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Reading Proficiency Trends Following Newborn Hearing Screening Implementation

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Abstract

OBJECTIVES: To investigate trends in population-level school-aged reading scores among students with hearing loss in an urban Colorado school district after implementation of universal newborn hearing screening (UNHS) and Early Hearing Detection and Intervention.

METHODS: The final sample included 1422 assessments conducted during the 2000–2001 through 2013–2014 school years for 321 children with hearing loss in grades 3 through 10. Longitudinal hierarchical linear modeling analyses were used to examine reading proficiency (controlling for birth year, grade in school, free and reduced lunch status, additional disability services, and English not spoken in the home). The Colorado Student Assessment Program was administered to students in third through 10th grades throughout the state. The test years chosen included children born before and after implementation of UNHS.

RESULTS: After implementation of UNHS, significant longitudinal reading proficiency improvements were observed by birth year and grade overall and for all subgroups. However, gains in reading proficiency were substantially less for children eligible for free and reduced lunch and those with moderate-severe to profound hearing loss. With each succeeding birth cohort and grade, increased numbers of children participated in testing because of improved language skills, with higher proportions identified as proficient or advanced readers.

CONCLUSIONS: Notable improvements in reading proficiency after Early Hearing Detection and Intervention implementation were demonstrated, as all groups of children with hearing

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loss became more likely to achieve proficient and advanced reading levels. On the other hand, some disparities increased, with greater improvements in reading proficiency for children in economically advantaged families.

Literacy outcomes of school-aged children with hearing loss in the United States on average have been below basic levels, with the gap with hearing peers increasing with age.[1] In 2003, the national gap in standardized reading comprehension scores increased from 2 grade levels (age 8) to 8 grade levels (age 18) (ie, fourth-versus 12th-grade equivalents).[2] Comparison of national standardized reading scores from 1974 to 2003 revealed limited progress in reducing those gaps; the gap for 17-year-olds with hearing loss decreased from 9 grade levels in 1974 to 8 in 2003.

Researchers in the 1990s reported that children with hearing loss who received early intervention services in infancy had substantially better language skills than those identified later.[3] Universal newborn hearing screening (UNHS) programs were implemented by many hospitals starting in the 1990s. US states then established Early Hearing Detection and Intervention (EHDI) programs, mostly in the late 1990s and early 2000s, to help ensure infants receive recommended follow-up diagnostic and early intervention services.[4] Established benchmarks are hearing screening by 1 month of age, diagnosis by 3 months of age, and enrollment into intervention by 6 months of age for those identified.[5]

With the establishment of UNHS and EHDI programs, studies reported better language outcomes for children with hearing loss who were identified early relative to those with late identification.[6-12] Specific findings have varied across studies and age groups. In a longitudinal cohort study in England, UNHS exposure was found to be associated with significantly better reading proficiency at ages 6 to 10 years among children with bilateral hearing loss but not at ages 13 to 19 years. More importantly, among those with UNHS whose hearing loss was confirmed by 9 months, there was no deterioration in reading comprehension, unlike those who were diagnosed with hearing loss later.[12]

No US studies to date have reported trends in reading scores of school-aged children benefiting from UNHS and early intervention. In the current study, we examined changes in third- through 10th-grade reading proficiency for children with hearing loss in a Colorado school district. In 1998, Colorado passed UNHS legislation, with >80% coverage achieved by 2000. Figure 1 depicts the percentage of Colorado births screened for hearing loss from 1992 to 2006. During 1992–2000, fewer than half of Colorado children who were identified with hearing loss met national EHDI benchmarks, but by 2007, 83% of Colorado infants who were identified with hearing loss were screened by 1 month, 87% were identified by 3 months, and 83% were enrolled in early intervention by 6 months.

This study addresses 3 questions. First, since the introduction of UNHS, has reading proficiency for children with hearing loss improved? Second, have children with hearing loss improved their relative reading proficiency with increasing grade level (ie, reduced the gap relative to hearing peers)? Third, have similar gains been achieved for children with risk factors, such as eligibility for free and reduced lunch (FRL), presence of additional

disabilities, non-English language spoken in the home, and varying laterality and degree of hearing loss?

METHODS

Participants

In this study, we examine reading proficiency based on the Colorado Student Assessment Program (CSAP) and the Transitional Colorado Assessment Program (TCAP)[13] for children with hearing loss enrolled in a large urban school district representing ≈15% of this Colorado population. Participants were students in third to 10th grades who were born between 1990 and 2006, were identified with hearing loss by educational audiologists, were enrolled in the district at some point during the 2000–2001 through 2013–2014 academic years, and had at least 1 state assessment. These years were chosen to capture children born before and after UNHS implementation.

Participants reflected the following 3 subsets of children with hearing loss based on Colorado Department of Education[14] criteria: (1) bilateral hearing loss as a 3-frequency pure tone average greater than 20 dB, (2) high-frequency hearing loss as a 2-frequency average in the better ear from 2000 to 6000 Hz, and (3) unilateral hearing loss as a 3-frequency pure tone average of ≥35 dB not reversible within a reasonable period of time. Children with additional disabilities in which the other disability was judged primary by an individual educational plan were not included. Children in a grade lower than third grade and older children with language and/or reading proficiency far below third-grade levels were exempt from testing. Per district policy, children in non–English-speaking homes who had not resided in Colorado for 3 years were similarly exempt. The number of children with hearing loss taking the CSAP and TCAP increased each year after UNHS implementation, reflecting fewer exemptions due to low language levels.

