

Kindergarten Readiness in Children Who Are Deaf or Hard of Hearing Who Received Early Intervention

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abstract

BACKGROUND: Children who are deaf or hard of hearing (D/HH) have improved language outcomes when enrolled in early intervention (EI) before the age of 6 months. Little is understood about the long-term impact of EI on outcomes of kindergarten readiness (K-readiness). The study objective was to evaluate the impact of EI before the age of 6 months (early) versus after 6 months (later) on K-readiness in children who are D/HH.

METHODS: In this study, we leveraged data from the Ohio Early Hearing Detection and Intervention Data Linkage Project, which linked records of 1746 infants identified with permanent hearing loss born from 2008 to 2014 across 3 Ohio state agencies; 417 had kindergarten records. The Kindergarten Readiness Assessment was used to identify children as ready for kindergarten; 385 had Kindergarten Readiness Assessment scores available. Multiple logistic regression was used to investigate the relationship between K-readiness and early EI entry while controlling for confounders (eg, hearing loss severity and disability status).

RESULTS: Children who were D/HH and entered EI early ($n = 222$; 57.7% of the cohort) were more likely to demonstrate K-readiness compared with children who entered EI later (33.8% vs 20.9%; $P = .005$). Children who entered early had similar levels of K-readiness as all Ohio students (39.9%). After controlling for confounders, children who entered EI early were more likely to be ready for kindergarten compared with children who entered later (odds ratio: 2.02; 95% confidence interval 1.18–3.45).

CONCLUSIONS: These findings support the sustained effects of early EI services on early educational outcomes among children who are D/HH. EI entry before the age of 6 months may establish healthy trajectories of early childhood development, reducing the risk for later academic struggles.



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Dr Meinzen-Derr conceptualized and designed the study, conducted the statistical analyses, drafted the initial manuscript, and reviewed and revised the manuscript; Dr Altaye assisted with the statistical analyses and interpretation of the work and reviewed and critically revised the manuscript; Dr Wiley helped conceptualize the study, assisted with the interpretation of the statistical analyses, drafted the initial manuscript, and edited the manuscript; Dr Folger assisted with the design of the study and interpretation of the statistical analyses and drafted, reviewed, and revised the manuscript; Dr Grove substantially contributed to the acquisition of data and conception of the study and critically reviewed and revised the manuscript; (Continued)

WHAT'S KNOWN ON THIS SUBJECT: Enrollment into early intervention (EI) before the age of 6 months is associated with enhanced language, compared with later enrollment ages. Little is understood about the impact of EI on outcomes occurring beyond the EI period (such as early academic outcomes).

WHAT THIS STUDY ADDS: In this study, we include public health and education data across 3 state agencies to provide evidence supporting enrollment into EI before the age of 6 months (versus later ages) for children who are deaf or hard of hearing on the increased likelihood of being kindergarten ready.

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Hearing loss influences all aspects of a child's language acquisition and, when left undetected, can delay a child's speech and language, social, and emotional development.¹⁻³ Children born with permanent hearing loss have improved speech and language outcomes when identified early and enrolled in early intervention (EI) before 6 months of age.³⁻⁵ Although rates vary by state, 1 to 2 per 1000 infants are born in the United States with hearing loss⁶; between 2005 and 2017, 65 000 infants who are deaf or hard of hearing (D/HH) have been early identified.⁷ This is an important public health issue because children who are D/HH are at an increased risk for language delays when interventions are not provided early.^{8,9}

The increased risk among children who are D/HH for significant delays in language development places them at risk for academic underachievement later in life.¹⁰⁻¹³ Early Hearing Detection and Intervention (EHDI) programs have been established in all 50 states to help ensure early diagnosis of hearing loss and subsequent intervention to help mitigate these delays. To maximize childhood outcomes for children who are D/HH, the Joint Committee on Infant Hearing recommends the following national EHDI benchmarks: screen infants for hearing loss before 1 month of age, diagnose hearing loss before 3 months of age, and enroll those infants with permanent hearing loss into EI before 6 months of age.¹⁴

