and potentially malleable learner characteristics raise or lower young children's risk for PMD, over and above the risk associated with socio-demographic, gestational, and birth characteristics included in the prior models (i.e., Models 1–3). All continuous predictor variables have been standardized (*Z*-scored) to facilitate effect size contrasts.

Results and Discussion

Table 2 displays the results from the logistic regressions models. Model 1 indicates that the odds that 24-month-old children with cognitive delay will experience PMD at 48 and 60 months of age are almost 4 times larger than for those without cognitive delay. Model 2 adds socio-demographic characteristics to the equation. Monotonic and very large predicted effects of low family SES are observed. Being in the lowest SES quintile raises the odds of PMD by a factor of almost 13 over the odds for the highest SES quintile. Odds for the other quintiles are also high. With these variables controlled, the odds ratio attributable to a prior history of cognitive delay decreases to about 3:1.

Model 3 adds gestational and birth characteristics to the equation. Children who are born with very low or moderately low birthweight are more likely to experience PMD. Model 4 adds a prior history of vocabulary difficulties, learning-related behavioral difficulties, whether the child was identified as delayed or disabled (was given an IEP), and whether the child attended no center care, Head Start, or non-Head Start center care. Both vocabulary difficulties and having an identified delay or disability increase the risk of PMD. Both Head Start and non-Head Start center attendance decrease this risk. These preschool center care variables have large, adjusted odds ratios of .60 and .49 for Head Start and non-Head Start center attendance respectively. Attending either approximately halves the risk of PMD. The coefficients in Model 4 of Table 2 show that the positive effects of preschool center based care on the risk of PMD effectively balance out the negative effects of 24-month cognitive delay.

Study 1 identifies risk factors for PMD prior to and by school entry, during a developmental period when children are initially learning about mathematics through informal interactions with parents, siblings, and childcare providers. Yet do these same types of risk factors remain predictive of PMD for children who are attending elementary and middle school? Study 2 uses the ECLS-K data to investigate this question by identifying factors, as measured by the spring of kindergarten, that increase children's risk of subsequently experiencing PMD until the end of 8^{th} grade.

Study 2

Database and Analytical Sample

Study 2 analyzed data from the ECLS-K. The ECLS-K is a nationally representative sample of children as they age through elementary and middle school. NCES recruited children attending both public and private schools offering full- or half-day kindergarten classes in 1998–1999. Data from these students were initially collected in the fall of 1998 when they entered kindergarten, and subsequently in the spring of 1999 and the fall of 1999 (from only a random subsample of students at this time point), and again in the spring of 2000, 2002, 2004, and 2007). This corresponded to data collection for most children during their kindergarten and 1^{st}, 3^{rd}, 5^{th}, and 8^{th} grade school years. We analyzed data from an analytical sub-sample of children ($N = 8{,}411$) who had Mathematics Test scores across the survey waves and other relevant variables available for each of the years under study. We used the NCES-constructed sampling weight c2_7fc0 to obtain nationally representative estimates.

Measures

Mathematics Difficulties, Persistent Mathematics Difficulties—We used scores from the ECLS-K Mathematics Test to identify children displaying MD by the spring of their kindergarten school year, as well as to identify children who were displaying PMD in 3^{rd}, 5^{th}, and 8^{th} grade (i.e., a score in the bottom 25% of the score distribution). The ECLS-K Mathematics Test is an individually administered, untimed measure based on the National Assessment of Educational Progress (NAEP). The Mathematics Test's content includes a wide range of age- and grade- appropriate mathematics skills (e.g., identify numbers and shapes, sequence, add, subtract, multiply, or divide, use rates and measurements, use fractions, calculate area and volume). All items were field tested. IRT methods were used to scale scores from different test form administrations and different grade levels to make the Mathematic Test scores comparable across time points (NCES, 2006b). Reliabilities of the

IRT scaled scores ranged from .91 to .95 (NCES, 2009). Those whose scores on the spring of kindergarten administration of the Mathematics Test were in the lowest 25% of the score distribution were identified as displaying MD. (We chose to use spring rather than fall test scores so as to identify children having mathematics learning difficulties even after receiving a year of school-based math instruction. This is also consistent with the fact that the achievement measure analyzed for the higher grades were all administered in the spring.)