Three hundred thirty-seven children with a total of 1475 assessments met these criteria, reflecting all students with hearing loss in the district as defined above. Fifty-three assessments were missing data on at least 1 non–hearing-related predictor; all 53 were missing additional disability services (DISAB+); 44 were also missing English not spoken in the home (ENSH) status, and 44 were also missing FRL status. This resulted in a final sample of 1422 assessments based on 321 unique children. The number of assessments each academic year for children from each of the birth year cohorts is summarized in Table 1. Before UNHS and in the study's early years, most children with bilateral hearing loss were exempted from taking the CSAP and TCAP because language levels were not sufficient. A district administrator estimated that ≥150 students with hearing loss were exempted from testing in 2000, but few have been exempted since UNHS and EHDI implementation.

Measures

Reading Proficiency—Reading proficiency is based on grade-specific criteria on the annual statewide standardized assessment. Four ordinal-scale proficiency levels are provided: unsatisfactory, partially proficient, proficient, and advanced. Given the low

number of advanced scores (n = 23 across 1422 assessments), proficient and advanced levels were combined into 1 group, resulting in a 3-level ordinal scale.

Birth year was estimated on the basis of age reported in school data. Therefore, birth year reflected the academic year cycle and was centered on the 2000–2001 academic year (eg, births during the 1991–1992 academic year were coded 9, whereas births during the 2005–2006 academic year were coded 5).

Grade—Grade is a student's grade level in school during a given academic year.

Non–Hearing Related Special Education Services: Additional Disability (DISAB+)—DISAB+ indicates whether a child received non–hearing-related special education services (0 = special education for hearing loss only; 1 = non–hearing-related special education).

FRL Status—FRL status was included as a marker for family socioeconomic status (0 = not eligible; 1 = eligible for FRL).

ENSH—ENSH was coded as a dichotomous variable (0 = English, 1 = language other than English).

Laterality and Degree of Hearing Loss—Laterality and degree of hearing loss was coded into a 3-level categorical variable: (1) unilateral, irrespective of degree; (2) mild-moderate bilateral; and (3) moderate-severe to profound bilateral hearing loss. Unilateral hearing loss served as the referent group.

Data Analysis—Because children born in different years experienced different exposure to UNHS and EHDI services, the effect for time was divided into 2 variables. Birth year was the year in which the child was born; later birth years reflected increased exposure to UNHS and EHDI diagnostic and early intervention. Thus, birth year captures the between-child differences based on birth cohort. Grade in school reflected the annual growth (or decline) in proficiency a child experienced, capturing the within-child differences over time.

Analyses began with multilevel (assessments nested within students) logistic regressions examining trends in the child characteristics over time. The primary analyses involved multilevel ordinal logistic regressions examining birth year and grade in school as predictors of proficiency level to capture the overall trend over time across birth cohorts (ie, the birth year cohort effects), controlling for maturational trends within each cohort (ie, the grade level effect). These analyses also controlled for child demographic predictors (FRL, ENSH, and DISAB+) and examined possible interactions between birth year cohort and child characteristics as predictors of proficiency levels. A final exploratory analysis examined the impact of laterality and degree of hearing loss on temporal trends in proficiency. Analyses were performed by using SPSS version 26.0 (IBM SPSS Statistics, IBM Corporation)[15] and HLM 8.0.[16]

The study was ruled exempt by the University of Colorado Boulder Institutional Review Board.

RESULTS

Descriptive Statistics

Descriptive statistics are summarized in Table 2. Reflecting the multilevel data, these are reported separately for level 1 data (ie, annual school data that change over time) and level 2 data (ie, child characteristics that do not change over time).

Child-Level Data—Among the 321 children, 32 (10.0%) were identified as DISAB+, whereas 85 children (26.5%) were in the ENSH group. Laterality was available for 75.4% of children, with 31.4% of those identified as having unilateral hearing loss, 42.1% as having mild-moderate bilateral hearing loss, and 26.4% as having moderate-severe to profound bilateral hearing loss.

Assessment-Level Data—The 1422 assessments took place across third through 10th grades, with more assessments in the lower grades. On average, children had 4.43 assessments, with a median of 4.0 and an interquartile range of 2 to 7. In 1043 (73.3%) assessments, the student was eligible for FRL, with 231 of the 321 students (72.0%) eligible for FRL at the time of at least 1 of their assessments. Reading proficiency was classified as unsatisfactory in 45.6% of the 1422 assessments (n = 649), partially proficient in 26.2% of assessments (n = 372), and proficient or advanced in 28.2% of assessments (n = 378 and n = 23, respectively). This reflected 150 children (46.7%) having at least 1 assessment classified as unsatisfactory and 94 (29.3%) having at least 1 classified as proficient or advanced (Fig 2). Preliminary analyses revealed that none of the child characteristics, including degree and laterality, varied over time.

As shown in Table 3, the number of assessments increased each year because of a new birth cohort entering the grades 3 through 10 testing window and fewer children being exempted from the test each year. Note that from 2007 to 2014, the percentage of district students without hearing loss who were identified as proficient or higher increased from 43% to 54% (odds ratio [OR] = 1.60), versus 19% to 37% for students with hearing loss (OR = 2.49).