EI refers to a wide range of services (ie, home visits, family training, counseling, audiological interventions, special instruction, and therapy) available to children who have disabilities or developmental delays from birth to 36 months. With the widespread implementation of EHDI programs, the body of evidence supporting the efficacy of EI services has been focused primarily on

language development.^{2,4,8,9,15} Research demonstrates that infants who are D/HH and receive EI before age 6 months have improved vocabulary and language development compared with those who receive EI after age 6 months.^{2,4,15} Additional evidence suggests potential sustaining benefits of universal newborn hearing screening and early identification, with improved reading skills later in life.^{16,17} Although the evidence is strongest regarding the effect of EI enrollment age on early language outcomes, few data exist regarding the association with early academic outcomes. This lack of data are partly due to challenges in sharing data across public health and education systems, thus contributing to the knowledge gap regarding the impact of EI on later ability to be school or kindergarten ready among children who are D/HH.

The concept of kindergarten readiness (K-readiness) reflects the competencies and skills children need to thrive during kindergarten.¹⁸ The state of Ohio measures a child's skills at the start of kindergarten that are associated with being able to fully access the kindergarten instruction by assessing 4 areas of early learning: social foundations, mathematics, language and literacy (LL), and physical well-being and motor development.¹⁹ Children who enter kindergarten "ready to learn" are more likely to be academically successful (eg, age- and/or grade-appropriate reading levels and high school graduation).^{20,21} Unfortunately, the majority of children who are D/HH enter kindergarten behind their hearing peers regarding specific literacy skills.²² Because they are at high risk for delays and deficits in communication, social, and academic skills throughout school,²³ it is vital to understand how EI experiences influence later outcomes because early experiences help shape

foundational skills necessary for school.²⁰

The primary objective of the current study was to evaluate the impact of EI enrollment before the age of 6 months on K-readiness in children who are D/HH. We focused on EI enrollment age because this is a national EHDI benchmark monitored and reported by all states. In the current study, we add to the literature by providing additional evidence in support of early access to EI, expanding to include early academic outcomes for children who are D/HH.

METHODS

Ohio EHDI Data Linkage Project

Through partnerships with the Ohio Departments of Health, Developmental Disabilities, and Education and support from the Centers for Disease Control and Prevention National Center on Birth Defects and Developmental Disabilities, we created a comprehensive longitudinal population-based database linking hearing screening and diagnostic data of 1746 infants identified with permanent hearing loss born from January 1, 2008, to December 31, 2014, with EI data and educational records.²⁴ Details regarding the Linkage Project are published elsewhere.²⁴ The EHDI and EI data systems were linked by using a deterministic, 2-staged algorithm with infant and mother information; 1262 infants were enrolled in EI. Education data through the school year (SY) of 2017 to 2018 available on 784 students, preschool to fourth grade, were linked by using a student identifier assigned to children served in EI. This study was approved by the institutional review boards of Cincinnati Children's Hospital Medical Center and Ohio Department of Health. Memoranda of understanding were created across institutions and agencies.

Variables

Outcome Measures

Ohio school districts administered the Kindergarten Readiness Assessment (KRA) in the first quarter of the SY to provide teachers with an understanding of a child's readiness to engage in the kindergarten curriculum.²⁵ The KRA, developed through a state partnership between Maryland and Ohio,^{26,27} captures foundational skills and behaviors demonstrated by students that prepare them for full participation in their learning and continued development. Administered by teachers in classrooms, the KRA includes 50 questions designed to address a child's growth and development in 4 areas of early learning: social foundations, mathematics, LL, and physical well-being and motor development. The administration manual includes accommodations for unique developmental needs of children (eg, vision impairment or American Sign Language communication). Raw scores are transformed into scaled scores (range of 202–298), with cutoffs representing skills and behaviors for instruction: emerging readiness (range of 202–257) describes students demonstrating minimal skills and/or behaviors, approaching readiness (range of 258–269) describes students demonstrating some foundational skills and/or behaviors, and demonstrating readiness (range of 270–298) describes students consistently demonstrating foundational skills and/or behaviors. The LL domain, assessing skills such as writing, reading, and letter recognition, is associated with third-grade reading performance.²⁸ A score ≥ 263 indicates a child is on track for future third-grade reading proficiency based on these skills. The KRA's overall and LL domain scores have a high level of internal consistency (Cronbach's α 0.93 and 0.81, respectfully).²⁷ Readiness categories