Reading Difficulties—Scores on the Reading Test were used to identify kindergarten children displaying RD. The ECLS-K Reading Test is an individually administered, untimed measure of children's basic skills (e.g., print familiarity, letter recognition, decoding, sight word recognition), vocabulary knowledge (receptive vocabulary), and comprehension (e.g., making interpretations, using personal background knowledge). The Reading Test includes items borrowed or adapted from published tests (e.g., the Peabody Picture Vocabulary Test–Revised, the Woodcock-Johnson Tests of Achievement–Revised). The Educational Testing Service, elementary school curriculum specialists, and practicing teachers supplied other items. All items were field tested. Reliability of the IRT-scaled scores for the spring of kindergarten Reading Test administration is .95 (NCES, 2009). Consistent with prior work (e.g., Fletcher et al., 1994; Locuniak & Jordan, 2008), we identified those children whose scores were in the lowest 25% of the score distribution on the spring of kindergarten Reading Test administration as experiencing RD.

Learning-related Behavioral Difficulties—We also used the frequency with which kindergarten teachers rated students as engaging in learning-related behaviors as a predictor of later PMD. The frequency of these behaviors (1 = *never;* 4 = *very often*) was rated by kindergarten teachers using the Approaches to Learning subscale of the Social Rating Scale, a modified version of the Social Skills Rating System (Gresham & Elliott, 1990). The items in this subscale are as follows: (a) remains attentive; (b) persists at tasks; (c) is flexible; and (d) and is organized. This subscale had a reliability of .89 (NCES, 2004). We considered those students whose teacher ratings were in the lowest 25% of the score distribution on the Approaches to Learning subscale as displaying learning-related behavioral difficulties (e.g., Hwang & James-Roberts, 1998).

Socio-demographic and Birth Characteristics—We used additional background variables, such as children's age, race, gender, birth characteristics (e.g., birth weight, mother's age at birth), and an index of household socioeconomic status stratified by quintile, based on surveys of parental education, occupation, and household income, to analyze to what extent these socio-demographic and birth characteristics predicted kindergarten children's risk of experiencing PMD. The continuous age variable indicated children's age in months at the start of kindergarten. The race variable indicated whether children were parent-identified as non-Hispanic White, non-Hispanic Black/African American, Hispanic, or Other. We combined all other races into the category "Other." and their mother's age at birth (<18, >35 years) as additional risk factors.

Disability Status—We included parent-reported information surveyed in kindergarten about whether or not children had attended Head Start or other center-based care.. This information was collected by ECLS-K field staff, who asked schools whether each child had an IEP, IFSP, or a 504 plan on file with the school district. Information was also collected from school personnel about whether or not the child was retained in grade between kindergarten and 1st grade, or between 1st grade and 3rd grade.

Analytical Strategy

We again estimated four sequential logistic regression models. Model 1 includes only children's prior history of MD. In addition to functioning as a strong statistical control, inclusion of this autoregressor allowed us to identify the relative stability of MD from kindergarten to the end of 8th grade. Including the autoregressor also helped us to more rigorously estimate the predicted effects of Study 2's additional risk factors, as well to control for invariant omitted variables. Model 2–3 adds socio-demographic characteristics, children's prior history of RD, prior history of frequently engaging in learning-related behaviors problems, having an IEP by the spring of 1st grade, and ever having been retained in grade by 3rd grade as risk factors. We used HLM with a logit link function to perform regressions that statistically adjusted for the spatially clustered nature of the sample design (i.e., students within schools). All continuous predictor variables were standardized (*Z*-scored) to facilitate effect size comparisons.

Results and Discussion

Table 4 presents the estimates from the four logistic regression models. Model 1 indicates that a prior history of MD has a very strong predicted effect on children's risk of later PMD. Specifically, experiencing MD by the spring of kindergarten increases children's odds of experiencing PMD throughout elementary and middle school by a multiplicative factor of almost 17. This is more than four times larger than the strong effect of prior history of cognitive delays estimated in Study 1 and is the largest effect found in any of our analyses. Thus MD begins early on to be very strongly predictive of later PMD. Children in the bottom 25% of the mathematics achievement distribution during the spring of kindergarten are 17 times more likely than their classmates to exhibit PMD in grades 3rd, 5th, and 8th.

Model 2 adds the socio-demographic factors to the regression equation. Males are less likely than females to experience PMD. Children who were older at the kindergarten assessment, or came from low SES families are more likely to later display PMD. It is noteworthy that even after controlling for the strongly predictive prior history of MD and other variables, the odds that children from the lowest SES quintile will experience PMD are 8 times higher than those from the highest quintile. As reported in Study 1, low SES also strongly predicts elevated risk of PMD in preschool and kindergarten. This is again observed in Study 2, after statistically controlling for a prior history of MD and Model 2's other predictors. This continuous and powerful effect of social class background on PMD is a striking finding, especially given the very early onset of the associated risk. Model 2 also shows that with these controls, children who are Black are more likely than White children, and Hispanic children are less likely than White children to experience PMD.

