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Population health begins in early childhood: Kindergarten EDI school readiness scores as a predictor of sixth-grade academic outcomes in the USA

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A B S T R A C T

School readiness skills in early childhood are strongly linked to later academic performance, health, and overall quality of life. Various tools, including the Early Development Instrument (EDI), have been used to assess children's school readiness skills. The EDI is an internationally utilized, holistic measure used to monitor population trends in developmental health and school readiness in early childhood. Although EDI scores demonstrated associations with later academic achievement in several countries, only one study in the United States has examined the EDI's predictive validity for third-grade outcomes. To expand this knowledge, the current study investigated the psychometric properties of the EDI in the United States, focusing on sixth-grade outcomes. Using a sample of kindergarteners ($N = 2610$) from five school districts in Orange County, California, this study examined whether kindergarten EDI scores predict academic proficiency in mathematics and English language arts by sixth grade. Findings show that kindergarten EDI scores are strong predictors of sixth-grade academic performance. Children classified as vulnerable or at risk in one or more EDI domains showed significantly lower proficiency in both mathematics and English language arts compared to their peers who were on track. Additionally, disparities in academic outcomes were observed across factors such as sex at birth, ethnoracial background, individualized education plan status, and eligibility for free or reduced-price lunch. Implications for early childhood population health are discussed.

1. Introduction

In 2006, Nobel laureate James Heckman published a model demonstrating that investing in early childhood is more cost-efficient for improving education and success in adulthood. (Heckman, 2006) His calculations were based on evidence available at the time. Since then, global evidence has steadily grown, confirming that children's development status at school entry is a reliable predictor of

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future academic and non-academic success. This underscores the importance of early childhood development in shaping long-term outcomes, which is critical for improving population health and quality of life. Some of this evidence comes from studies using the Early Development Instrument (EDI), (Janus and Offord, 2007) a Canadian tool adapted and validated in countries like Australia, (Brinkman et al., 2013) Jordan, (Ababneh et al., 2022) Brazil, (Janus et al., 2014) and Ethiopia. (Admas and Tefera, 2022) Unlike earlier "school readiness" conceptualizations that focused solely on cognitive skills, (Blair, 2002) the EDI takes a holistic, positivist approach, assessing five key developmental domains: physical health and well-being, language and cognitive development, social competence, emotional maturity, and communication skills and general knowledge.

Research shows the EDI's predictive power up to grade 7 in Canada (Fortier, 2025) and Australia, (Brinkman et al., 2013) and up to grade 3 in the US. (Duncan et al., 2020) Given that EDI results are actively used by schools and communities to address population strengths and needs, it is crucial to determine whether EDI scores predict academic achievement beyond third grade in the United States. The current study expands the international research on the EDI by addressing the following research question: What is the relationship between population-level EDI scores and sixth-grade standardized test scores in the United States? Unlike existing studies outside of the United States that use the EDI, we also incorporate indicators of children's ethnoracial background and income hardship.

1.1. *School readiness*

Promoting school readiness skills in early childhood is a key public health priority for improving children's population health. School readiness encompasses a range of skills—language, motor, cognitive, and social—that prepare children for school. (Bender et al., 2011; Williams et al., 2019) These skills ease the transition to formal education and have lasting implications for academic performance, health, and well-being. (Zuckerman and Halfon, 2003) School readiness is linked to academic achievement and well-being throughout childhood and adolescence. (Duncan et al., 2020; Duncan et al., 2007; Fitzpatrick et al., 2020; Gregory et al., 2021; Ricciardi et al., 2021) These associations extend into adulthood, with research showing that early childhood attention problems, lower reading skills, and reduced peer acceptance are linked with lower educational attainment. (Rabiner et al., 2016)

In the United States, about one-third of children aged 3 to 5 years are not healthy and ready to learn, (Ghandour et al., 2024) with disparities especially evident among children from low-income families, (Waldfogel et al., 2011) English learners, (Perrigo et al., 2024) ethnoracial minoritized populations, (Reardon and Portilla, 2016) and those facing early adversities. (Jackson et al., 2021) Environmental factors such as parental stress, (Soltis et al., 2015) exposure to poverty, (Hair et al., 2015; Ryan et al., 2005) and parental education (Mollborn, 2016) also contribute to gaps in school readiness.

