Early Physical Health Conditions and School Readiness Skills in a Prospective Birth Cohort of U.S. Children

Abstract

Extant research identifies associations between early physical health disparities and impaired functioning in adulthood, but limited research examines the emergence of these associations in the early years of children's lives. This study draws on data from the Early Childhood Longitudinal Study Birth Cohort (ECLS-B; N = 5,900) to assess whether a host of early health indicators measured from birth to age five are associated with children's cognitive and behavioral skills at age five. After adjusting for a host of child and family characteristics, results revealed that children's neonatal risks (prematurity or low birth weight) and reports of poor health and hospitalizations were associated with lower cognitive skills, and neonatal risks and poor health predicted lower behavioral functioning at age five. Some of the association between neonatal risks and school readiness skills were indirect, functioning through children's poor health and hospitalization. Analyses further found that associations between early physical health and children's school readiness skills were consistent across subgroups defined by family income and child race/ethnicity, suggesting generalizability of results. Findings emphasize the need for more interdisciplinary research, practice, and policy related to optimizing child well-being across domains of physical health and development in the early years of life.

Keywords: Physical Health; School Readiness; Cognitive Skills; Learning Skills

Introduction

Mounting research suggests that early physical health status may forecast children's long-term functioning throughout childhood and into adulthood. A major proponent of the fetal origins hypothesis, Barker (1995) argued that a child's experiences in utero, such as inadequate fetal nutrition, could alter fetal growth processes and negatively affect long-term health. Studies testing this theory have found that children who experienced neonatal risks, such as low birth weight and premature birth, were more likely than their counterparts to suffer health complications throughout adulthood, such as cardiovascular and respiratory disease (Almond & Currie, 2011; Barker, 1995; Barker, Osmond, Forsen, Kajantie, & Eriksson, 2005). Neonatal risks have also been associated with long-term functioning in other arenas, predicting lower educational attainment, social status, and economic productivity across the lifecourse (Case, Fertig & Paxson, 2005; Knudsen, Heckman, Cameron & Shonkoff, 2006; Lê, Roux & Morgenstern, 2013; Ziol-Guest, Duncan, Kalil & Boyce, 2012). These findings are in line with a primary tenet of the fetal origins hypothesis suggesting that early "programming" in utero may remain dormant through the early part of an individual's life (Almond & Currie, 2011).

An opposing hypothesis is that neonatal health insults will have more immediate consequences for human development. Indeed, researchers have found that neonatal risks predispose children to additional childhood health problems such as ear infections, respiratory infections, and hospitalizations, as well as asthma diagnosis and special health care needs (Hack et al., 2005; Lepomnyaschy & Reichman, 2006; Stein, Siegel, & Bauman, 2006). Moreover, neonatal risks may impair other arenas of early development. A number of studies have identified associations between neonatal risks and lower cognitive skills assessed across the first five years of life (Delobel-Ayoub et al., 2006; Mikkola et al., 2005; Morse, Zheng, Tang, &

Roth, 2009). These studies attribute deficits in cognitive functioning to reduced brain size and immature neurophysiology (Reichman, 2005). Together, this research suggests the possibility that early health conditions may mediate associations between neonatal risks and children's development, although this hypothesis has not been directly tested in the literature.

Nonetheless, it is important to note that many early health conditions emerge in children without neonatal risks, and an emerging body of literature has found specific early health indicators to be associated with children's development. Of these indicators, asthma is the most common chronic condition of childhood (Currie, 2005) and has been linked with lower cognitive functioning (Halterman et al., 2001; Liberty, Pattemore, Reid, & Tarren-Sweeney, 2010) as well as behavior problems among children aged 4 to 9 (Weil et al., 1999). Acute health conditions such as respiratory and ear infections similarly have predicted lower cognitive functioning in kindergarten (Roberts et al., 2000). Parental reports of children's poor general health have also been associated with lower cognitive skills and psychological adjustment between kindergarten and 1st grade (Crosnoe, 2006; Janus & Duku, 2007; Spernak, Shottenbauer, Ramey, & Ramey, 2006). Research suggests that these health conditions may limit children's access to early learning opportunities or require treatment that interferes with the ability to learn or socialize with peers (Currie, 2005), thus inhibiting the development of nascent cognitive, self-regulatory, and behavioral skills.

On the whole, evidence links a variety of individual health indicators to young children's cognitive functioning and, less consistently, to behavioral or psychological functioning, but this literature suffers from numerous limitations. One concern is the use of small, epidemiological samples drawn from restricted economic strata, racial/ethnic subgroups, or urban centers (Halterman et al., 2001; Roberts et al., 2000; Weil et al., 1999). The use of such samples inhibits

the generalizability of results to a broader sample of children. A second limitation is that, with few exceptions (e.g., Crosnoe, 2006; Spernak et al., 2006), prior studies have taken a piecemeal approach to studying children's health, by neither accounting for the multi-faceted nature of health (Martinez, 2002; National Research Council/Institute of Medicine) nor assessing the dynamic nature of health conditions over an extended period of time. For example, much of the literature linking specific early health conditions to children's developmental competencies have not adjusted for children's neonatal risks (e.g., Crosenoe, 2006; Halterman et al. 2001; Roberts et al., 2000; Spernak et al., 2006), potentially overestimating the role of such conditions. Relatedly, studies on neonatal risks have rarely attended to other aspects of children's health (e.g., Morse et al., 2009), thus overlooking the possibility that other health conditions may be a conduit through which neonatal risks are associated with later development.