Model 3 adds additional learner characteristics and whether or not the student attended Head Start or non-Head Start preschool to the equation. Reading difficulties and learning-related behavioral difficulties each uniquely increase kindergarten children's risk of PMD. Controlling for these variables decreases the odds ratio for a prior history of MD by about half, from 13.19 to 7.6. Thus, and although an earlier history of MD and low SES remain the strongest predictors of later PMD, a prior history of either RD or learning-related behavioral difficulties, being disabled, or retained in grade, also strongly predicts an increased risk of PMD. Study 2's analyses indicate that attending preschool care is no longer a protective factor for later PMD when measured from 3^{rd}–8^{th} grade.

Study 2's results indicate that students experiencing MD as kindergarteners are at greatly increased risk of experiencing MD as 3^{rd}, 5^{th}, and 8^{th} graders. Those most likely to experience PMD throughout these grades are those experiencing the onset of MD by the end of kindergarten. Statistically controlling for a prior history of MD and other variables, being from a low SES family is the next greatest risk factor for later PMD. The risk for low SES is observable prior to and immediately following kindergarten entry. Additional educationally relevant risk factors for PMD include RD, a prior history of learning-related behavioral difficulties, being retained, and being disabled.

Summary and Concluding Discussion

Results from our studies extend the field's limited knowledge base about PMD in at least four important ways. First, some but not other socio-demographic characteristics of children and their families are reliably associated with the incidence of PMD during both developmental periods. In particular, low family SES is an overwhelmingly important predictor of PMD during the preschool, elementary, and middle school time periods. The few available longitudinal studies have largely been based on small convenience samples, typically of non-U.S. students, limiting the knowledge base about which population sub-groups are most at risk of later experiencing PMD in the U.S. Prior work has reported inconsistent findings as to whether low SES increases children's risk of MD or mathematics disabilities (Badian, 1999; Shalev et al., 2005). In contrast, and across both Study 1 and Study 2, we observed a monotonic and increasingly strong relation between the lower SES quintiles and children's risk of PMD. Prior work has sometimes reported that females are at greater risk for lower mathematics achievement or MD (e.g., Fryer & Levitt, 2010; Jordan et al., 2006, but see Lachance & Mazzocco, 2006). Yet it has also been reported that males may be far more likely to have mathematics disabilities, but that this relation is then explained by other factors (Geary et al., 2009). Whether females may be at risk for PMD has not been conclusively established. Our study extends this prior work by establishing that, by kindergarten, females are at greater risk for PMD and that this risk is not attributable to other measured confounds. We found that students with disabilities were very likely to be experiencing PMD, with this elevated risk evident across both developmental periods and despite extensive covariate adjustment.

Second, we found that low birthweight increased children's risk of entering kindergarten with PMD. However, and importantly, we found that both Head Start and non-Head Start center care significantly reduced PMD at 48 and 60 months of age, although this was not observed for PMD when measured at 3^{rd}, 5^{th} and 8^{th} grade. Consequently, increased access to preschool care may act to provide children, including those born low birthweight, with increased learning opportunities that help at least initially to reduce their risk for PMD. However, additional supports may need to be provided to at-risk children as they continue throughout elementary and middle school.

Third, a small number of additional learner characteristics, which could be targeted in multi-faceted preschool- or school-based early intervention efforts, predicted PMD. These educational policy- and practice-relevant factors included vocabulary difficulties, RD, and inattention and other learning-related behavioral difficulties. Finally, the risk associated with this small set of socio-demographic and learner characteristics, including low SES, vocabulary difficulties, RD, and learning-related behavioral difficulties, was very robust. This is because these factors remained predictive of later PMD (which, in both studies, was observed beginning two years later) despite extensive statistical control, including potential confounds including delayed cognitive functioning or a prior history of MD—factors that themselves greatly elevate children's risk for PMD.