Primary Analyses—Results of the multilevel ordinal logistic regression are presented in the first panel of Table 4. Grade and FRL status were entered as level 1 variables; all other predictors were level 2 variables, with the intercept treated as a random effect. Birth year was statistically significant even after controlling for other characteristics. Specifically, the odds of being identified with a higher level of proficiency increased by 23.3% for children born in each subsequent birth year cohort. Furthermore, the odds of being in a higher proficiency level increased by 22.0% with each year in school. Additional student factors were related to decreased odds of being in a higher proficiency level. Specifically, the odds of being in a higher proficiency level decreased by 73.9% with DISAB1, by 78.4% with ENSH, and by 71.1% with FRL status in any given year.

Follow-up analyses revealed no significant interaction between birth year cohort and DISAB+ (OR = 0.888 [95% confidence interval (CI) 0.656–1.203]), ENSH (OR = 1.106 [95% CI 0.914–1.339]), or grade in school (OR = 1.015 [95% CI 0.991–1.040]). Despite the surprising nonsignificant interactions, Table 5 (DISAB1) and Table 6 (ENSH) are included

to highlight the similarity in development gain. In contrast, a significant interaction was observed between FRL status and birth year cohort (OR = 0.815 [95% CI 0.707–0.939]). Specifically, whereas a birth year cohort effect was observed among children identified as eligible for FRL (OR = 1.166 [95% CI 1.058–1.285]), the effect was greater for those not identified as eligible for FRL (OR = 1.431 [95% CI 1.244–1.646]). Although reflecting a disparity in benefits, for context, even among children eligible for FRL the odds of being in a higher proficiency level more than quadrupled (OR = 4.645) over a 10-year period (eg, children born in 2005 versus those born in 1995). This is on par, albeit it in the opposite direction, with the effects of FRL status, DISAB+, and ENSH. This differential effect is illustrated in Fig 3, which presents the annual frequency distributions of proficiency levels separately for each group.

Exploratory Analysis: Degree and Laterality of Hearing Loss—A final set of analyses added a 3-level variable indicating degree and laterality: (1) moderate-severe to profound unilateral, (2) mild-moderate bilateral, and (3) moderate-severe to profound bilateral hearing loss, with unilateral hearing loss (ie, group 1) serving as the referent group. A total of 79 of the 321 children (24.6%) were missing this variable, and further analysis suggested data were not missing at random. For example, those missing data on degree and laterality were at greater odds of being identified as eligible for FRL ($\chi_1^2 [n = 321] = 5.527$; $P = .019$; OR = 2.126). In addition, reflecting state criteria, children with unilateral hearing loss (<35 dB) were not classified as having hearing loss and thus not included in these data. Therefore, this analysis is seen as exploratory.

Results after adding degree and laterality are presented in the second panel of Table 4. Degree and laterality was related to proficiency level ($\chi_2^2 [n = 321] = 12.405$; $P = .002$). No difference was found between unilateral and mild-moderate bilateral hearing loss (OR = 0.651 [95% CI 0.262–1.616]); however, the moderate-severe to profound bilateral group did have significantly lower odds of being in a higher proficiency level than the unilateral group (OR = 0.162 [95% CI 0.057–0.461]). Follow-up analyses not included in Table 4 revealed that those with moderate-severe to profound bilateral hearing loss also had lower odds of being in a higher proficiency level those with mild-moderate bilateral hearing loss (OR = 0.249 [95% CI 0.091–0.683]). Subsequent analysis found that degree and laterality did not interact with birth year cohort ($\chi_2^2 [n = 321] = 0.369$; $P > .500$), indicating consistency across birth years.

DISCUSSION

After the implementation of UNHS and EHDI in Colorado, significant improvements in reading proficiency of successive birth cohorts of students with hearing loss were observed. Decreased exemptions from testing were associated with increases in the number of children taking state assessments each year. With each successive test year, the proportion of children in the proficient or advanced category increased as the proportion in the unsatisfactory category decreased. Gains were observed both within students, year-to-year over time, and between students in different birth year cohorts. These gains indicate that students with hearing loss made significant progress in closing the gap in reading proficiency relative to

typically developing youth during the study period.[17] This study is the first to demonstrate a long-term temporal improvement in reading proficiency after UNHS implementation when 80% of the Colorado population met national benchmarks. A previous UK study reported that improved reading proficiency in a UNHS cohort observed at ages 6 to 10 was no longer significant at ages 13 to 19, although teenagers confirmed with hearing loss by age 9 months had significantly better reading scores, highlighting the importance of UNHS accompanied by early identification.[12]

Despite sociodemographic disparities, significant shifts to higher levels of proficiency since 2000–2001 were observed in all groups with hearing loss. Reading proficiency gains were similar irrespective of the language spoken in the home. Children with unilateral hearing loss had similar proficiency gains to children with mild-moderate bilateral hearing loss. The findings are consistent with previous reports from Colorado that earlier identification and intervention significantly improved the developmental outcomes of all subgroups of younger children (through 3 years of age) with hearing loss, irrespective of degree of hearing loss or presence or absence of additional disabilities and maternal level of education.[3,7,8]

Not all groups of children, however, experienced equivalent gains in reading proficiency. Children with moderate-severe to profound hearing loss had significant gains of lesser magnitude than those with unilateral or mild-moderate bilateral hearing loss. Most concerning was that although children eligible for FRL made significant gains, these gains were less than half the gains experienced by children from higher-income families. By 2013–2014, 70.5% of the children ineligible for FRL were proficient or advanced and only 4.5% had unsatisfactory scores, whereas among those eligible for FRL, 24.5% were proficient or advanced and 41.3% had unsatisfactory scores. FRL eligibility remains a powerful negative predictor of reading outcomes. These findings are consistent with literature on the relationship between disadvantage and language, cognitive, and neurologic development.[18,19]