To address these limitations, this study examined a large, nationally representative sample of children followed prospectively from infancy through school entry to test associations between five indicators of physical health assessed throughout early childhood (neonatal risks, asthma, acute conditions, hospitalizations, and general health) on children's development at age five, when most were entering kindergarten. We assess a broad range of developmental competencies, and further focus on the crucial transition period of kindergarten entry due to growing scientific consensus over the central role of school readiness skills for children's long-term success. Indeed, policy makers, practitioners, and researchers agree that children who enter kindergarten with key developmental competencies adjust more easily to the tasks of formal schooling, exhibit heightened academic achievement and school success, and show greater educational attainment and economic productivity in adulthood (Duncan et al., 2007; Knudsen et al., 2006; Lo Paro & Pianta, 2000; Rimm-Kaufman, Pianta, & Cox, 2000). These school

readiness competencies include cognitive skills, most prominently nascent reading and math skills; learning skills, such as the ability to sustain attention and engage in learning activities; and behavioral skills, including peer social skills and the ability to constrain inappropriate behaviors (High, 2008; National Education Goals Panel, 1997; Snow, 2006).

In addition to attending to disparities in developmental competencies associated with a broad range of early childhood health conditions, this study also attends to the essential issues of economic and racial/ethnic disparities. Extensive research documents heightened levels of neonatal risks and other early health conditions among poor and racial/ethnic minority children (Braveman & Barclay, 2009; Fiscella, Franks, Gold, & Clancy, 2000). Similarly, research clearly delineates economic and racial/ethnic disparities in children's school readiness skills (Brooks-Gunn, Rouse, & McLanahan, 2007). Yet these differences within these domains of functioning do not inform us of whether the associations between health and development might differ across subgroups of the population. There is ample reason to hypothesize that this may indeed by the case, although limited prior literature on this topic is mixed (Currie, 2005; Figlio, Guryan, Karbownik, & Roth, 2013; Reichman, 2005). Economically disadvantaged and racial/ethnic minority families have less consistent access to health care and enriching learning opportunities for children than their advantaged and White counterparts (Newacheck, Hughes, & Stoddard, 1996; Weinick & Krauss, 2000) and, as a result, may be less able to quickly and fully address childhood health conditions, resulting in more negative repercussions for children's learning. Similarly, with more limited economic and social resources, poor families may experience greater stress and disruption from children's health problems, in turn limiting supports for children's healthy development. To address inconsistencies in prior literature at this intersection, this study examines interactions between children's physical health and family

income, and between health and race/ethnicity in order to assess whether links between early childhood health and school readiness skills are consistent or vary across different subgroups of U.S. children.

Methods

Participants

Data for this study were drawn from the Early Childhood Longitudinal Study Birth Cohort (ECLS-B), a prospective, multi-method study of a birth cohort of children born in 2001 and followed from infancy through school entry (Flanagan & West, 2004). The ECLS-B is nationally representative of the nearly 4 million children who were born in 2001, excluding children born to mothers who were less than 15 years old and children who died before the first interview. In the first wave of the survey approximately 10,700 children (NCES requires that all *N*s be rounded to the nearest 50) and their primary caregivers (98% biological mothers) participated in interviews and child assessments conducted in either English, Spanish, or with a translator. Data collection began in 2001, when focal children averaged 10 months old, with families re-interviewed in 2003-2004 (2 years old), in 2005-2006 (4 years old), and 2006-2007, when children averaged 5 years old and most (77%) were entering kindergarten. Weighted response rates were 74.1% at Wave 1 ($N \approx 10{,}700$), 93.1% at Wave 2 ($N \approx 9{,}850$), 91.3% at Wave 3 ($N \approx 8{,}900$), and 91.8% at Wave 4 ($N \approx 6{,}950$). Teachers (kindergarten or preschool) were also interviewed in Wave 4 (response rates of 76% for kindergarten teachers and 92% for preschool providers). The analytic sample for the current study was limited to children who remained in the sample through Wave 4 and who were not identified as having any severe disabilities, such as cerebral palsy or Down's Syndrome, yielding an analytic sample of 5,900.

Measures

School readiness skills. Children's school readiness skills were assessed at Wave 4, when children averaged five years old, in order to capture most children's entrance into kindergarten. Trained interviewers directly assessed each child's nascent math and reading skills using assessments derived from well-validated measures such as the PreLAS 2000 (Duncan & DeAvila, 1998), the Peabody Picture Vocabulary Test-Third Edition (PPVT-III; Dunn & Dunn, 1997), the Test of Early Mathematics Ability (TEMA-3; Ginsburg & Baroody, 2003) and the Preschool Comprehensive Test of Phonological and Print Processing (Pre-CTOPPP; Lonigan, Wagner, Togesen & Rashotte, 2002), as well as items created specifically for the ECLS-B. The early reading assessment (α = .92) consisted of 74 items measuring letter knowledge, word recognition, print conventions, and phonological awareness. The math assessment (α = .92) included 58 items focused on number sense, properties, operations, and probability. Both assessments were subject to rigorous validation processes and were scored using item-response theory (IRT) procedures (Najarian, Snow, Lennon, Kinsey, & Mulligan, 2010).