were never established for the other domains because of the insufficient number of points for each domain. KRA data were available for the 2014–2015 SY (when administration began) to 2018 (last year of available data) on 385 kindergartners. Data from 32 additional students administered a different assessment before 2015 were excluded.

Exposure Variable

EI exposure was defined by using the national EHDI benchmark of enrollment into EI before the age of 6 months. Children were classified as entering EI early if they enrolled before the age of 6 months and classified as entering EI later if they enrolled at or after the age of 6 months.

Statistical Analysis

Statistical analyses were conducted by using SAS version 9.4 (SAS Institute Inc, Cary, NC) software. Data distributions were assessed for normality. Differences in child and maternal characteristics between children who entered EI early and children who entered EI later were tested by using χ^2 (for categorical variables) or *t* tests (for continuous variables). Students who were D/HH who entered EI early were compared with students who entered EI later regarding the percentage of students who were ready for kindergarten as measured by the KRA. K-readiness results of all Ohio kindergartners during the same time frame were illustrated as a reference. Logistic regression was conducted to evaluate the relationship between early versus later EI enrollment and K-readiness, while controlling for possible confounders. Covariates and known or suspected confounders from the literature or statistically associated with the outcome were tested in the models and included the age of hearing loss identification, hearing loss severity and laterality, and presence of diagnosed disability reported while the child was in EI. Results were reported as an odds

ratio (OR) with 95% confidence interval (CI). A similar model was constructed to evaluate the independent relationship between EI enrollment age and having on track LL from the KRA. Because we did not have the same detailed data on all Ohio kindergartners, we did not statistically compare regression models with all kindergartners.

Eight (of 385) children had missing overall KRA scores although they received scores in ≥ 1 subdomains. To reduce bias and maximize use of available information, we conducted a sensitivity analysis, imputing the missing values using a multiple imputation method (see Supplemental Table 4). For the figures that illustrated K-readiness, we imputed the missing values by taking the average of the imputed data across the imputed databases.

RESULTS

Participants

Of the 784 students who were D/HH (preschool to fourth grade) who had been served in EI, 417 had kindergarten assessment records. Of those with records, 385 students had KRA scores between the 2014–2015 SY and 2018; 222 (57.7%) were enrolled in EI early (before the age of 6 months). Of the 163 who enrolled in EI later, 108 (66.3%) enrolled between the age of 6 and 12 months, and only 11 children enrolled after the age of 24 months. The characteristic differences of kindergarten children who were D/HH and enrolled into EI early versus later are illustrated in Table 1. Children who entered EI early were more likely ($P < .05$) to have had hearing loss confirmed at an earlier age (median 2.4 vs 5.7 months), a risk indicator for hearing loss (47% vs 36%), and a co-occurring disability diagnosis reported in the EI system (40% vs 18%) compared with children who entered EI later.