1.2. *School readiness measures*

To enhance school readiness, it is essential to measure it accurately. Various tools assess children's readiness in the US, including the Healthy and Ready to Learn (HRTL) measure, which evaluates school readiness in five developmental domains: early learning, self-regulation, socioemotional development, motor skills, and health. (Ghandour et al., 2024, 2019, 2021) Piloted in 2016, the HRTL uses parent-reported data from the annual National Survey of Children's Health to estimate the proportion of children on track, needing support, or at risk regarding school readiness. (Ghandour et al., 2021) While promising, the HRTL currently offers state-level estimates and remains a pilot measure, with survey modifications as recent as 2022. (Ghandour et al., 2024; Maternal and Child Health Bureau 2022) As a result, its psychometric properties are still being investigated, and long-term population trends are yet to be fully determined. (Maternal and Child Health Bureau 2022)

Another widely used measure is the Desired Results Developmental Profile (DRDP), a comprehensive teacher-reported tool that assesses developmental status across multiple domains from infancy to kindergarten. (Draney et al., 2022; Kriener-Althen et al., 2020; Sutter et al., 2017) The DRDP aligns with the National Education Goals Panel's domains of school readiness and its validity and reliability have been established, (Chen-Gaddini et al., 2022a, 2022b; Draney et al., 2022; Kriener-Althen et al., 2020) but further studies are needed to assess its predictive validity. (Draney et al., 2022) In addition, the DRDP is resource-intensive, requiring teachers to complete the measure within 60 days of a child's enrollment and every 6 months thereafter, with continuous observations. (Desired Results Training and Technical Assistance Project 2024)

The EDI is an internationally used school readiness measure for young children aged 3.5 to 6.5, that assesses physical health and well-being, social competence, emotional maturity, language and cognitive development, and communication and general knowledge. (Janus and Offord, 2007; Janus et al., 2010, 2021) Like the HRTL, the EDI provides population-level data but is distinguished by its established reliability and validity through extensive psychometric testing. (Janus and Offord, 2007; Janus et al., 2010, 2021; Offord Centre for Child Studies 2019) The EDI requires only 7 to 20 min per child to complete, in contrast to the DRDP's multi-week process. (Desired Results Training and Technical Assistance Project 2024; Janus et al., 2023)

1.3. *Global use of the EDI*

Originally developed in Canada, the EDI has demonstrated strong psychometric properties across various cultural contexts, including Germany, Hong Kong, Jamaica, and Peru. (Ababneh et al., 2022; Georg et al., 2020; Ip et al., 2013; Janus et al., 2014; Janus et al., 2010, 2016) The original study confirmed the instrument's psychometric acceptability, which has been further supported by nearly two decades of research. (Janus and Offord, 2007) The EDI's construct validity has been established in multiple Canadian studies (Forer and Zumbo, 2011; Hymel et al., 2011; Janus et al., 2019) and cross-culturally in countries such as Indonesia, (Brinkman et al., 2017; Duku et al., 2015) the Philippines, (Duku et al., 2015) and Scotland. (Geddes et al., 2014) However, some studies have found measurement invariance and differential item functioning across gender (Curtin et al., 2016; Hagquist and Hellström, 2014; Mousavi and Krishnan, 2016) and English as a second language status. (Mousavi and Krishnan, 2016) Research has also confirmed the EDI's internal consistency (Curtin et al., 2013; Georg et al., 2020) and between-group reliability. (Guhn et al., 2007; Muhajarine et al., 2011) In a US sample, the EDI showed excellent internal consistency across its five domains (α = .82–.96). (Janus et al., 2010)

Although the EDI provides a holistic view of a child's development at school entry, it has also been shown to predict later outcomes, including academic achievement. In Canada, kindergarten EDI scores were significantly associated with numeracy and literacy scores in Grades 3 and 4. (Davies et al., 2016, 2022; Guhn et al., 2016; Lloyd and Hertzman, 2009) Other Canadian studies found that kindergarten EDI scores accounted for 34 % of the variance in Grade 1 academic achievement (Forget-Dubois et al., 2007) and predicted Grade 4 performance. (D'Angiulli et al., 2009) In Australia, Brinkman and colleagues (Brinkman et al., 2013) found that EDI scores at age 5 predicted reading and numeracy outcomes at ages 8, 10, and 12 (Grades 3, 5, and 7). An Indonesia-based study found that EDI scores in language and cognitive development at age 4 were the only consistent predictors of language and math scores at ages 6 to 9. (Brinkman et al., 2017)

1.4. EDI in the United States

Recent EDI studies in the United States show that kindergarteners from underserved neighborhoods face greater school readiness challenges than those in more equitable neighborhoods. (Aguilar et al., 2024) In a Californian sample, African American kindergarteners were the least likely to be developmentally on track, irrespective of income. (Perrigo et al., 2023) Asian students consistently performed the best, whereas white students' performance varied with income. That is, low-income white students had school readiness scores similar to Black and Latino/a peers, whereas higher-income white students' scores aligned with Asian students. (Perrigo et al., 2023) A study on English learners found they scored higher in social, emotional, and physical health domains but faced greater challenges in communication and cognitive skills. (Perrigo et al., 2024) The EDI has also been utilized to examine the impact of the COVID-19 pandemic on the developmental health and school readiness of U.S. kindergarteners. (Perrigo et al., 2025) This study observed various COVID-related trends in kindergartners' developmental health, including significant declines in language and cognitive development, social competence, and communication and general knowledge. (Perrigo et al., 2025)

Of significance, only one U.S. study has examined the EDI's predictive validity. Duncan and colleagues (Duncan et al., 2020) found that kindergarten EDI scores predicted third-grade proficiency in English language arts (ELA) and mathematics, with the language and cognitive development domain most strongly correlated to these outcomes. However, all EDI domains were significant predictors of academic proficiency. (Duncan et al., 2020) Given this is the only U.S. study on predictive validity, further studies are necessary to examine the EDI's psychometric properties among U.S. samples, especially its predictive validity beyond third grade.