Children's behavioral skills were rated by kindergarten or preschool teachers using items drawn from established measures that included the Social Skills Rating System (SSRS; Gresham & Elliott, 1990), the Preschool and Kindergarten Behavior Scales (PKBS-2; Merrell, 2003), the Family and Child Experiences Study (FACES), and items created specifically for the ECLS-B. Replicating prior research (Coley, Votruba-Drzal, Miller & Koury, 2013), principal component factor analyses identified three distinct dimensions of children's behavioral functioning, delineated as learning skills, prosocial behaviors, and externalizing problems. Learning skills were measured using six items such as "child pays attention well" and child "works/plays independently" rated on a 5-point scales from *not true* to *very true* (α = .89). Prosocial behaviors

were measured using six items including "child is accepted by other children" and "child makes friends easily," also rated on 5-point scales from *not true* to *very true* ($\alpha = .87$). Externalizing problems were assessed using seven items on 5-point scales ranging from *never* to *very often*, capturing behaviors such as "child is physically aggressive," ($\alpha = .92$).

Physical health indicators. Five measures of children's physical health from infancy through age five were assessed, including dichotomous indicators of neonatal risk, asthma diagnosis, hospitalization, and poor health, and a count of acute illnesses. All but neonatal risks were reported on by mothers. Birth certificate information was used to classify children born low birth weight (<2500 grams) or prematurely (before 37 weeks gestation), which are two of the most common risks at birth that are widely associated with short- and long-term functioning (U.S. Department of Health and Human Services, 2013). These indicators were combined into a dichotomous variable capturing *neonatal risks*, coded 1 if the child was either low birth weight of premature, and 0 otherwise. At each wave of the ECLS-B surveys, mothers reported whether a doctor or health professional ever diagnosed the child with *asthma*, which were combined into a dichotomous variable to indicate ever receiving an asthma diagnosis. Children's experiences of *acute conditions* including ear infections and respiratory illnesses were measured at each wave using a count of the number of doctor-diagnosed conditions since the prior wave (since birth at wave 1), which were summed across the waves and topcoded at 4 SDs above the mean to minimize the influence of outliers. Number of ear infections was assessed as a count at each wave, but due to a limitation in data collection procedures, respiratory illnesses were measured dichotomously in Waves 1 and 2 and as number of diagnoses at Waves 3 and 4, suggesting that this variable may be a conservative estimate of children's acute conditions in infancy and toddlerhood. To assess the severity of health conditions, parents reported at each wave whether

the child had ever been *hospitalized* for asthma or a respiratory infection; like the asthma variable, this was coded dichotomously to indicate whether the child had ever been hospitalized. Additionally, parental reports of the child's *general health* were assessed at each wave using a scale ranging from 1 = *excellent* to 5 = *poor*, a single item measure that has shown strong reliability and discriminant validity in terms of health conditions, use of health services, and mortality (Bowling, 2005). In line with prior research (Currie et al., 2008), general health was coded dichotomously to differentiate children who were ever reported to be in poor, fair, or good health from children consistently in very good or excellent health.

Child and family covariates. Numerous variables that prior literature has associated with physical health and development were included as covariates to help address concerns of omitted variable bias and identify unique associations between health and development. Child characteristics included indicators for gender, being a twin or triplet, and diagnosis of autism or ADHD (included due to established associations between these conditions, physical health, and developmental competencies; Gurney, McPheeters, & Davis, 2006; Halfon, Larson, & Slusser, 2013). Child race/ethnicity was coded as White, Black, Hispanic, Asian/Pacific Islander, or multiracial. The amount of children's kindergarten exposure and age at assessment were coded continuously in months. Children's enrollment in private or public health insurance was assessed each wave and coded categorically to capture whether each child always had private insurance, always had public insurance, or had unstable health insurance coverage. Family covariates included maternal age in years, which was reported at Wave 4, as well as the number of minors in the home, and yearly family income (in $10,000 units), both of which were measured at each wave and averaged. Indicators noted whether families included an immigrant parent and a primary home language other than English. Highest level of parental educational

attainment was coded as less than high school, high school or GED, some college, or college degree. Maternal marital status, employment, and family receipt of public assistance (i.e., Supplemental Nutrition Assistant Program, Women, Infants and Children, or Temporary Assistance to Needy Families) were assessed each wave and coded to indicate whether these characteristics of the household were always, sometimes, or never experienced across the four waves of data. Geographic region was coded for Northeast, South, Midwest, or West.