A limitation of this study is the inability to individually link children to UNHS results, making it impossible to differentiate children with late identification and acquired and progressive losses. However, these groups should be equally represented in each test year. Another limitation is that we only had data for FRL eligibility and not the socioeconomic variables that predict FRL eligibility. Also, data are based on one district in a single state; however, this district does reflect a population that is typically seen as being at relatively higher overall levels of risk. In addition, this is not a randomized control study, but it is a population-based description of change over time. For >30 years minimal improvement in average reading proficiency of children with hearing loss[1,2] was documented until the implementation of UNHS. Efficacy of interventions, such as hearing aids and cochlear implants, has been dependent on earlier access, possible only after UNHS implementation.[20]

CONCLUSIONS

This study provides pediatricians with further evidence that children with hearing loss post UNHS and EHDI implementation can experience substantial literacy gains. Pediatricians can encourage parents of children with unilateral or bilateral hearing loss to follow through

with all audiology and early intervention appointments, which can help ensure children receive appropriate services and achieve optimal developmental outcomes. Ineligibility of children with unilateral hearing loss for early intervention services until a delay is found should be reconsidered. The children with unilateral and mild-moderate bilateral hearing loss in this study had similar developmental needs.

Of particular encouragement is the narrowed gaps in language performance between children with hearing loss relative to typically developing students. The closing of the gap in reading comprehension in a population of children with significant risk factors is an important and novel finding.

Although most groups experienced similar reading proficiency gains over time, children eligible for FRL and those with moderate-severe to profound bilateral hearing loss experienced significantly smaller gains. The increased sociodemographic disparity in reading proficiency among children with hearing loss in this study indicates a health equity issue. This is of particular concern because it suggests that the provision of intervention services after early identification may favor children in relatively advantaged families compared with those in disadvantaged families. In future studies, researchers may assess whether greater intensity or different methods of delivering interventions before third grade to children in families of lower sociodemographic status and those with moderate-severe to profound bilateral hearing loss may help to attenuate disparities in reading proficiency.

UNHS is only the first step in the EHDI process; improved outcomes depend on early diagnosis and intervention along with minimizing disparities in receipt of services.[10] Children with hearing loss can benefit from multiple interventions, both within the health domain and within the educational domain. All types of intervention, whether educational or involving assistive technology, can be more effective in improving language outcomes with earlier initiation.

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ABBREVIATIONS

CI	confidence interval
CSAP	Colorado Student Assessment Program
DISAB+	additional disability services
EHDI	Early Hearing Detection and Intervention
ENSH	English not spoken in the home
FRL	free and reduced lunch

OR	odds ratio
TCAP	Transitional Colorado Assessment Program
UNHS	universal newborn hearing screening

REFERENCES

1. Traxler CB. The Stanford Achievement Test, 9th Edition: national norming and performance standards for deaf and hard-of-hearing students. J Deaf Stud Deaf Educ.2000;5(4):337–348 [PubMed: 15454499]
2. Qi S, Mitchell RE. Large-scale academic achievement testing of deaf and hard-of-hearing students: past, present, and future. J Deaf Stud Deaf Educ. 2012; 17(1):1–18 [PubMed: 21712463]
3. Yoshinaga-Itano C, Sedey AL, Coulter DK, Mehl AL. Language of early- and later-identified children with hearing loss. Pediatrics. 1998;102(5):1161–1171 [PubMed: 9794949]
4. Grosse SD, Mason CA, Gaffney M, Thomson V, White KR. What contribution did economic evidence make to the adoption of universal newborn hearing screening policies in the United States? Int J Neonatal Screen. 2018; 4(3):25 [PubMed: 30123850]
5. American Academy of Pediatrics; Joint Committee on Infant Hearing. Year 2007 position statement: principles and guidelines for early hearing detection and intervention programs. Pediatrics. 2007;120(4):898–921 [PubMed: 17908777]
6. Wake M, Ching TY, Wirth K, et al. Population outcomes of three approaches to detection of congenital hearing loss. Pediatrics. 2016;137(1):e20151722
7. Yoshinaga-Itano C, Coulter D, Thomson V. The Colorado Newborn Hearing Screening Project: effects on speech and language development for children with hearing loss. J Perinatol. 2000;20(8, pt 2): S132–S137 [PubMed: 11190694]
8. Yoshinaga-Itano C, Coulter D, Thomson V. Developmental outcomes of children with hearing loss born in Colorado hospitals with and without universal newborn hearing screening programs. Semin Neonatol. 2001;6(6):521–529 [PubMed: 12014893]
9. Tomblin JB, Harrison M, Ambrose SE, Walker EA, Oleson JJ, Moeller MP. Language outcomes in young children with mild to severe hearing loss. Ear Hear. 2015;36(suppl 1):76S–91S [PubMed: 26731161]
10. Yoshinaga-Itano C, Sedey AL, Wiggin M, Chung W. Early hearing detection and vocabulary of children with hearing loss. Pediatrics. 2017;140(2):e20162964 [PubMed: 28689189]
11. McCann DC, Worsfold S, Law CM, et al. Reading and communication skills after universal newborn screening for permanent childhood hearing impairment. Arch Dis Child. 2009;94(4):293–297 [PubMed: 19015215]
12. Pimperton H, Blythe H, Kreppner J, et al. The impact of universal newborn hearing screening on long-term literacy outcomes: a prospective cohort study. Arch Dis Child. 2016;101(1):9–15 [PubMed: 25425604]
13. Colorado Department of Education. About CSAP/TCAP. Available at: www.cde.state.co.us/assessment/coassess-about. Accessed April 19, 2021
14. Colorado Department of Education Exceptional Student Services. Standards of practice for audiology services in the schools. 2004. Available at: www.cde.state.co.us/sites/default/files/documents/cdesped/download/pdf/stndrs_practice_audiology_svcs.pdf. Accessed April 19, 2021
15. IBM SPSS Statistics for Windows [computer program]. Version 26.0. Armonk, NY: IBM Corporation; 2019
16. Raudenbush SW, Bryk AS, Cheong YF, Congdon RT Jr, du Toit M. HLM8: Hierarchical Linear and Nonlinear Modeling. Skokie, IL: Scientific Software International; 2019
17. Colorado Department of Education. CSAP / TCAP - data and results. Available at:https://www.cde.state.co.us/assessment/coassess-dataandresults. Accessed April 19, 2021
18. Lloyd JEV, Li L, Hertzman C. Early experiences matter: lasting effect of concentrated disadvantage on children's language and cognitive outcomes. Health Place. 2010;16(2): 371–380 [PubMed: 20022550]