Research linking kindergarten readiness to later academic outcomes is limited in the U.S. While several school-based reports associate kindergarten readiness with ELA scores in sixth grade (First 5 Alameda County 2018; San Francisco Department of Early Childhood 2023) and math scores in sixth and eighth grade, (San Francisco Department of Early Childhood 2023) empirical studies are sparse. Duncan et al. (Duncan et al., 2007) observed a significant relationship between school entry skills and later academic achievement in reading and math at ages 13 and 14. However, more research is needed to better understand the long-term impact of kindergarten readiness on academic success.

1.5. Current study

This study examined whether U.S. kindergarten EDI school readiness scores predict sixth-grade academic proficiency in mathematics and ELA ($N = 2610$). This research is crucial given the persistent school readiness and achievement gaps in the United States. (Hung et al., 2020) With increasing state investments in transitional and prekindergarten programs, (Alawsaj et al., 2023; Johnson, 2024) identifying best practices and effective measures that provide a holistic view of school readiness and predict academic performance is essential. While prominent school readiness measures like the HRTL and DRDP have not yet established predictive validity, our study contributes to the literature by examining the EDI—a widely used school readiness assessment—in relation to sixth-grade academic outcomes. Based on strong global evidence of the EDI's predictive validity, we hypothesized that it would also predict sixth-grade academic proficiency in this U.S. sample.

2. Method

2.1. Study setting and sample

The study examined a cohort of kindergarteners ($N = 2610$) from five school districts in Orange County, California, assessed in 2012 using the EDI to measure their developmental health and school readiness. This cohort, part of a larger countywide effort to gather EDI data, was also among the first to participate in the statewide Smarter Balanced Assessments (SBA). By 2018, they had completed their sixth-grade SBA exams. Administrative records from the school districts enabled the linkage of kindergarten EDI assessments to sixth-grade SBA performance.

Orange County, in Southern California, has a population of about 3.17 million, making it the sixth most populous county in the United States, with more residents than 22 states, including Iowa, Utah, and Mississippi. (Orange County Children's Partnership 2023) The county's median family income stands at $106,209, significantly higher than the national median of $74,755. (U.S. Census Bureau 2024) Despite this, 52.9 % of the student population in the county qualifies for free or reduced-price lunches. (Orange County

Children's Partnership 2023) The largest ethnoracial group among students is Hispanic or Latino, representing 49.7 % of the student body, followed by white (22.5 %); Asian, Pacific Islander, or Filipino (17.7 %); Black (1.3 %); and other groups (8.8 %). (Orange County Children's Partnership 2023) About 20.5 % of students in Orange County are identified as English learners, slightly above the California average of 19 %. (Orange County Children's Partnership 2023)

2.2. Measurements

2.2.1. Early development instrument (EDI)

The primary predictor was the EDI, a teacher-reported assessment of early childhood developmental health and school readiness. Teachers reported on each student in their classroom using an online data-entry platform, at least three months into the school year, allowing sufficient time to become familiar with their students. The EDI includes five key domains: physical health and well-being (e.g., "*the child has proficiency at holding a pen, crayons, or paintbrush")*, social competence (e.g., "*the child demonstrates respect for adults")*, emotional maturity (e.g., "*the child kicks, bites, or hits other children or adults")*, language and cognitive development (e.g., "*the child is able to write simple words in the language of instruction")*, and communication and general knowledge (e.g., *"the child has the ability to understand on the first try what is being said to him/her")*. In each domain, children are categorized into one of three groups based on their average scores across EDI items: "vulnerable" (below the 10th percentile), "at risk" (between the 10th and 25th percentiles), and "on track" (above the 25th percentile). Overall EDI is a composite measure based on five developmental domains. Children were categorized as "vulnerable overall" if they were classified as vulnerable in one or more domains, "at risk overall" if they were at risk in at least one domain but not vulnerable, and "on track" if they were on track in all five domains.

The EDI's psychometric properties, including multilevel validity, internal consistency, factor structure, and differential item functioning, have been rigorously tested and validated across several countries, including the United States, Canada, and Australia. (Duncan et al., 2020; Janus and Offord, 2007; Janus et al., 2010) Despite some minor cultural adaptations, the EDI has consistently demonstrated a stable factor structure and strong internal consistency across domains globally. (Brinkman et al., 2017; Georg et al., 2020)

2.2.2. Academic performance

The primary outcomes of this study were standardized test scores in ELA and mathematics, measured by the SBA at the sixth-grade level. The cohort analyzed in this study completed these assessments in 2018.