Additional measures of children's baseline functioning in infancy (Wave 1) were included in a series of robustness checks. Children's early cognitive ability was assessed using the Bayley Short Form-Research Edition (BSF-R; Bayley, 1993), which measured early abilities in the domains of objects and pre-verbal communication, was scored using IRT to create an overall score of early mental ability ($\alpha = .80$). Children's temperament was assessed using mother and interviewer-report items from the Infant/Toddler Checklist (ITSC; DeGangi, Poisson, Sickel & Wiener, 1995) and the Behavior Rating Scale (BRS; Bayley, 1993). Items measured self-regulation, engagement, and attention, and were combined into a composite of general adaptability (15 items, $\alpha = .70$).

Analytic Approach

Prior to conducting multivariate analyses, data were assessed for missingness and distribution. Missing data analysis revealed 2% to 30% missing data at the measure level on child outcomes, 0% to 2% missing on physical health indicators, and 0% to 5% missing on child and family covariates. Multiple imputation was conducted using a bootstrap-based expectation maximization Bayesian algorithm in R to produce 20 imputed datasets (Honaker & King, 2010). Preliminary analyses checked continuous dependent variables for violations of assumptions of

OLS regression, revealing limited evidence of violations. Additionally, variance inflation factors below 4 indicated no issues with multicollinearity among the independent variables.

OLS regression models tested associations between children's physical health indicators and each school readiness outcome. The first set of models included the neonatal risk variable and all child and family covariates as predictors of each school readiness variable. The second set of models added the other health variables, asthma, acute conditions, general health, and hospitalization. A third set of models tested whether neonatal risks were associated with school readiness skills through other early childhood health conditions. Logistic and Poison regression analyses first predicted each health condition variable using neonatal risks and the full set of covariates. Next, Sobel tests were used to calculate indirect effects from neonatal risk through each health condition to each of the school readiness variables. A fourth set of models tested interactions between each child health measure and both family income and child race/ethnicity to examine whether associations between health and school readiness skills varied across subgroups of children. Finally, as a robustness check, analyses were rerun including baseline measures of children's cognitive functioning (predicting math and reading skills) or temperament (predicting learning skills, prosocial behavior, and externalizing problems) to address concerns about unmeasured heterogeneity.

All analyses incorporated the W4R0 survey weight using the Taylor Series linearization method to maximize the sample of participating families in Wave 4, to account for differential selection into the sample and attrition, to adjust for the complex survey design, and to yield unbiased parameter estimates, thus permitting generalization to the population of U.S. children born in 2001 (Hahs-Vaugn, McWayne, Bulotsky-Shearer, Wen, & Faria, 2011).

Results

Associations Between Physical Health and School Readiness Skills

Table 1 presents weighted descriptive statistics on all analytic variables. The sample was 51% male, and children ranged in age from 57 to 75 months, with an average age of 65 months (*SD* = 3.78) at Wave 4. Considering children's health conditions, 7% of children showed neonatal risks from low birth weight or prematurity. In addition, 17% received an asthma diagnosis and 29% were reported to ever be in poor, fair, or good health by age five. Children experienced an average of over four acute health episodes (ear infections or respiratory illnesses), and 14% were hospitalized at least once for either respiratory illnesses or asthma-related incidents by age 5.

Table 1. Sample Descriptives

	M/%	SD	Range
Child Health Indicators			
Neonatal Risk	7%		
Asthma Diagnosis	17%		
Acute Conditions	4.10	4.69	0-25
Hospitalization	14%		
Poor General Health	29%		
School Readiness Outcomes			
Math Skills	40.79	10.79	11.10-69.69
Reading Skills	38.81	15.47	12.39-82.48
Learning Skills	3.90	0.75	1-5
Prosocial Behaviors	3.89	0.68	1-5
Externalizing Problems	1.94	0.8	1-5
Covariates			
Child Age (months)	64.72	3.78	56.70-74.50
Child Gender (male)	51%		
Child Race			
White	53%		
Black	14%		
Hispanic	26%		
Asian/Pacific Islander	3%		
Multiracial	3%		
Autism/ADHD Diagnosis	2%		
Twin or Triplet	3%		
Kindergarten Exposure (months)	2.30	1.85	0-7
Child's Health Insurance			
Always Private	44%		
Always Public	33%		
Unstable Arrangement	23%		
Mother is Married			

Always Married	60%		
Sometimes Married	17%		
Never Married	23%		
Maternal Employment			
Always Employed	34%		
Sometimes Employed	46%		
Never Employed	20%		
Parental Education			
Less than High School	11%		
High School/GED	25%		
Some College	30%		
Advanced Degree	34%		
Household Income ($10k)	5.67	5.33	0.25-20.0
Minors in Household	2.31	1.06	1-6
Non-English Speaking Household	25%		
Immigrant Household	19%		
Public Assistance Receipt			
Always Received	25%		
Sometimes Received	33%		
Never Received	42%		
Geographic Region			
Northeast	22%		
South	17%		
Midwest	36%		
West	25%		
Child Infant Functioning			
Cognitive Skills	76.99	9.75	33.84-126.34
Temperament	0.08	0.50	-1.87-1.28

Table 2 presents results for OLS regression models linking physical health conditions with children's school readiness skills. In the first set of models testing associations between neonatal risks and child functioning, controlling for the broad list of child and family covariates, results show that neonatal risks were modestly associated with lower cognitive and learning skills. Adjusting for covariates, children with neonatal risks scored .17 SDs [95% CI = -.24, -.10] lower in math skills, .12 SDs [95% CI = -.19, -.04] lower in reading skills, and .13 SDs [95% CI = -.25, -.01] lower in learning skills in comparison to their peers without neonatal risks.