19. Johnson SB, Riis JL, Noble KG. State of the art review: poverty and the developing brain. Pediatrics. 2016;137(4): e20153075 [PubMed: 26952506]

20. Ching TYC, Dillon H, Button L, et al. Age at intervention for permanent hearing loss and 5-year language outcomes. Pediatrics. 2017;140(3): e20164274 [PubMed: 28864712]

WHAT'S KNOWN ON THIS SUBJECT:

Exposure to universal newborn hearing screening predicted better language and higher reading scores for children in England at 6 to 10 years of age, but not at 13 to 19 years, although diagnosis before 9 months was associated with better reading scores.

WHAT THIS STUDY ADDS:

This study documents notable improvements in third-through 10th-grade reading proficiency after universal newborn hearing screening and Early Hearing Detection and Intervention implementation, irrespective of test year, grade, free and reduced lunch status, language spoken in the home, presence/absence of an additional disability, and laterality and degree of hearing loss.

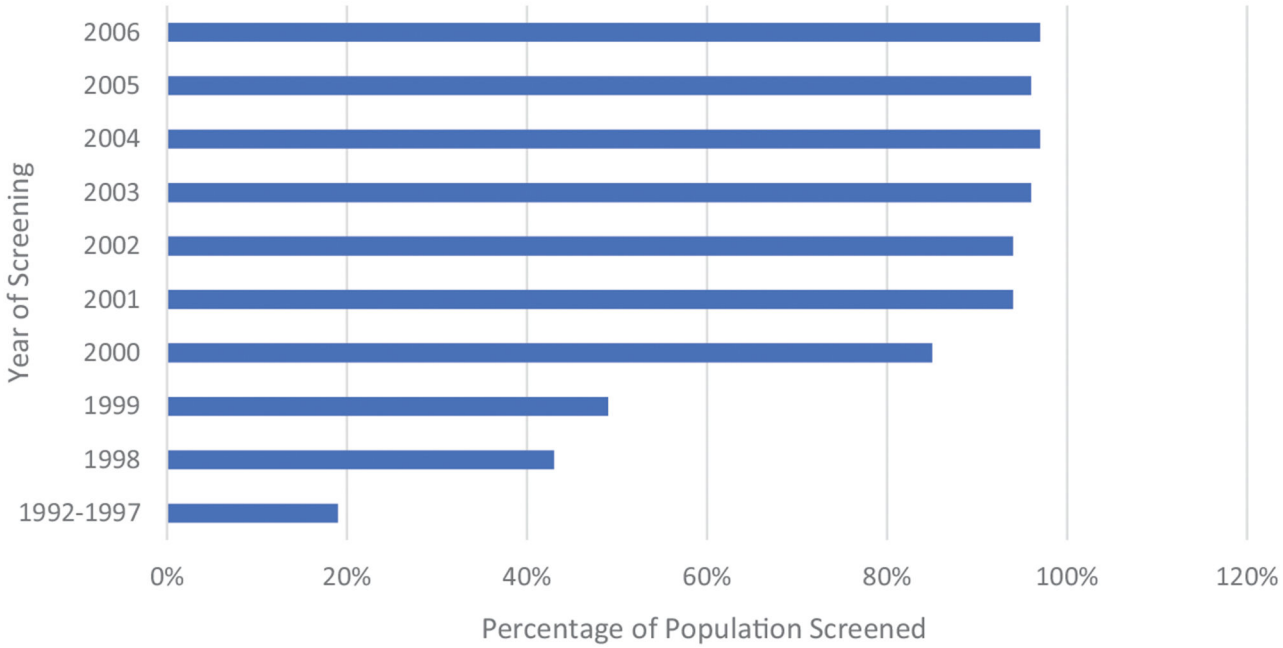

FIGURE 1.
Percentage of Colorado births screened from 1992 to 2006.