The SBA assesses four domains in each subject. In mathematics, these domains are concepts and procedures, problem solving, communicating reasoning, and modeling and data analysis. (Smarter Balanced Assessment Consortium 2015) For ELA, these domains are reading, writing, speaking and listening, and research. (Smarter Balanced Assessment Consortium 2015) Performance on both assessments is reported as continuous scores, which are classified into four levels according to established SBA benchmarks: Level 4 (exceeds standard), Level 3 (meets standard), Level 2 (approaches standard), and Level 1 (does not meet standard).

2.2.3. Covariates

The models in this study account for several baseline demographic factors, including sex at birth, English learner status (coded binarily: yes or no), and ethnoracial background, with Hispanic serving as the reference category. Hispanic was chosen as the reference group due to its size and to avoid the conventional practice of comparing all other racial and ethnic groups to white. Age at kindergarten entry was included as a continuous covariate and was mean-centered by subtracting the sample mean from each individual value. Mean-centering facilitates the interpretation of model intercepts by ensuring that the intercept represents the expected outcome for a child with the average age in the sample, rather than an age of zero, which would be outside the plausible range for kindergarten entry. Additionally, the models included whether the parent attended at least one parent–teacher conference and whether the child had an individualized education plan (IEP), which is designed to ensure that children with legally recognized disabilities receive tailored instruction and necessary support services. Finally, the models included lunch status, a binary variable serving as a proxy for family socioeconomic status, indicating whether children received free or reduced-price lunch or no assistance.

2.3. Data analysis plan

To examine the association between children's school readiness scores and their academic performance by sixth grade, we estimated separate linear regression models with neighborhood fixed effects for each academic outcome. For both mathematics and ELA, we specified two sets of models: one using the overall EDI classification as the primary predictor, and another incorporating all five individual EDI domains simultaneously within the same model. The overall EDI model captured children's cumulative developmental vulnerability across domains, while the domain-specific model enabled the identification of the unique contribution of each developmental domain to later academic outcomes. To assess the potential conceptual and statistical correlation among the five EDI domains, we conducted multicollinearity diagnostics by calculating variance inflation factors (VIFs) and examining pairwise Pearson correlations. The results indicated no evidence of problematic multicollinearity, supporting the inclusion of all domains within a single model.

We defined neighborhoods based on the ZIP codes of children's residence while attending kindergarten. U.S. census tracts were used as the smallest units, aggregated into community-defined neighborhoods. Consultation with and input from local experts ensured that neighborhoods represented distinct geographical regions acknowledged by residents, policymakers, and community leaders and characterized by shared social interactions and institutions. These neighborhoods served as proxies for a child's socioeconomic environment. For more details on these community-defined neighborhoods, see R. J. Duncan et al. (Duncan et al., 2020)

The final sample included 52 neighborhoods, with the number of children per neighborhood ranging from 1 to 152 ($SD = 74$). The intraclass correlation coefficients were 0.10 for SBA mathematics proficiency and 0.13 for SBA ELA proficiency. Neighborhood fixed effects account for time-invariant characteristics in neighborhoods, allowing the analysis to focus on variations in neighborhoods. This approach minimizes the risk of omitted variable bias. Unbiased estimates of the relationship between children's school readiness and

Table 1
Descriptive statistics.

	%	95 % CI	*n*
Baseline covariates			
Sex			2610
Female	47.4	45.6, 49.1	1236
Male	52.6	50.9, 54.4	1374
Age[a]	5.8	5.8; 5.8	2610
Race and ethnicity			2609
Hispanic or Latino/a	79.6	73.0, 84.8	2076
Asian, Native Hawaiian, or other Pacific Islander	7.9	5.6, 11.2	207
White	5.9	4.2, 8.3	154
African American or Black	0.9	0.5, 1.7	24
Other	5.7	4.3, 7.5	148
English learner status			2610
No	23.9	19.7, 28.7	624
Yes	76.1	71.3, 80.3	1986
IEP status			2585
No	94.9	93.8, 95.9	2454
Yes	5.1	4.1, 6.2	131
Lunch status			2554
No assistance	20.8	15.4, 27.4	531
Free or reduced-price lunch	79.2	72.6, 84.6	2023
Parent attended at least one parent–teacher conference			2610
No	2.8	2.1, 3.8	73
Yes	97.2	96.2, 97.9	2537
Main predictor			
Total EDI			2610
On track	45.4	41.8, 49.0	1184
At risk	29.3	27.1, 31.6	764
Vulnerable	25.4	23.0, 27.9	662
EDI domains			
Physical health and well-being			2610
On track	77.2	74.3, 79.8	2014
At risk	15.1	13.2, 17.2	394
Vulnerable	7.7	6.5, 9.2	202
Social competence			2610
On track	76.5	73.7, 79.1	1997
At risk	14.6	13.2, 16.1	382
Vulnerable	8.9	7.1, 10.9	231
Emotional maturity			2584
On track	80.7	78.3, 82.8	2084
At risk	12.7	11.1, 14.4	327
Vulnerable	6.7	5.4, 8.3	173
Language and cognitive development			2610
On track	67.2	63.2, 70.9	1753
At risk	22.7	20.0, 25.7	593
Vulnerable	10.1	8.5, 11.9	264
Communication skills and general knowledge			2610
On track	66.3	63.4, 69.0	1730
At risk	20.5	18.7, 22.5	536
Vulnerable	13.2	11.6, 14.9	344
Outcomes			
English language arts test, Grade 6			2610
Level 1: standard not met	41.6	36.5, 46.8	1085
Level 2: standard nearly met	25.9	23.9, 28.0	675
Level 3: standard met	22.0	19.2, 25.2	575
Level 4: standard exceeded	10.5	7.5, 14.6	275
Mathematics test, Grade 6			2610
Level 1: standard not met	48.2	43.4, 53.0	1258
Level 2: standard nearly met	27.5	25.6, 29.4	717
Level 3: standard met	14.4	12.6, 16.4	376
Level 4: standard exceeded	9.9	7.2, 13.6	259