In the second set of models that included all five physical health indicators assessed across the first five years of life, neonatal risks, poor health and hospitalization were all associated with children's school readiness skills. Ever being in poor health predicted lower cognitive and behavioral skills, with effect sizes of .11 SDs [95% CI = -.18, -.04] for math and

reading, .11 SDs [95% CI = -.20, -.01] for learning skills, and .10 SDs for prosocial skills [95% CI = -.19, -.004]. Likewise, hospitalization was associated with lower cognitive skills on the order of .12 SDs [95% CI = -.21, -.03] for math and .09 SDs [95% CI = -.16, -.02] for reading. There was no evidence that asthma diagnoses or acute conditions predicted school readiness skills, or that health conditions predicted externalizing problems.

In this set of models, the pattern of associations between neonatal risks and school readiness skills were maintained with modest decreases in the size of coefficients (decreases of 9% for math skills, 12% for reading skills, and 10% for learning skills). Neonatal risks predicted lower school readiness skills with effect sizes of .16 [95% CI = -.23, -.08] for math, .10 [95% CI = -.17, -.03] for reading, and .12 [95% CI = -.23, -.01] for learning. In order to clarify whether other health conditions indirectly explained associations between neonatal risks and school readiness, we estimated a series of logistic and Poisson regression analyses in which neonatal risks predicted whether the child was ever diagnosed with asthma, the number of diagnosed acute conditions, ever in poor health status, and ever hospitalized by the age of 5. As shown in Table 3, results from these models revealed that neonatal risks predicted a greater likelihood of asthma diagnosis (OR = 1.67, 95% CI = 1.30, 2.12), of being in poor health (OR = 1.55, 95% CI = 1.22, 1.95), and of hospitalization (OR = 1.84, 95% CI = 1.39, 2.41). These estimates were used to conduct Sobel tests, which quantify and test the statistical significance of indirect effects (Hayes, 2013). Sobel tests demonstrated that significant indirect effects emerged from neonatal risks to math skills through poor health (z = 2.38) and hospitalization (z = 2.26) and from neonatal risks to reading skills through poor health (z = 2.36) and hospitalization (z = 2.19). In short, results identified both direct effects and indirect effects (functioning through poor general health and hospitalizations) of neonatal risks on children's school readiness skills.

As a robustness check, the second set of models were rerun including measures of children's early cognitive skills and temperament in infancy to control for baseline cognitive and social functioning, as an additional control against unmeasured heterogeneity. Results from these models replicated patterns delineated above, with modestly weaker effect sizes (results available upon request), indicating that neonatal risks, poor general health, and hospitalizations were associated with less advanced school readiness skills among children, most consistently for cognitive skills. These findings suggest that links between children's health problems and school readiness skills generally hold, even after controlling for baseline indicators of functioning that might exert consistent influences on cognitive and behavioral functioning over time. It is important to highlight that the baseline functioning measures were attained after the measurement of some health conditions (after neonatal risks and conditions that occurred between birth and Wave 1); thus, their inclusion helps to adjust for potential unmeasured biasing factors, but may over-control the effects of early health conditions.