Limitations

This study is limited by the study designs of the ECLS-B and -K. One resulting limitation is that some (e.g., learning-related behavioral difficulties) but not all the factors of interest could be evaluated across both developmental time periods. For example, Study 1 does not include a statistical control for a prior history of MD, but instead controls for a prior history of cognitive delay, while Study 2 includes a control for a prior history of MD but not also of cognitive delay. In part these are developmental considerations, as RD and MD would not be expected to manifest as early as 24 months of age. However, estimates of the contribution of cognitive delay, vocabulary difficulties, RD, and MD, as well as a range of socio-demographic, gestational, and birth characteristics, have previously been unavailable, particularly as derived from population-based, multivariate, longitudinal samples of U.S. children in which PMD was later identified over multiple years. We also were unable, as has been reported on in other studies (e.g., Toll et al., 2011; Vukovic & Siegel, 2010), to evaluate those precursor academic or cognitive impairments (e.g., poor counting ability, working memory deficits) that might be contributing to the occurrence of PMD observed in the ECLS-B and -K samples, or fully investigate the risk for delays in acquiring specific mathematical subskills. Although our secondary data analyses allow for hypothesis generation, they do not allow for unambiguous causal inferences. This is because our analyses are based on non-experimental data. Studies using experimental designs are necessary to establish whether and to what extent positively impacting the potentially malleable factors identified here as predictive of PMD subsequently decreases the incidence of PMD. Our analyses are based on individual levels in relative mathematics achievement instead of absolute levels when estimating children's risk of PMD. Because of this and time limitations in the ECLS-B and –K data collection, we are unable to report on risk factors for below minimal levels of mathematics achievement that may be necessary for college completion, gainful employment, and other life-course outcomes.

Contributions and Implications

Our study has both theoretical and practical implications. To date, the contribution of specific socio-demographic and learner characteristics and policy-relevant variables to the occurrence of PMD has largely been unknown, with inconsistent theoretical positions or empirical findings sometimes being reported. Few longitudinal studies of PMD have been conducted, despite calls for this type of research (e.g., Geary, 2011). The majority of existing studies, which are based on the one time occurrence of MD, have been identified as methodologically flawed (e.g., Mazzocco & Myers, 2003). To date, low family SES has been theorized to strongly contribute to later differences in children's learning particularly in reading (e.g., Hart & Risley, 1999), yet its contribution to PMD has rarely been directly assessed. When evaluated, contradictory findings regarding its relation to learning failure in mathematics have sometimes been reported (Badian, 1999; Shalev et al., 2005). One might expect that children raised in low SES households would only be more likely to experience PMD prior to school entry, when their opportunities to informally learn mathematics might be constrained. Yet our analyses indicate that this is not the case. Instead, low family SES is strongly predictive of PMD throughout both very early and early-to-middle childhood. Kindergarten children in the U.S. who are raised in low SES families are at risk for later experiencing PMD despite subsequently receiving many years of school-based instruction. Thus, school-based instruction, at least as presently delivered, does not seem to be "counteracting" the risk of PMD attributable to being raised by low SES parents. Similarly, the contribution of vocabulary difficulties to PMD has not been extensively studied, although some researchers theorize that vocabulary and other language learning is centrally related to children's acquisition of early mathematical knowledge while others conclude that it has only a secondary relation (Carey, 2004; Gelman & Butterworth, 2005; Geary, 1993; Landerl et al., 2004). Our analyses indicate that vocabulary difficulties predict PMD, and this relation occurs prior to school entry and remains evident even when also controlling for delays in general cognitive functioning and other strong confounds. Further, a strong relation between RD and MD has been observed in some studies (Jordan et al., 2002; Mazzocco & Murphy, 2003), but not others (Barbaresi et al., 2005; Andersson, 2010). Our analyses indicate that RD is a significant and unique predictor of PMD, and an RD-PMD relation is evident even after extensive statistical control, including for a prior history of MD. Children's capacity to maintain attention and engage in other learning-related behaviors has been hypothesized to have a relatively time-specific relation to mathematical learning. That is, these behaviors have been considered to be more important during children's early years, when they are attempting to learn basic skills (e.g., counting, adding small sets), but less so as they age, when problem solving processes become more automatized (Aunola et al., 2004). Other researchers have hypothesized that observed relations between attention and learning difficulties may itself be spurious and instead result from a third, unmeasured factor, including general cognitive functioning (Conway et al., 2002), or are related to MD generally instead of interfering with particular types of mathematics skills (Geary, 1993). We find that inattention and other learning-related behavioral difficulties increase children's risk of PMD throughout elementary and middle school (up to the end of 8^{th} grade), and that this relation is robust to statistical control for prior experience of MD as well as many additional confounds, including a prior history of reading difficulties. However, this relation is not evident prior to this time and following statistical control for lower cognitive functioning. Our findings extend those of Geary, Hoard, and Nugent (2012) as well of others (e.g., Duncan et al., 2007) by establishing that learning-related behavior problems are a risk factor for PMD specifically.