For descriptive purposes, Table 1 presents the actual (untransformed) age distribution of the sample.

later academic performance were obtained by controlling for unmeasured factors that might otherwise influence both the predictors and outcomes. (Wooldridge, 2010) For instance, aspects of neighborhood socioeconomic status might simultaneously affect children's EDI scores and academic performance.

Although children were clustered in classrooms, we did not incorporate classroom-level effects into the model due to significant changes in classroom compositions between kindergarten and sixth grade. Furthermore, although schools were clustered in five school districts, the small number of districts (i.e., five) would likely limit the statistical power of the model, (Hox et al., 2017) which informed our decision not to incorporate district-level effects. Additionally, school districts represent broader geographic areas that may obscure nuanced factors influencing child development, which are more accurately captured at the neighborhood level.

Cases with missing values on any covariates included in the model were excluded through listwise deletion. Given that the proportion of missing data was low across variables (<5 %), this approach was deemed appropriate and unlikely to introduce significant bias.

3. Results

Table 1 presents the baseline demographic characteristics of the sample, along with their EDI domain classifications and academic performance in mathematics and ELA for Grade 6. Slightly more than half of the students were male (52.6 %) and 79.6 % identified as Hispanic or Latino/a/x. At baseline, roughly three-quarters of the sample was classified as an English language learner (76.1 %), and most students (94.9 %) did not have an IEP. Approximately 4 in 5 children (79.2 %) received free or reduced-price lunch. The overwhelming majority of children (97.2 %) had parents who attended at least one parent–teacher conference. For the overall EDI, 45.4 % of students were classified as on track, nearly one-third (29.3 %) were classified as at risk, and about a quarter (25.4 %) were classified as vulnerable. In terms of EDI domains, a substantial proportion of students were on track, ranging from 66.3 % in communication skills and general knowledge to 80.7 % in emotional maturity. Regarding academic outcomes, the largest proportion of students did not meet standards in both ELA (41.6 %) and mathematics (48.2 %).

3.1. EDI as a main predictor of academic performance at grade 6

As shown in models with the overall EDI classification as the main predictor (Table 2), children categorized as vulnerable performed significantly worse than those on track, both in ELA ($b = -0.77$, 95 % CI [−0.9, −0.7], $p < .001$) and mathematics ($b = -0.75$, 95 % CI [−0.8, −0.7], $p < .001$). Similarly, children classified as at risk in one or more domains showed lower performance in both ELA ($b = -0.41$, 95 % CI [−0.5, −0.3], $p < .001$) and mathematics ($b = -0.40$, 95 % CI [−0.5, −0.3], $p < .001$).

In terms of EDI domains (Table 3), children categorized as vulnerable in the general knowledge and communication domain performed worse than those on track in this domain, both in ELA ($b = -0.41$, 95 % CI [−0.5, −0.3], $p < .001$) and mathematics ($b = -0.4$, 95 % CI [−0.5, −0.3], $p < .001$). Similarly, children classified as at risk in this domain showed lower performance in both ELA (*b*

Table 2
Regression with neighborhood fixed effects: Overall EDI.