TABLE 1 Characteristics of Kindergarteners Who Are Deaf/HH

Characteristic	Enrolled in EI Early (<i>n</i> = 222; 57.7%)	Enrolled in EI Later (<i>n</i> = 163; 42.3%)	<i>P</i>
Sex, male	118 (53.2%)	85 (52.2%)	.85
Race			.21 ^a
White	187 (84.2%)	126 (77.3%)	—
Black or African American	23 (10.4%)	24 (14.7%)	—
Other	7	7	—
Unknown	5 (2.3%)	6 (3.7%)	—
Ethnicity, Hispanic	3 (1.4%)	5 (3.2%)	.29 ^a
Premature birth	53 (24.7%)	33 (21%)	.41
Hearing loss confirmed, median age in mo (IQR)	2.4 (1.4 to 4.9)	5.7 (3.4 to 12.8)	<.001
Enrollment in EI, median age in mo (IQR)	3.4 (2.4 to 4.3)	9.2 (7.5 to 15.4)	<.001
Median duration in mo (IQR) between confirmation and enrollment	1.1 (−1.2 to 1.9) ^b	2.5 (0.9 to 6.0)	<.001
Has risk indicator for hearing loss	104 (46.9%)	58 (35.6%)	.03
Developmental delay in at least 1 of 5 domains ^c	44 (19.8%)	48 (29.5%)	.03
Disability diagnosis reported on EI form	88 (39.6%)	29 (17.8%)	<.001
Mother has some college	145 (69.1%)	84 (56%)	.01
Receive private insurance	130 (58.6%)	73 (44.8%)	.008
Bilateral hearing loss	156 (70.3%)	130 (79.8%)	.04
Severe to profound hearing levels	69 (31.1%)	43 (26.4%)	.32

IQR, interquartile range; —, *P* missing for race comparison.

^a Fisher's exact test was used.

^b A negative duration indicates enrollment into EI before the hearing loss being officially diagnosed.

^c Domains measured during EI include cognitive, adaptive, communication, socioemotional, and physical.

K-Readiness

Overall, 28.3% (*n* = 109) of children who were served by the Ohio EHDI program demonstrated K-readiness, according to the overall KRA scores. Children entering EI early were more likely to be ready for kindergarten compared with children entering EI later (33.8% [*n* = 75] vs 20.9% [*n* = 34]; *P* = .005; Fig 1). Children entering EI early were more likely to have LL scores classified as on track (60% vs 42.2%, respectively; *P* = .0006; Fig 2). Statewide, Ohio kindergartners for the same years had similar levels of K-readiness (39.3%) and on track LL (62.5%) as students who were D/HH and had entered EI early.

Logistic regression results indicated that, after controlling for previous disability diagnosis, maternal education level (receiving some college education, less than college, or unknown education), insurance status, and laterality of hearing loss, children who entered EI early had an increased odds of demonstrating K-readiness compared with children who entered EI later (OR: 2.02; 95%

CI 1.18–3.45). Table 2 includes the results of the logistic regression model for K-readiness. Factors of degree of hearing loss, race, and sex were not significant in the final model (*P* > .1). The sensitivity analysis resulted in results consistent with the final model (Supplemental Table 4).

Logistic regression results for LL were similar to the K-readiness model results (Table 3). Children enrolled in EI early were more likely to have an on track LL score from the KRA compared with children enrolled later (OR: 2.16; 95% CI 1.33–3.50). Factors associated with an increased odds of being on track included having private insurance and some college education for the mother. Having a diagnosed disability and bilateral hearing loss were factors associated with a decreased odds (OR: <1) of on track LL. Hearing loss severity levels, race, and sex were not significant in the model (*P* > .1).

DISCUSSION

Results of this study indicate that children who were D/HH and entered

EI early (before the age of 6 months) were more likely to demonstrate K-readiness by the start of kindergarten compared with those who entered EI later (after age 6 months). The proportion of early EI children who were ready for kindergarten was comparable with the results for all Ohio kindergarteners. Similar findings were seen with the proportion of children who were considered on track regarding LL. Additional factors associated with better outcomes included education status of mother, insurance status, and unilateral hearing loss. Factors associated with poorer outcomes included a diagnosed co-occurring disability and bilateral hearing loss. The observed effects of early EI enrollment were not conditional on the degree of hearing loss or age of identification, suggesting that early enrollment is beneficial irrespective of these factors. Based on these findings, the receipt of EI before the age of 6 months appears to provide some benefit for children who are D/HH entering kindergarten.