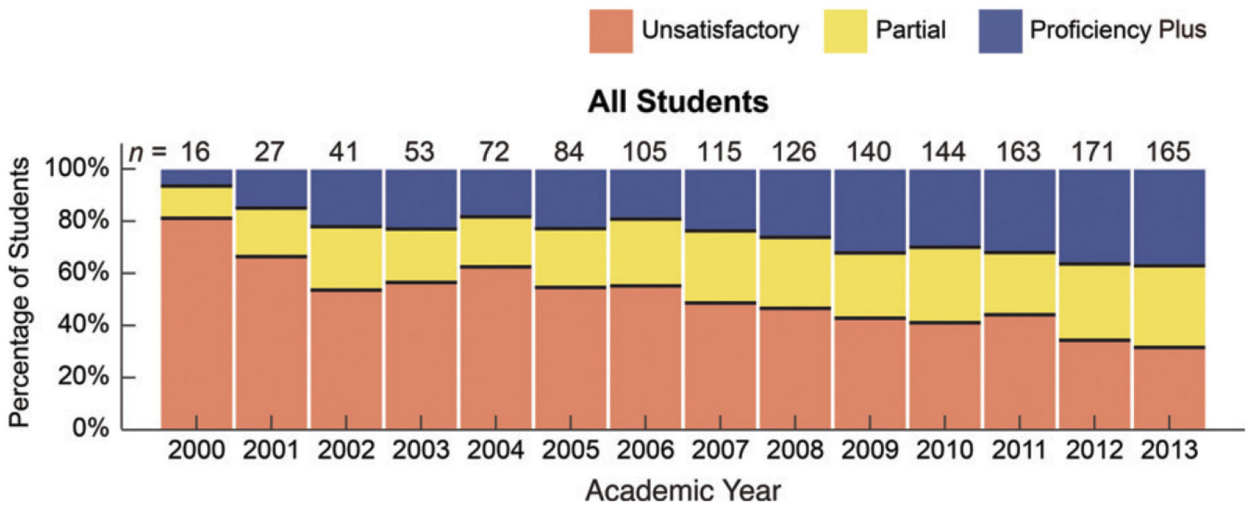

FIGURE 2.

Percentage of students by test year (2000–2013) with proficient or advanced, partially proficient, and unsatisfactory reading proficiency for all students who were deaf or hard of hearing and took the CSAP.

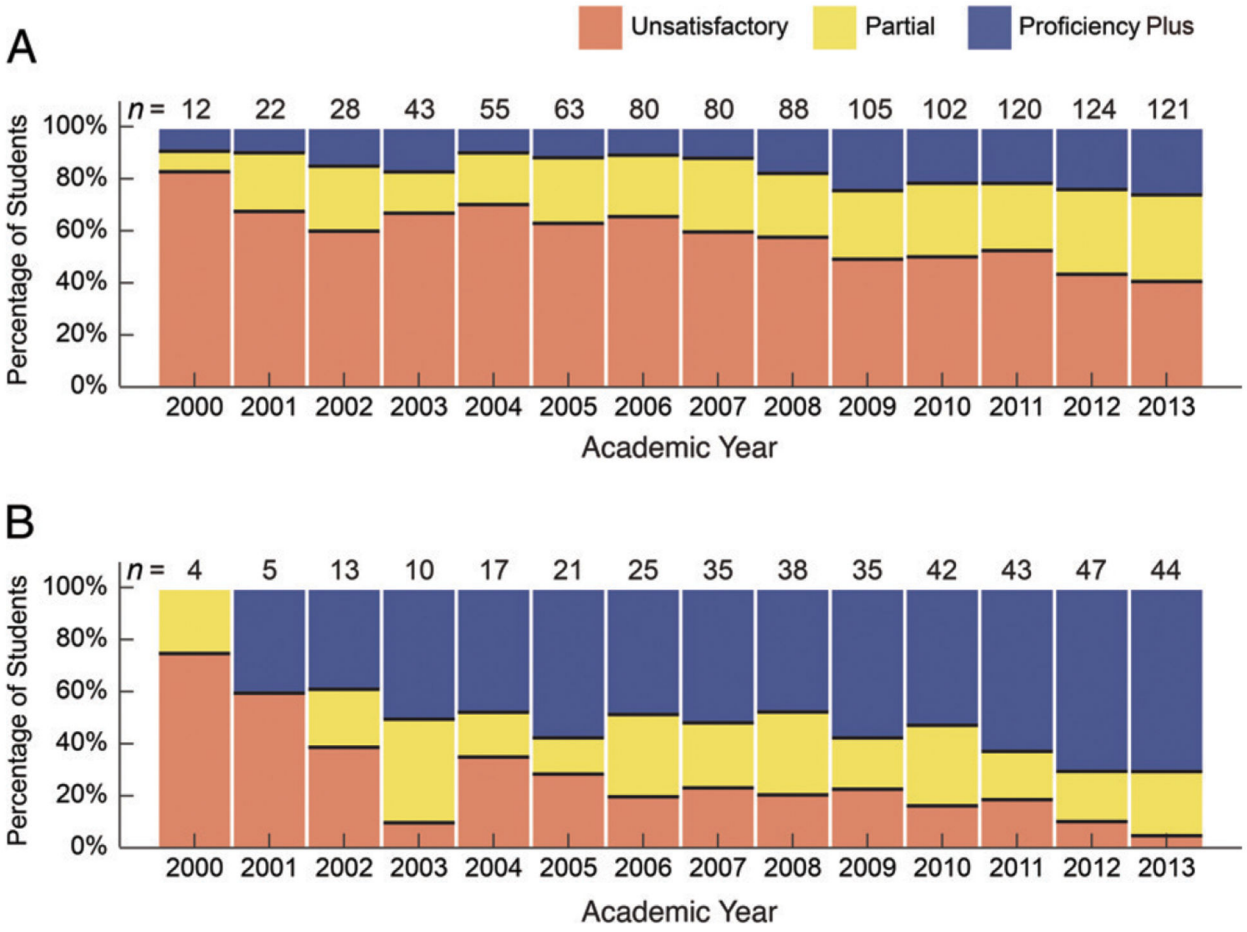

FIGURE 3.