	English Language Arts		Mathematics	
	b	95 % CI	*b*	95 % CI
Overall EDI [a]				
At risk	−0.41***	−0.5, −0.3	−0.40***	−0.5, −0.3
Vulnerable	−0.77***	−0.9, −0.7	−0.75***	−0.8, −0.7
Baseline demographics				
Sex (male)	−0.14***	−0.2, −0.1	0.11**	0.0, 0.2
Age [b]	0.04	−0.1, 0.2	−0.04	−0.2, 0.1
Race [c]				
Asian, Native Hawaiian, or other Pacific Islander	0.69***	0.5, 0.8	0.79***	0.7, 0.9
White	0.05	−0.1, 0.2	0.16	−0.0, 0.3
African American or Black	0.16	−0.2, 0.5	0.13	−0.3, 0.5
Other	0.23**	0.1, 0.4	0.22**	0.1, 0.4
IEP	−0.17*	−0.3, −0.0	−0.20*	−0.4, −0.0
English learner	−0.09	−0.2, 0.0	−0.03	−0.1, 0.1
Parent attended at least one parent–teacher conference	0.13	−0.1, 0.3	0.09	−0.1, 0.3
Free or reduced-price lunch	−0.13**	−0.2, −0.3	−0.16**	−0.3, −0.1
Constant	2.40***	2.2, 2.6	2.10***	1.9, 2.3
Observations	2528		2528	
$R^{(2)}$	0.2		0.2	
Number of neighborhoods	52		52	

[a] Reference category is on track.
[b] Regression models include mean-centered age at kindergarten entry, calculated by subtracting the sample mean from each individual value.
[c] Reference category is Hispanic.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

Table 3
Regression with neighborhood fixed effects: Individual EDI domains.

	English Language Arts		Mathematics	
	b	95 % CI	*b*	95 % CI
EDI domains [a]				
Physical health and well-being				
At risk	0.01	−0.1, 0.1	0.07	−0.0, 0.2
Vulnerable	−0.12	−0.3, 0.0	−0.04	−0.2, 0.1
Social competence				
At risk	−0.04	−0.2, 0.1	−0.06	−0.2, 0.1
Vulnerable	0.01	−0.1, 0.2	−0.01	−0.2, 0.2
Emotional maturity				
At risk	−0.13*	−0.3, −0.0	−0.17**	−0.3, −0.1
Vulnerable	0.01	−0.2, 0.2	−0.09	−0.3, 0.1
Language and cognitive development				
At risk	−0.42***	−0.5, −0.3	−0.41***	−0.5, −0.3
Vulnerable	−0.57***	−0.7, −0.4	−0.48***	−0.6, −0.3
General knowledge and communication				
At risk	−0.28***	−0.4, −0.2	−0.29***	−0.4, −0.2
Vulnerable	−0.41***	−0.5, −0.3	−0.40***	−0.5, −0.3
Baseline demographics				
Sex (male)	−0.16***	−0.2, −0.1	0.10**	0.0, 0.2
Age [b]	0.03	−0.1, 0.1	−0.05	−0.2, 0.1
Race [c]				
Asian, Native Hawaiian, or other Pacific Islander	0.67***	0.5, 0.8	0.78***	0.6, 0.9
White	0.03	−0.1, 0.2	0.14	−0.0, 0.3
African American or Black	0.04	−0.3, 0.4	−0.00	−0.4, 0.4
Other	0.19*	0.0, 0.4	0.18*	0.0, 0.3
IEP	−0.11	−0.3, 0.0	−0.14	−0.3, 0.0
English learner	−0.06	−0.2, 0.0	0.00	−0.1, 0.1
Parent attended at least one parent–teacher conference	0.17	−0.0, 0.4	0.13	−0.1, 0.3
Free or reduced-price lunch	−0.11*	−0.2, −0.0	−0.14**	−0.2, −0.1
Constant	2.31***	2.1, 2.5	2.01***	1.8, 2.2
Observations	2502		2502	
R^2	0.2		0.2	
Number of neigborhoods	52		52	

[a] Reference category is on track.
[b] Regression models include mean-centered age at kindergarten entry, calculated by subtracting the sample mean from each individual value.
[c] Reference category is Hispanic.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

$= -0.28$, 95 % CI [−0.4, −0.2], $p < .001$) and mathematics ($b = -0.29$, 95 % CI [−0.4, −0.2], $p < .001$). Similarly, children classified as vulnerable in the language and cognitive development domain had worse outcomes in both ELA ($b = -0.57$, 95 % CI [−0.7, −0.4], $p < .001$) and mathematics ($b = -0.48$, 95 % CI [−0.6, −0.3], $p < .001$) compared to those on track. Children at risk in this domain also performed worse in both ELA ($b = -0.42$, 95 % CI [−0.5, −0.3], $p < .001$) and mathematics ($b = -0.41$, 95 % CI [−0.5, −0.3], $p < .001$). Only children classified as at risk in the emotional maturity domain performed statistically significantly worse than their on-track peers in both ELA ($b = -0.13$, 95 % CI [−0.3, −0.02], $p < .05$) and mathematics ($b = -0.17$, 95 % CI [−0.3, −0.1], $p < .01$). No statistically significant results were found for other groups or domains.