Our findings also have practical implications, particularly given prior work indicating that lower levels of mathematics achievement increase the likelihood of unemployment (Bynner, 1997) as well as socio-emotional maladjustment (Lin et al., 2013; Morgan et al., 2012). Findings from both Study 1 and 2 provide some indication of potentially malleable factors that might be included in subsequent interventions to prevent or remediate PMD. For preschool students, interventions may need to target low general cognitive functioning and, in addition, vocabulary difficulties. The odds ratios uniquely associated with Head Start and non-Head Start preschool center participation on reduced PMD risk at 48–60 months suggest that these centers may be successfully targeting many of these domains—at least initially. For elementary school students, these multi-faceted interventions may need to target RD as well as MD, and, again, the frequency of attention and other learning-related behaviors. Early screening, identification, and intervention is likely necessary if children with PMD are to experience greater educational and societal opportunities over their later life course.

Acknowledgments

Funding for this study was provided by the National Center for Special Education Research, Institute of Education Science, U.S. Department of Education (R324A070270, R324A120046). Infrastructure support was provided by the Penn State Population Research Institute through funding from the National Institute of Child Health and Human Development, National Institutes of Health (R24HD041025-11). No official endorsement should thereby be inferred.

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Table 1

Descriptive Statistics of the ECLS-B Analysis Sample, Weighted.

	M or % (SD)
Bayley Score at 24 Months	127.6 (10.2)
Child's Age at 60 month Assessment	64.8 (3.7)
Child is Male	50.5 %
Lowest SES Quintile at 48 Months	17.7 %
Second Lowest SES Quintile at 48 Months	20.3 %
Middle SES Quintile at 48 Months	21.2 %
Second Highest SES Quintile at 48 Months	20.4 %
Highest SES Quintile at 48 Months	20.4 %
Mother's Age at Birth > 35 years	14.0 %
Mother's Age at Birth < 18 years	3.7 %
Mother Not Married at Child Birth	31.8 %
Child is White	55.5 %
Child is African-American	14.2 %
Child is Hispanic	22.7 %
Other	7.6 %
Child's Birth Weight < 1500 grams	1.2 %
Child's Birth Weight 1500 to 2500 grams	6.2 %
Labor Complications	28.3 %
Medical Risk Factors	15.1 %
Behavioral Risk Factors	11.7 %
Obstetric Procedures	48.2 %
Congenital Anomalies	5.0 %
Word Score at 24 Months	29.5 (11.7)
Approaches to Learning at 24 Months	14.1 (3.5)
IEP/IFSP at 48 Months	4.5 %
Head Start at 48 Months	15.4 %
Center Based Care at 48 Months	54.8 %
Mathematics Test Score at 48 month Assessment	29.3 (9.5)
Mathematics Test Score at 60 month Assessment	40.9 (10.5)

N=5,950. Population rounded in accordance with IES security restrictions.

Table 2

Multiple Logistic Regression Models of 48–60 Month Repeated Mathematics Difficulty Using 24 Month Predictors, ECLS-B Data (Odds Ratios)

	Model 1	Model 2	Model 3	Model 4
Cognitive Delay at 24 Months	3.64 ***	2.76 ***	2.68 ***	1.94 ***
Child's Age at 60 month Assessment		0.79 ***	0.79 ***	0.80 ***
Child is Male		1.22	1.25 *	1.15
Lowest SES Quintile at 48 Months		12.59 ***	12.44 ***	10.08 ***
Second Lowest SES Quintile at 48 Months		6.87 ***	6.79 ***	5.55 ***
Middle SES Quintile at 48 Months		4.79 ***	4.79 ***	4.29 ***
Second Highest SES Quintile at 48 Months		2.90 **	2.90 ***	2.75 **
Mother's Age at Birth > 35 years		0.99	0.96	0.95
Mother's Age at Birth < 18 years		1.41	1.39	1.42
Mother Not Married at Child Birth		1.17	1.16	1.19
Black		1.12	1.10	1.23
Hispanic		1.27	1.28	1.32
Other		1.09	1.09	1.12
Child's Birth Weight < 1500 grams			2.26 ***	1.94 ***
Child's Birth Weight 1500 to 2500 grams			1.64 ***	1.64 ***
Labor Complications			0.85	0.85
Medical Risk Factors			0.99	0.96
Behavioral Risk Factors			1.07	1.05
Obstetric Procedures			1.01	1.02
Congenital Anomalies			0.81	0.77
Low Word Score at 24 Months				1.50 **
Low Approaches to Learning at 24 Months				1.31
IEP/IFSP at 48 Months				2.32 **
Head Start at 48 Months				0.60 **
Center Based Care at 48 Months				0.49 ***

Note: N=5,950.