Percentage of students by test year (2000–2013) with proficient or advanced, partially proficient, and unsatisfactory reading proficiency for students who were deaf or hard of hearing and eligible for FRL and those ineligible for FRL who took the CSAP and TCAP. A, FRL status: eligible. B, FRL status: noneligible (paid).

TABLE 1

Number of Assessments Each Year Based on Student Birth Cohort

Birth Cohort	2000–2001	2001–2002	2002–2003	2003–2004	2004–2005	2005–2006	2006–2007	2007–2008	2008–2009	2009–2010	2010–2011	2011–2012	2012–2013	2013–2014	Total
1990–1991	1	1	1	1	0	1	0	0	0	0	0	0	0	0	5
1991–1992	6	4	5	5	5	5	5	2	0	0	0	0	0	0	37
1992–1993	9	10	11	12	15	16	15	14	1	1	1	0	0	0	105
1993–1994	0	12	12	13	14	12	12	10	11	3	0	0	0	0	99
1994–1995	0	0	12	14	14	13	12	11	12	13	2	1	0	0	104
1995–1996	0	0	0	8	9	9	9	9	11	11	9	3	0	0	78
1996–1997	0	0	0	0	15	14	16	16	17	15	18	18	4	0	133
1997–1998	0	0	0	0	0	14	16	16	16	14	14	16	14	2	122
1998–1999	0	0	0	0	0	0	20	20	22	21	20	22	23	20	168
1999–2000	0	0	0	0	0	0	0	17	17	18	17	16	16	19	120
2000–2001	0	0	0	0	0	0	0	0	19	20	22	20	20	17	118
2001–2002	0	0	0	0	0	0	0	0	0	24	25	22	24	22	117
2002–2003	0	0	0	0	0	0	0	0	0	0	16	16	17	17	66
2003–2004	0	0	0	0	0	0	0	0	0	0	0	29	29	29	87
2004–2005	0	0	0	0	0	0	0	0	0	0	0	0	24	24	48
2005–2006	0	0	0	0	0	0	0	0	0	0	0	0	0	15	15
Total	16	27	41	53	72	84	105	115	126	140	144	163	171	165	1422

TABLE 2

Frequencies for Both Child-Level Characteristics That Do Not Vary Over Time And Assessment-Level Variables That May Change at Each Assessment

	Value	*n*	%
Child-level variable			
Special education services other than hearing loss	Hearing loss only	289	90.0
	Other than hearing loss	32	10.0
Language in home	English	236	73.5
	Non-English	85	36.5
Type of hearing loss	Unilateral	76	31.4
	Bilateral, mild or moderate	102	42.1
	Bilateral, severe to profound	64	26.4
Assessment-level variable			
Proficiency	Proficient or advanced	401	28.2
	Partially proficient	372	26.2
	Unsatisfactory	649	45.6
FRL	Non-FRL	379	26.7
	FRL	1043	73.3
Grade	Third grade	236	16.6
	Fourth grade	233	16.4
	Fifth grade	215	15.1
	Sixth grade	187	13.2
	Seventh grade	165	11.6
	Eighth grade	143	10.1
	Nineth grade	140	9.8
	10th grade	103	7.2

Seventy-nine children were missing data for degree and laterality of hearing loss.

TABLE 3

Reported Proficiency Levels for Children With Hearing Loss, by Academic Year

		Raw Counts			Percentage, %			
Academic Year	**Total, *n***	**Unsatisfactory**	**Partially Proficient**	**Proficient Plus**	**Unsatisfactory**	**Partially Proficient**	**Proficient Plus**	**Proficient Plus, District %**
2000–2001	16	13	2	1	81.3	12.5	6.3	40.0
2001–2002	27	18	5	4	66.7	18.5	14.8	40.0
2002–2003	41	22	10	9	53.7	24.4	22.0	41.0
2003–2004	53	30	11	12	56.6	20.8	22.6	40.0
2004–2005	72	45	14	13	62.5	19.4	18.1	40.0
2005–2006	84	46	19	19	54.8	22.6	22.6	40.0
2006–2007	105	58	27	30	55.2	25.7	19.0	44.0
2007–2008	115	56	32	27	48.7	27.8	23.5	43.0
2008–2009	126	59	34	33	46.8	27.0	26.2	46.0
2009–2010	140	60	35	45	42.9	25.0	32.1	47.0
2010–2011	144	59	42	43	41.0	29.2	29.9	50.0
2011–2012	163	72	39	52	44.2	23.9	31.9	49.0
2012–2013	171	59	50	62	34.5	29.2	36.3	52.0
2013–2014	165	52	52	61	31.5	31.5	37.0	54.0