3.2. Other predictors of academic performance at grade 6

Regarding other covariates in our models, sex consistently emerged as a significant predictor of academic performance. Specifically, male students performed worse than their female peers in ELA, both in models with the overall EDI (Table 2; $b = -0.14$, 95 % CI [−0.2, −0.1], $p < .01$) and EDI domain scores (Table 3; $b = -0.16$, 95 % CI [−0.2, −0.1], $p < .01$). Conversely, male students outperformed their female counterparts in mathematics in both the overall EDI model ($b = 0.11$, 95 % CI [0.04, 0.2], $p < .01$) and EDI domain model ($b = 0.1$, 95 % CI [0.03, 0.2], $p < .01$).

Children identifying as Asian, Native Hawaiian, or Pacific Islander consistently outperformed their Hispanic or Latino/a/x peers in both ELA and mathematics, regardless of whether the model included overall EDI or EDI domain scores. Additionally, children receiving free or reduced-price lunch performed worse than those who did not receive assistance in both ELA and mathematics, with consistent results across models. Finally, the model with overall EDI scores (Table 2) indicated that children with an IEP performed worse than their peers without an IEP in both ELA ($b = -0.17$, 95 % CI [−0.3, −0.01], $p < .05$) and mathematics ($b = -0.2$, 95 % CI [−0.4, −0.04], $p < .01$). However, no significant effects were found for this covariate in models with EDI domain scores (Table 3).

4. Discussion

This study examined the association between population-level EDI school readiness scores and sixth-grade standardized mathematics and ELA test scores in a California sample ($N = 2610$). Children who demonstrated poor school readiness in kindergarten were less likely to achieve proficiency in literacy and mathematics by Grade 6. This finding contributes to the growing body of international research linking early childhood school readiness, as measured by the EDI, to long-term academic outcomes (Brinkman et al., 2013; Davies et al., 2016, 2022; Duncan et al., 2007; Fitzpatrick et al., 2020). Specifically, children classified as vulnerable or at risk in one or more EDI domain(s) had significantly lower proficiency in both ELA and mathematrics compared to their peers who were on track, supporting the hypothesis that the overall EDI has predictive validity beyond early elementary grades in a U.S. context.

Furthermore, our findings suggest that early language and communication skills are critical components of school readiness, influencing academic outcomes into middle childhood. This aligns with earlier research indicating that early cognitive and communication skills play a pivotal role in literacy and numeracy development. (Forget-Dubois et al., 2007; Guhn et al., 2016) These findings carry significant weight in the U.S. context, where literacy losses in young children accelerated by the COVID-19 pandemic persist (Georgiou and Parrila, 2023) and approximately 40 % of public school children across the nation read below grade level. (National Education Association 2022) To support children's longer-term academic performance, caregivers and early childhood practitioners should use practices associated with positive outcomes in language, cognitive, and communication development, such as child-directed speech, (Golinkoff et al., 2019) storytelling, (Maureen et al., 2022; Melzi et al., 2023) and guided play. (Skene et al., 2022)

Building on prior Canadian and Australian studies – where the EDI is most widely used – that often did not account for race/ethnicity (except in some cases for Indigenous or Aboriginal populations) or include individual-level socioeconomic indicators such as free-lunch eligibility (Guhn et al., 2007; Muhajarine et al., 2011; Williamson et al., 2019), this study adds to the literature by incorporating key demographic factors, incuding eligibility for free-lunch meal assistance, sex, IEP status, and ethnoracial background. In fact, our study highlights persistent inequities in school readiness and academic achievements, with significant gaps observed across ethnoracial and other demographic groups. Our results reveal significant differences in academic performance by race and ethnicity, with Asian, Native Hawaiian, and Pacific Islander children outperforming their Latino/a/x peers in both ELA and mathematics. These findings mirror previous studies that have documented racial and ethnic disparities in school readiness and achievement. (Reardon and Portilla, 2016) They also build on a California-based study that observed the highest levels of kindergarten school readiness and health development among Asian, Native Hawaiian, and Pacific Islander students across income levels as measured by the EDI. (Perrigo et al., 2023) These ethnoracial differences in early school readiness and development align with academic achievement disparities by race and ethnicity in middle childhood. Although the reasons behind these disparities are multifaceted, they may reflect differences in access to early childhood education, linguistic diversity, and cultural capital. (Perrigo et al., 2024) Research is needed to explore the intersectionality of race, ethnicity, and other factors such as language proficiency and neighborhood resources to better understand these disparities. Additionally, it is important to note that the aggregation of Asian, Native Hawaiian, and Pacific Islander students into the same ethnoracial category may mask differences in academic performance among these groups. (Hall, 2015) For example, a study of Hawaiian children's ELA performance by Singh and colleagues (Singh et al., 2020) observed disparities in academic performance between Asian and Pacific Islander subgroups and no statistically significant difference in ELA scores between Asian and white students. Continued research is necessary to identify differences in academic performance and improve interventions for specific ethnoracial subgroups.