EI and School Readiness

Part C of the 2004 federal Individuals with Disabilities Education Act is focused on appropriate and effective services to optimize child growth and development in preparation for successful school entry.²⁹ Per the Individuals with Disabilities Education Act, most children who are D/HH are integrated into mainstream educational settings.²⁹ Although the intent is for children who are D/HH to develop the skills necessary for mainstream kindergarten classrooms, little research has been focused on the K-readiness of this population. For children who are D/HH, the positive effects of EI on language and vocabulary development have been relatively well documented.^{2,8,9,14–16,30–41} Research on the early ages of EI enrollment has provided stronger evidence toward improved outcomes for children who are D/HH.^{2,4,8,9,15,16,42,43} Many children

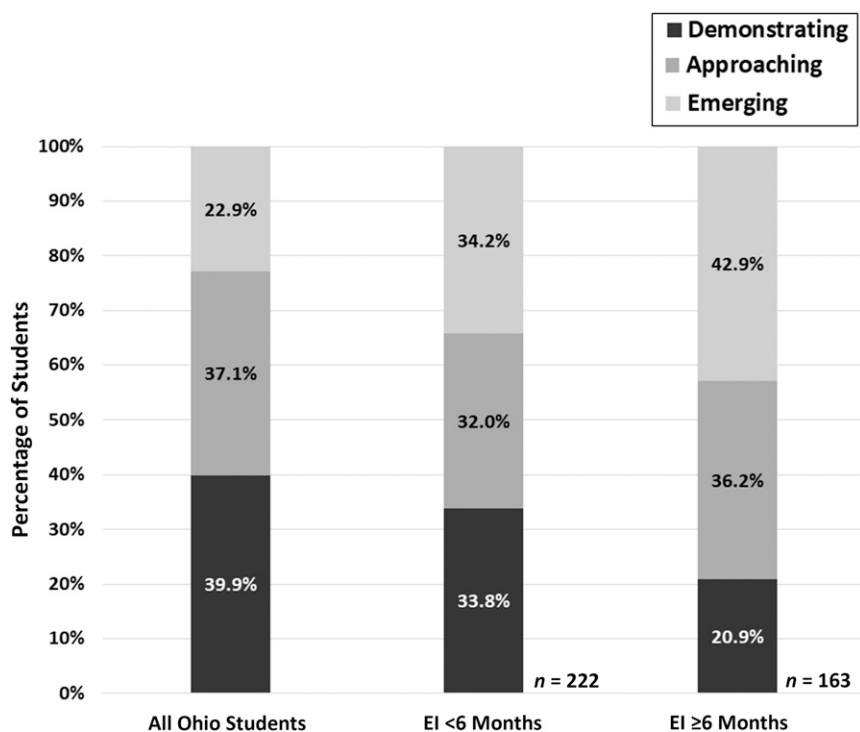


FIGURE 1 The percentage of kindergarten children who were D/HH, had been served by Ohio EI, and demonstrated K-readiness. K-readiness was measured by using the KRA. Children enrolled in EI before the age of 6 months and after the age of 6 months and all Ohio kindergarten students (as a reference) are included in the graph.

who are D/HH and their families receive some specialized EI services focused on goals that support the needs specific to D/HH educational practice (eg, family skills and accessible language). Transitioning from EI to academic settings can be difficult because a school's primary focus is on the academic and social performance of the child.^{44,45} The EI and education systems may not be congruent, (ie, separate oversight agencies, distinct funding sources, and disparate data systems). Linked state databases provide a comprehensive data system to address the short- and long-term outcomes for children served in a state EHDI program. This study benefitted from an established data linkage that allows an understanding of the longitudinal impact of services on child development.²⁴

It has been previously suggested that later ages of EI enrollment are associated with lower school readiness scores.⁴⁶ Our data on

children who are D/HH indicate that those who start receiving EI by the age of 6 months have similar rates of K-readiness as all Ohio kindergarteners (~34%) and are more likely to be ready for kindergarten compared with children who receive EI after the age of 6 months. Children who were D/HH and entered EI early were more likely to have LL scores that were on track compared with their later EI entry counterparts. Our findings are aligned with literature regarding the effects of EI before the age of 6 months on language development and naturally extends the evidence to outcomes in the kindergarten period.