Table 2. OLS Regressions Predicting School Readiness Skills

	Math	Reading	Learning	Prosocial	Externalizing
	β (SE)	β (SE)	β (SE)	β (SE)	β (SE)
Model 1					
Neonatal Risk	-1.88 (0.38)**	-1.81 (0.57)**	-0.10 (0.04)*	-0.04 (0.04)	0.03 (0.05)
Child Age	0.75 (0.05)**	0.89 (0.08)**	0.02 (0.01)*	0.01 (0.00)	0.01 (0.01)
Child Gender	-0.42 (0.28)	-1.71 (0.40)**	-0.29 (0.03)**	-0.23 (0.03)**	0.39 (0.03)**
Child Race					
Black	-1.07 (0.54)+	1.09 (0.79)	-0.05 (0.05)	-0.00 (0.05)	0.03 (0.06)
Hispanic	-2.33 (0.54)**	-1.51 (0.75)*	-0.02 (0.05)	0.01 (0.04)	-0.03 (0.05)
Asian/Pacific Islander	1.34 (0.58)*	3.96 (0.86)**	0.01 (0.06)	-0.08 (0.05)	-0.06 (0.06)
Multiracial	-1.52 (0.82)+	-0.90 (1.06)	-0.07 (0.07)	-0.05 (0.06)	0.07 (0.07)
Autism/ADHD Diagnosis	-3.70 (1.04)**	-4.26 (1.42)**	-0.66 (0.09)**	-0.49 (0.09)**	0.88 (0.11)**
Twin or Triplet	-1.23 (0.45)**	-0.36 (0.63)	-0.05 (0.04)	0.00 (0.04)	0.04 (0.05)
Kindergarten Exposure	1.16 (0.10)**	2.48 (0.15)**	-0.06 (0.01)**	-0.01 (0.01)	0.01 (0.01)
Maternal Age	0.10 (0.03)	0.01 (0.03)	-0.00 (0.00)	-0.00 (0.00)	0.00 (0.00)
Mother is Married					
Sometimes	-1.01 (0.49)*	-1.52 (0.59)*	-0.13 (0.05)**	-0.09 (0.04)*	0.15 (0.05)**
Never	-0.97 (0.44)*	-2.07 (0.63)**	-0.14 (0.05)**	-0.11 (0.04)*	0.11 (0.06)+
Maternal Employment					
Sometimes	-0.14 (0.39)	-0.84 (0.56)	-0.02 (0.04)	-0.01 (0.03)	-0.04 (0.04)
Never	-0.17 (0.45)	-0.27 (0.68)	0.04 (0.05)	-0.02 (0.05)	-0.15 (0.04)**
Parental Education					
Less than High School	-5.17 (0.73)**	-8.46 (1.01)**	-0.15 (0.08)+	-0.01 (0.07)	0.14 (0.08)
High School/GED	-3.15 (0.51)**	-4.90 (0.65)**	-0.10 (0.05)+	-0.07 (0.05)	0.07 (0.06)
Some College	-2.29 (0.46)**	-3.49 (0.55)**	-0.08 (0.05)+	-0.04 (0.04)	0.09 (0.05)+
Household Income	0.34 (0.06)**	0.40 (0.08)**	0.01 (0.01)	0.01 (0.00)	-0.00 (0.01)
Minors in Household	-0.73 (0.16)**	-1.57 (0.23)**	0.00 (0.02)	-0.01 (0.02)	-0.05 (0.02)**
Non-English Speaking	-0.91 (0.73)	-1.58 (1.06)	0.08 (0.06)	0.04 (0.06)	-0.08 (0.06)
Immigrant Household	0.31 (0.56)	0.77 (0.92)	-0.02 (0.05)	-0.07 (0.06)	-0.04 (0.06)
Public Assistance Receipt					
Always	-1.93 (0.62)**	-2.59 (0.98)*	-0.12 (0.07)+	-0.00 (0.06)	0.12 (0.07)
Sometimes	-1.33 (0.45)**	-2.18 (0.73)**	-0.08 (0.05)	-0.00 (0.00)	0.03 (0.05)
Child's Health Insurance					
Always Public	-0.46 (0.53)	0.13 (0.75)	-0.01 (0.05)	-0.02 (0.05)	0.03 (0.06)

Unstable Arrangement	-0.23 (0.50)	-0.04 (0.74)	0.01 (0.05)	0.01 (0.05)	0.04 (0.06)
Geographic Region					
South	1.05 (0.61)+	0.72 (0.97)	0.03 (0.05)	0.03 (0.04)	-0.07 (0.06)
Midwest	0.15 (0.46)	1.73 (0.76)*	-0.00 (0.04)	0.03 (0.04)	0.01 (0.05)
West	0.52 (0.52)	1.08 (0.75)	0.05 (0.04)	-0.01 (0.04)	-0.05 (0.04)
Constant	-6.64 (3.10)*	-17.24 (4.83)**	3.45 (0.33)**	3.77 (0.30)**	1.98 (0.38)**
Model F Value	138.00**	113.56**	11.71**	5.91**	11.99**
Model R^2	0.39	0.41	0.13	0.08	0.15
Model 2: Adding Other Health Conditions					
Neonatal Risk	-1.71 (0.38)**	-1.59 (0.55)**	-0.09 (0.04)*	-0.04 (0.04)	0.03 (0.05)
Asthma Diagnosis	0.59 (0.47)	0.57 (0.53)	0.05 (0.04)	-0.01 (0.04)	-0.04 (0.05)
Acute Conditions	0.00 (0.03)	0.02 (0.05)	-0.00 (0.00)	0.00 (0.00)	0.01 (0.00)
Poor Health	-1.19 (0.38)**	-1.67 (0.55)**	-0.08 (0.03)*	-0.07 (0.03)*	0.05 (0.04)
Hospitalized	-1.30 (0.50)*	-1.40 (0.56)*	-0.06 (0.05)	0.01 (0.05)	0.04 (0.05)
Constant	-6.18 (3.13)+	-16.68 (4.89)**	3.48 (0.33)**	3.78 (0.30)**	1.96 (0.38)**
Model F Value	128.42**	115.23**	11.81**	5.48**	10.72**
Model R^2	0.40	0.41	0.13	0.08	0.15

Note. ** $p < 0.01$ * $p < 0.05$ + $p < 0.10$. Coefficients are unstandardized. Covariates for Model 2 (not shown) are the same as those included in Model 1.