TABLE 4

Primary and Exploratory Multilevel Ordinal Logistic Regressions Predicting Higher Proficiency Level on the Basis of Birth Cohort, Grade Level, Presence of Other Disabilities, Language in the Home, FRL Status, and Laterality and Degree of Hearing Loss

	Primary Analysis			Exploratory Analysis: Degree of Hearing Loss		
Effect	**Coefficient**	**OR**	**95% CI**	**Coefficient**	**OR**	**95% CI**
Intercept	−1.53	0.22	0.11 ∓0.44	−0.82	0.44	0.17–1.17
Threshold δ_2	2.98	19.73	14.61–26.64	3.20	24.58	16.93–35.69
Birth year	0.21	1.23	1.13–1.35	0.12	1.13	1.01–1.26
Multiple disabilities	−1.34	0.26	0.08–0.85	−2.05	0.13	0.03–0.59
Home language	−1.53	0.22	0.11–0.45	−1.64	0.19	0.09–0.44
Grade	0.20	1.22	1.13–1.32	0.19	1.21	1.11–1.33
FRL status	−1.24	0.29	0.16–0.51	−1.39	0.25	0.12–0.51
Bilateral, mild or moderate	—	—	—	−0.43	0.65	0.26–1.62
Bilateral, severe to profound	—	—	—	−1.82	0.16	0.06–0.46

Primary analyses: δ_2, grade, FRL degrees of freedom = 1098; all other degrees of freedom = 317. Exploratory analyses examining degree of hearing loss: δ_2 grade, FRL degrees of freedom = 847; all other degrees of freedom = 236. “Birth year” represents the year of birth based on the academic year and centered on 2000–2001. “Multiple disabilities” is defined as follows: 0 = hearing loss only; 1 = presence of an additional disability. “Home language” represents the primary language in the home (0 = English; 1 = any language other than English). “Grade” represents the grade in school. “FRL status” is defined as follows: 0 = not identified as eligible for FRL; 1 = identified as eligible for FRL. “Bilateral, mild or moderate” represents the degree of hearing loss (0 = unilateral or bilateral, severe to profound; 1 = bilateral, mild or moderate). “Bilateral, severe to profound” represents the degree of hearing loss (0 = unilateral or bilateral, mild or moderate; 1 = bilateral, severe to profound). δ2 is an additional term needed to reflect the distinction between 3 categories; —, indicates variables not included in the primary analysis mode.

TABLE 5

Reported Proficiency Levels for Children With Hearing Loss, by Academic Year and Presence of Multiple Disabilities

	Hearing Loss Only				Multiple Disabilities			
Academic Year	**Unsatisfactory, %**	**Partially Proficient, %**	**Proficient Plus, %**	***n***	**Unsatisfactory, %**	**Partially Proficient, %**	**Proficient Plus, %**	***n***
2000–2001	85.7	14.3	0.0	14	50.0	0.0	50.0	2
2001–2002	68.0	20.0	12.0	25	50.0	0.0	50.0	2
2002–2003	52.6	26.3	21.1	38	66.7	0.0	33.3	3
2003–2004	55.3	23.4	21.3	47	66.7	0.0	33.3	6
2004–2005	62.5	20.3	17.2	64	62.5	12.5	25.0	8
2005–2006	56.0	24.0	20.0	75	44.4	11.1	44.4	9
2006–2007	54.4	26.7	18.9	90	60.0	20.0	20.0	15
2007–2008	49.0	27.5	23.5	102	46.2	30.8	23.1	13
2008–2009	45.5	26.8	27.7	112	57.1	28.6	14.3	14
2009–2010	41.7	26.0	32.3	127	53.8	15.4	30.8	13
2010–2011	40.3	29.1	30.6	134	50.0	30.0	20.0	10
2011–2012	43.6	22.8	33.6	149	50.0	35.7	14.3	14
2012–2013	33.1	28.8	38.1	160	54.5	36.4	9.1	11
2013–2014	29.5	32.7	37.8	156	66.7	11.1	22.2	9

TABLE 6

Reported Proficiency Levels for Children With Hearing Loss, by Academic Year and Language Spoken in the Home

	English				Non-English			
Academic Year	**Unsatisfactory, %**	**Partially Proficient, %**	**Proficient Plus, %**	***n***	**Unsatisfactory, %**	**Partially Proficient, %**	**Proficient Plus, %**	***n***
2000–2001	78.6	14.3	7.1	14	100.0	0.0	0.0	2
2001–2002	63.6	22.7	13.6	22	80.0	0.0	20.0	5
2002–2003	51.4	25.7	22.9	35	66.7	16.7	16.7	6
2003–2004	51.1	24.4	24.4	45	87.5	0.0	12.5	8
2004–2005	56.9	22.4	20.7	58	85.7	7.1	7.1	14
2005–2006	44.3	29.5	26.2	61	82.6	4.3	13.0	23
2006–2007	46.4	29.0	24.6	69	72.2	19.4	8.3	36
2007–2008	38.3	32.1	29.6	81	73.5	17.6	8.8	34
2008–2009	37.9	27.6	34.5	87	66.7	25.6	7.7	39
2009–2010	32.0	29.0	39.0	100	70.0	15.0	15.0	40
2010–2011	33.3	29.4	37.3	102	59.5	28.6	11.9	42
2011–2012	40.2	20.5	39.3	112	52.9	31.4	15.7	51
2012–2013	28.1	25.4	46.5	114	47.4	36.8	15.8	57
2013–2014	28.9	28.1	43.0	114	37.3	39.2	23.5	51