K-Readiness and D/HH

Although K-readiness may be considered predictive of academic success (eg, age- and/or grade-appropriate reading levels and high school graduation),^{20,21} in children who are D/HH, K-readiness measures

may not be sufficient predictors. Antia et al⁴⁷ noted average reading skills in kindergartners who were D/HH; by second grade, reading comprehension scores were nearly 2 SD below population norms. Other research has revealed that a high proportion of students consistently have reading skills below age- and grade-appropriate levels.^{13,22,23} It appears that these early skills may not be sustained over time. Kindergarten assessments provide an understanding of foundational skills (eg, common vocabulary, shapes, and language comprehension) but may not reflect the more complex skills necessary for later reading and academics. Because of the risk for communication, social, and academic delays throughout school,²³ alternative approaches to reading instruction may be needed for children who are D/HH to achieve more complex skills (eg, complex syntax and advanced vocabulary) necessary for reading proficiency. In fact, we found 34% of children who received EI early had only emerging K-readiness levels compared with 23% of Ohio kindergartners. This early academic gap for students who are D/HH highlights an area in which EI interventionists and preschool teachers can help facilitate improved outcomes before the kindergarten transition.

Challenges

In this study, we used data collected by public health and education systems; thus, some limitations exist. We did not have language assessments at the time of kindergarten, which could help elucidate reasons for K-readiness. We did know whether they had on track LL levels according to the KRA. Information on updated audiologic data or hearing-device use (ie, hearing aids and cochlear implants) was not available. Although device information may be important for understanding factors associated with the outcome, we do not believe it would impact the relationship

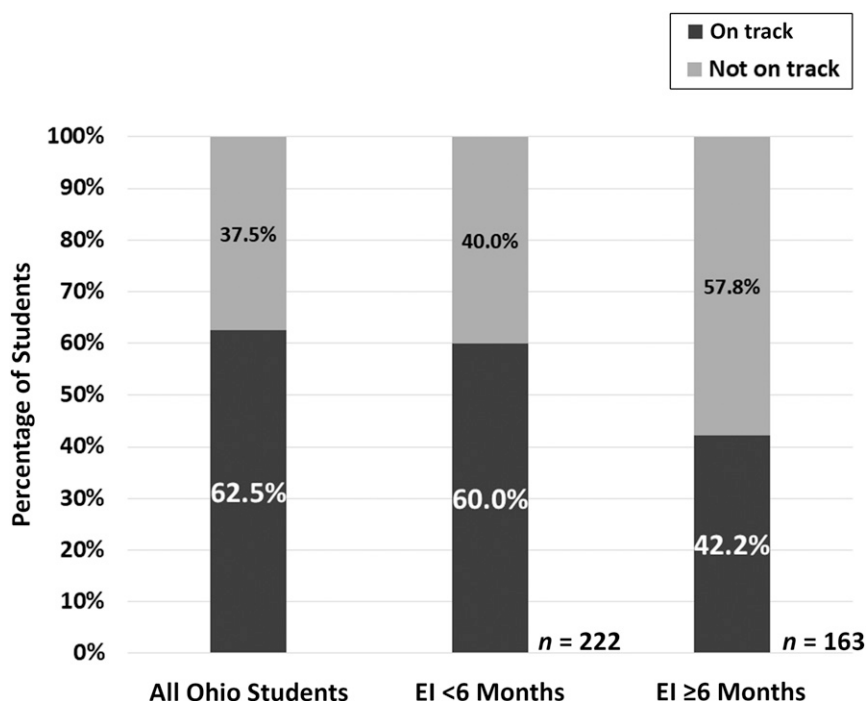


FIGURE 2 The percentage of kindergarten children who were D/HH and considered on track for LL (cutoff score of 263) on the basis of the KRA. Children enrolled in EI before the age of 6 months and after the age of 6 months and all Ohio kindergarten students (as a reference) are included.