Table 3. Poisson and Logistic Regressions Predicting Children's Health Conditions by Age 5

	Asthma	Acute Conditions	Poor Health	Hospitalization
	B (SE)	B (SE)	B (SE)	B (SE)
Neonatal Risk	0.51 (0.12)**	0.05 (0.06)	0.44 (0.12)**	0.61 (0.14)**
Constant	-2.07 (1.08)+	0.91 (0.53)+	-1.22 (1.04)	-1.39 (1.18)
Model F Value	9.28**	20.86**	15.56**	8.50**

Note. ** $p < 0.01$ * $p < 0.05$ + $p < 0.10$. Coefficients are unstandardized. Models include all covariates (not shown) as in Models 1 and 2.

Moderation by Family and Child Demographic Characteristics

A final set of analyses examined whether associations between physical health indicators and children's school readiness skills differed by family income or by child race/ethnicity. Interactions with family income to needs were tested using both continuous and categorical (<100%, 100-200%, +200% poverty line) variables. Across all moderation analyses, no notable patterns of associations emerged, with only two significant interactions of 75 interaction effects tested, below the rate expected by chance (results available upon request).

Discussion

A growing body of evidence supports the notion that children's physical health is central to the development of skills needed for a successful transition to kindergarten and for engagement in the first formal schooling experience (Currie, 2005; Lewit & Baker, 1995), with the potential for long-term consequences. Yet, limited research has assessed a broad range of early health conditions, limiting understanding of the unique roles of neonatal risks versus other health conditions among young children. In response to these concerns, the present study examined associations between the multi-faceted components of early physical health and key domains of early development. Using a nationally representative sample of U.S. children followed prospectively from infancy through age 5, regression analyses revealed that multiple aspects of early health, specifically neonatal risks, poor general health, and hospitalization, independently predicted lower cognitive and learning skills and less consistently, lower prosocial skills among children. Moreover, mediation analyses found that some of the effect of neonatal risks was indirect, operating through poor general health and hospitalization in early childhood. One of the major strengths of this study was the large and diverse sample, which allowed us to assess whether links between early health and development were universal or were heightened

among certain subgroups of children. Results revealed no evidence of moderation across family income or child race/ethnicity, suggesting that the magnitude and direction of associations linking physical health and development are not significantly different across economic strata or demographic subgroups. In essence, findings support the idea that the lifelong associations between poor health and development emerge as early as kindergarten entry.

It is important to note that effect sizes for associations between early health and children's development were small, ranging from .09 to .17 standard deviation units. These effects are comparable in size to effects delineated in other literature on repercussions of poor health with large, nationally representative samples (Crosnoe, 2006) and smaller epidemiological samples (Roberts et al., 2000). One way of interpreting the practical significance of results is to compare them to other standard measures of import. For example, the effects of neonatal risks, poor general health, and hospitalization on children's school readiness skills identified in this study were approximately the same size as the effect of living with an always married versus a never married mother, and were about 4 times larger than the effect of a $10,000 increment in annual family income.

One of the strengths of this study was assessment of a broad array of children's skills seen as essential for a successful transition into and progression through school (Snow, 2006), including reading and math skills, learning skills, prosocial behaviors, and externalizing problems. In line with extant literature linking physical health more strongly to impairments in cognitive development rather than socio-emotional development (Halterman et al., 2001; Liberty et al., 2010), this study found consistent links between early health conditions and children's reading and math skills, with limited links with behavioral functioning. In an important extension of the literature, this study also identified associations between early health and

children's learning behaviors, including skills in attention, persistence, and motivation to learn, essential aspects of self regulation that are integral for supporting long-term academic achievement (Blair, 2002; Duncan et al., 2007; McClelland, Acock, & Morrison, 2006). These results help to illuminate other factors involved in the development of self-regulatory skills beyond previously identified socioeconomic and sociocultural influences (Raver, 2004).

The consistency of links between early childhood health and children's cognitive and learning skills suggests two potential pathways that require further empirical attention. One potential explanation is that the biological insults associated with children's health status influence the neural connections necessary for optimal development of these nascent skills (Blair, 2002). A second explanation is that illnesses or the treatments required to address health conditions interfere with children's access to early learning experiences or inhibit their ability to engage in and benefit from such experiences. These hypotheses are in line with transactional-ecological theories from developmental psychology (Bronfenbrenner & Morris, 1998; Sameroff & Chandler, 1975), which argue that personal characteristics affect both the contexts that individuals select into as well as the experiences they have in those contexts, in turn affecting future development. For example, children with precarious health statuses may be limited in exposure to early childhood education programs or receive less home cognitive stimulation from parents who are preoccupied with the child's physical health (Currie, 2005; Rosales-Rueda, 2014). Identifying both the biological and psychological mechanisms that link children's health and development are crucial next steps for this line of research (Shonkoff et al., 2009).