* $p < 0.05$;

** $p < 0.01$;

*** $p < 0.001$.

Population rounded in accordance with IES security restrictions. 25.9% lowest = Low Word Score; 22% lowest = Low Approaches to Learning; 25% lowest = Low Bayley. Multiple imputation used, regression weighted, and complex sample design used. PMD= 15.6%

Table 3

Descriptive Statistics of the ECLS-K Analysis Sample, Weighted.

	M or % (SD)
Mathematics Test Score at Spring Kindergarten	36.4 (11.9)
Child Age at Spring 1st Grade	86.9 (4.2)
Child is Male	51.7 %
Lowest SES Quintile at 1st Grade	18.0 %
Second Lowest SES Quintile at 1st Grade	19.6 %
Middle SES Quintile at 1st Grade	19.4 %
Second Highest SES Quintile at 1st Grade	21.3 %
Highest SES Quintile at 1st Grade	21.7 %
Mother's Age at Birth > 35 years	12.7 %
Mother's Age at Birth < 18 years	1.8 %
Mother not Married at Spring 1st Grade	29.9 %
Child is White	57.5 %
Child is Black	17.0 %
Child is Hispanic	18.2 %
Child is Other Race	7.3 %
Child's Birth Weight < 1500 grams	0.9 %
Child's Birth Weight 1500 to 2500 grams	7.0 %
Reading Test Score at Spring Kindergarten	46.4 (13.9)
Approaches to Learning at Spring Kindergarten	3.1 (0.7)
IEP/IFSP/504 at Spring 1st Grade	8.6 %
Ever in Head Start	17.3 %
Ever in Center Based Care	60.9 %
Child Retained in Grade at 3rd Grade	2.4 %
Mathematics Test Score at 3rd Grade	99.0 (25.0)
Mathematics Test Score at 5th Grade	122.7 (25.5)
Mathematics Test Score at 8th Grade	139.2 (23.3)

N=8,411

Table 4

Multiple Logistic Regression Models of Kindergarten Predictors of PMD for 3rd, 5th, and 8th grade, ECLS-K Data (Odds Ratios)

	Model 1	Model 2	Model 3
Low Mathematics Test Score at Spring Kindergarten	16.84 ***	13.19 ***	7.60 ***
Child Age at Spring 1st Grade		1.04 *	1.04
Child is Male		0.68 *	0.48 ***
Lowest SES Quintile at 1st Grade		8.19 ***	6.43 ***
Second Lowest SES Quintile at 1st Grade		4.86 ***	4.23 ***
Middle SES Quintile at 1st Grade		3.67 ***	3.43 ***
Second Highest SES Quintile at 1st Grade		2.25 **	2.17 **
Mother's Age at Birth > 35 years		1.35	1.32
Mother's Age at Birth < 18 years		1.50	1.37
Mother not Married at Spring 1st Grade		1.12	1.03
Child is Black		1.87 ***	1.87 **
Child is Hispanic		0.65 **	0.73
Child is Other Race		1.04	1.10
Child's Birth Weight < 1500 grams		0.73	0.48
Child's Birth Weight 1500 to 2500 grams		1.35	1.44
Low Reading Test Score at Spring Kindergarten			1.84 ***
Low Approaches to Learning at Spring Kindergarten			2.54 ***
IEP/IFSP/504 at Spring 1st Grade			2.16 ***
Ever in Head Start			1.28
Ever in Center Based Care			0.93
Child Retained in Grade at 3rd Grade			2.26 *

Note: N=8,411,

* $p < 0.05$;

** $p < 0.01$;

*** $p < 0.001$.

Low Spring Kindergarten Mathematics Score < 24%, weighted; Low Spring Kindergarten Reading Test Score < 25%, weighted; Low Spring Kindergarten Approaches to Learning < 24%. Multiple imputation done, regression weighted, and complex sample design used. PMD = 16.1%