In addition to ethnoracial disparities, our study noted differences in academic achievement based on socioeconomic status. A substantial body of literature has established that socioeconomic status is a predictor of academic achievement, with children from low socioeconomic backgrounds experiencing poorer academic performance, reduced literacy, and lower graduation rates than their peers from higher socioeconomic backgrounds. (Devenish et al., 2017; Johnson et al., 2021; Perrigo et al., 2023; Reardon, 2018; Waldfogel et al., 2011; Waters et al., 2021) Consistent with this research, children from low-income families (i.e., those receiving free or reduced-price lunch) were more likely to perform poorly on both ELA and mathematics assessments. As such, our results further underscore the critical role of socioeconomic factors in shaping academic success. Children from marginalized backgrounds often face compounded challenges, including exposure to poverty, parental stress, and limited access to high-quality early childhood education. (Hair et al., 2015; Soltis et al., 2015) Addressing these broader structural inequities is crucial for closing the achievement gap and ensuring that all children enter school ready to learn.

Sex differences in academic performance were also observed, with female students outperforming their peers in ELA and male students outperforming their peers in mathematics. These results are consistent with previous findings on sex differences in academic achievement (Thomas, 2024; Voyer and Voyer, 2014) and may result from various factors including sociocultural expectations and school characteristics that differentially affect the academic development of boys and girls. In line with previous research highlighting the academic challenges faced by students with learning disabilities, (McGregor, 2020; Neece et al., 2020) we found that children with IEPs performed worse in both ELA and mathematics, however, the results were not statistically significant. The lack of significant results in models with EDI domains is likely attributable to the uneven distribution of IEP status in the sample, with only 5 % of children classified as having an IEP. This skewed distribution can lead to limited statistical power, reducing the likelihood of detecting significant effects in subgroups, particularly when the sample size is small for the category of interest. Research with more balanced sample distributions or specialized models that can account for such disparities is needed to explore the relationship between early developmental risks and later academic performance in children with IEPs.

4.1. Implications

As states continue to invest in early childhood programs, such as prekindergarten and transitional kindergarten, (Johnson, 2024) the EDI can serve as a valuable measure for identifying children at risk of later academic difficulties and targeting interventions accordingly. In particular, the EDI's development as a population-level measure of developmental health and school readiness is fundamental in illustrating and responding to academic achievement gaps across communities. (Janus et al., 2021) Alternative measures of school readiness such as the DRDP have been developed for fundamentally different purposes, such as informing curriculum development to support individual children and classrooms. (Kriener-Althen et al., 2020) In contrast to many of these measures, the EDI can provide population estimates and neighborhood-level aggregation to identify local developmental disparities and engage communities in collective planning to improve early childhood services and systems (Guhn et al., 2007; Janus et al., 2021) As achievement gaps persist in communities across the United States, strong population-level measures, such as the EDI, can play an important role in surveilling academic achievement disparities and promoting educational equity.

The observed disparities in academic performance based on children's EDI scores also underscore the importance of early interventions for children who exhibit vulnerabilities in key developmental domains. Early childhood education programs designed to mitigate these vulnerabilities and promote school readiness skills in young children, such as Head Start, have been recognized for their potential to address school readiness gaps in early childhood and beyond. (Williams et al., 2019) Given that academic proficiency in middle childhood has been linked to long-term educational attainment and well-being, (Rabiner et al., 2016) our findings reinforce the necessity of early childhood policies and programs that focus on improving school readiness, particularly for children from underserved communities.

4.2. Limitations

Although our study offers valuable insights into the long-term academic impacts of school readiness, it is not without limitations. First, the study relied on teacher-reported data for the EDI, which may introduce bias due to subjectivity in assessments. Moreover, further research is needed to explore the role of additional factors, such as family dynamics, in shaping academic outcomes. Additionally, although this study included conceptually important covariates such as ethnoracial background and socioeconomic status, multiple additional factors–such as parental stress and parental educational attainment–could not be accounted for and may influence the relationship between kindergarten school readiness and later academic performance. Additional replication studies in other U.S. regions and among diverse populations are essential to assess the generalizability of these findings, as the current study was conducted in a single county and may not be broadly generalizable.

4.3. Conclusion

Our findings contribute to a growing body of international literature establishing the EDI's utility as a predictor of academic achievement in early and middle childhood. Research should continue to use longitudinal data to link EDI scores to later academic outcomes beyond sixth grade. Additionally, these results demonstrate the critical influence of early childhood development on later academic outcomes, reaffirming the necessity of investment in evidence-based interventions in early childhood applied alongside population-level measures to monitor their impact over time on children's academic and social trajectories.

CRediT authorship contribution statement

Judith L. Perrigo: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Conceptualization. **Leyla Karimli:** Writing – review & editing, Writing – original draft, Formal analysis. **Anna Ginther:** Writing – review & editing, Writing – original draft. **Lisa Stanley:** Project administration, Data curation. **Magdalena Janus:** Writing – review & editing, Resources.

Declaration of competing interest

None.

Data availability

The data that support the findings of this study are not publicly available, but the materials used in this study can be available from the Principal Investigator (last author) upon reasonable request, with appropriate ethical considerations.

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