between the age of EI (early versus later) and outcomes. We were unable to identify children who had cognitive disabilities, which would impact K-readiness because details on specific coexisting disabilities were not available. Although the types and intensities of EI services may be important parameters for outcomes, the evaluation of service types on outcomes was beyond this study's scope. The rationale for focusing on

EI age was directly linked to delineating the impact of EHDI benchmarks. Evaluating the association between outcomes and specific EI parameters is our next step for this research. There is also a chance for unmeasured confounding.

Data were included on children served in private school who had individualized education programs in

TABLE 2 Results of Multiple Logistic Regression Indicating Age of EI Enrollment as an Independent Predictor of K-Readiness

Predictor	Adjusted OR	95% CI
Early EI entry, before the age of 6 mo	2.02	1.18–3.45
Late EI late, at or after the age of 6 mo	Reference	—
Disability diagnosis while in EI	0.24	0.13–0.45
No disability diagnosis	Reference	—
Mother education level		
Some college or higher	3.21	1.67–6.17
Unknown educational level	1.22	0.31–4.79
No college	Reference	—
Private insurance	2.70	1.52–4.81
Public or self-pay insurance	Reference	—
Bilateral hearing loss	0.45	0.25–0.78
Unilateral hearing loss	Reference	—

—, not applicable.

place because that data would be reported to the state's department of education. We did not have information on children who were served in private schools with no individualized education program in place. Finally, the KRA is not designed to rank children by ability; rather, it is a formative assessment intended to understand foundational skills present at the start of kindergarten. As with any skill, skill attainment can vary widely among children of similar ages. Reliance on data from all Ohio kindergartners as a reference comparison allowed consideration of the variability inherent in children at this age. Unfortunately, KRA reliability data on children who are D/HH were unavailable.

CONCLUSIONS

Our study demonstrates that an integrated data system can address relevant and important topics regarding early academic outcomes (K-readiness and reading levels) among children who received EI. The current findings provide a new context by evaluating later outcomes among children who are D/HH, building on the previous literature on the impact of EI on language. We have shown earlier EI enrollment may have a lasting influence on a child's ability to be ready for kindergarten. Additional research is needed to understand how different EI service types impact outcomes because enrollment age is a marker of EI exposure. Because school readiness begins at birth, integrating this readiness into EI programs can help children develop a strong and lasting foundation in language, literacy, and social-emotional skills. EI interventionists can help facilitate improved outcomes post-EI and kindergarten transition through early developmental supports. Further research is needed to understand interventions designed to enhance early academic readiness. Ensuring

TABLE 3 Results of Multiple Logistic Regression Indicating Age of EI Enrollment as an Independent Predictor of Having on Track LL

Predictor	Adjusted OR	95% CI
Early EI entry, before age 6 mo	2.16	1.33–3.50
Late EI late, at or after age 6 mo	Reference	—
Disability diagnosis	0.32	0.19–0.54
No disability diagnosis	Reference	—
Mother education level		
Some college or higher	2.40	1.43–4.03
Unknown educational level	1.78	0.69–4.58
No college	Reference	—
Private insurance	3.03	1.85–4.96
Public or self-pay insurance	Reference	—
Bilateral hearing loss	0.41	0.24–0.71
Unilateral hearing loss	Reference	—

—, not applicable.

that children who are D/HH receive what is developmentally necessary is important to building critical foundational skills before kindergarten.

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ABBREVIATIONS

CI: confidence interval
D/HH: deaf or hard of hearing
EHDI: Early Hearing Detection and Intervention
EI: early intervention
KRA: Kindergarten Readiness Assessment
K-readiness: kindergarten readiness
LL: language and literacy
OR: odds ratio
SY: school year

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