Despite prior literature identifying associations between chronic and acute health conditions and children's development (Crosnoe, 2006; Halterman et al., 2001; Patrianakos-Hoobler et al., 2009; Roberts et al., 2000; Spernak et al., 2006), this study found no relations

between either asthma or ear and respiratory infections and children's school readiness skills. The null findings for asthma diagnosis in this study may reflect the crude operationalization, which did not capture the degree or maintenance of a child's illness, such as related limitations or preventive efforts to control the illness. Indeed, Halterman et al. (2001) found lower cognitive skills only among children who experienced functional limitations related to their asthma diagnosis. The associations between hospitalization and children's cognitive skills found in this study may reflect the possibility that negative effects of asthma are contained to children with severe illnesses requiring serious medical attention. On the other hand, the null associations between acute conditions and school readiness may reflect the normative nature of such illnesses in early childhood and their positive role in building immunity (McCormick, 2008).

Limitations and Concerns

In considering the implications and contributions of this research, it is essential to first acknowledge its limitations. One important limitation of this study was the derivation of children's health indicators solely from parental reports. Parents reported only if the child was diagnosed by a doctor or health professional with a series of health conditions, and then probed on how these health conditions were treated. It is possible that these measures yield conservative estimates of children's health conditions, since some parents may have not brought their child to a doctor's office or health clinic for diagnosis even if the child displayed symptoms of an illness. Relatedly, parental reports are inadequate in the extent to which they can capture the severity and breadth of a child's health condition, which could only be proxied through reports of hospitalization. It is also essential to highlight the correlational nature of the data used in this analysis, which preclude us from drawing causal inferences about the relations between children's health and development. Although rich, prospective analyses adjusted for a broad

range of child and family covariates associated with health conditions and children's development, with additional models adjusting for early child functioning, it is possible that unmeasured variables biased the results. Future research should employ more rigorous methodological approaches that illuminate causal links, such as the quasi-experimental techniques employed by economists in studies testing the fetal origins hypothesis (Almond & Currie, 2011). Additional research is also needed in identifying mechanisms that may explain the associations unearthed in this study.

Despite concern about the use of parental reports of children's physical health, the widespread links between poor general health and both cognitive and behavioral domains of development among this sample of young children draw attention to the predictive validity of parental ratings of children's health. Much debate exists around how to best assess overall health using either single-item indicators, such as the parental report of general health, or broader measures assessing multiple health domains and conditions (Bowling, 2005; McCormick, 2008). Although parents' ratings of children's general health were predictive of cognitive, learning, and behavioral skills measured using direct assessments and teacher reports, reports of the child's health have limited practical implications for doctors and clinicians as well as designers of early intervention and prevention programs. Thus, unpacking how parents rate their child's general health and what constitutes a rating of "poor" health, as well as validating broader measures to capture a holistic picture of child health are important next steps (NRC/IOM, 2004).

Conclusions

Overwhelming evidence from recent studies supports the need for interdisciplinary research that addresses the intersections between child health and development (Fiscella & Kitzman, 2009), especially given the value of promoting physical, cognitive, and social

functioning for long-term population well-being (Knudsen et al., 2006). By investigating associations between multi-dimensional indicators of children's physical health and a comprehensive set of school readiness indicators, the present study adds support for these claims. Results also emphasize the importance of prevention and intervention efforts that promote child health and development in the early years of life. Additionally, future research should continue to illuminate and rigorously test such policy levers that may optimize the well-being of our nation's youngest citizens.

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Appendix 1. Measures

Measures of Interest	Response Scale	Reliability	Measures and Questions from which Items were Adapted
School Readiness Outcomes			
Math Skills	IRT-based scoring procedure	α = .92	Test of Early Mathematics Ability (TEMA-3; Ginsburg & Baroody, 2003)
Reading Skills	IRT-based scoring procedure	α = .92	PreLAS 2000 (Duncan & DeAvila, 1998), Peabody Picture Vocabulary Test-Third Edition (PPVT-III; Dunn & Dunn, 1997), Preschool Comprehensive Test of Phonological and Print Processing (Pre-CTOPPP; Lonigan, Wagner, Togesen & Rashotte, 2002)
Learning Skills	1 = *not true* to 5 = *very true*	α = .89	Social Skills Rating System (SSRS; Gresham & Elliott, 1990), the Preschool and Kindergarten Behavior Scales (PKBS-2; Merrell, 2003) and the ECLS-K
Prosocial Behaviors	1 = *not true* to 5 = *very true*	α = .87	Same as above
Externalizing Problems	1 = *never* to 5 = *very often*	α = .92	Same as above
Health Predictors			
Neonatal Risk	0 = *no*, 1 = *yes*		Child's birth weight and gestational age drawn from birth certificate
Asthma Diagnosis	0 = *no*, 1 = *yes*		"Since the last interview, has a doctor, nurse, or other medical professional told you that the child has asthma?"
Acute Conditions	Count		Same as above; inquires about ear infections and respiratory illnesses; how many times

		diagnosed
Poor Health	0 = *no*, 1 = *yes*	"Would you say the child's health is: excellent, very good, good, fair, poor?" Dichotomized to indicated excellent or very good vs. good, fair, or poor
Hospitalization	0 = *no*, 1 = *yes*	"Since our last interview, has the child been taken to an emergency room or hospitalized for at least one night because of asthma?" Also inquires about hospitalization for respiratory illness