Impact of Social Determinants of Health on Early Hearing Detection and Intervention Screening/Diagnosis Outcomes

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Abstract

Purpose: We reviewed how Social Determinants of Health relate to health inequities and disparities for Early Hearing Detection and Intervention (EHDI) programs. Then, we examined links between specific sociodemographic factors (maternal age, maternal education, race/ethnicity) and hearing screening and diagnostic audiology follow-up for newborns in the United States and its territories.

Methods: Maternal demographic, hearing screening, and diagnostic data extracted from publicly available Centers for Disease Control and Prevention (CDC) records were reported to CDC by personnel responsible for EHDI programs. Data were subjected to statistical analysis using analysis of variance and multiple regression techniques.

Results: Results showed no significant differences in screening follow-up outcomes for maternal age, education, or race/ethnicity. There was a significant difference for maternal education and race/ethnicity for diagnostic follow-up outcomes, but not for maternal age.

Conclusion: Results of this study are consistent with the findings of previous studies regarding hearing screening follow-up and diagnostic audiologic follow-up outcomes. Maternal education and race/ethnicity were linked to hearing diagnostic audiologic follow-up for newborns in the United States and its territories. Suggestions for future research, policy, and practice to improve the effectiveness of EHDI efforts are provided.

Key Words: newborn hearing screening, diagnosis, Early Hearing Detection and Intervention, Social Determinants of Health, health disparities

Acronyms: CDC = Centers for Disease Control and Prevention; EHDI = Early Hearing Detection and Intervention; HSFS = Hearing Screening and Follow-Up Survey; IS = Information Systems; LTF/D = loss-to-follow-up/loss to documentation; SDoH = Social Determinants of Health

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The Early Hearing Detection and Intervention (EHDI) system, established to identify infants with hearing loss and to minimize long-term adverse effects that can result from unidentified congenital or early onset hearing loss, directly benefits American families across the 50 U.S. states and territories. EHDI's precise goals are screening for hearing loss by age 1 month/30 days, diagnosis by age 3 months/90 days for those not passing the screening, and enrollment in early intervention services by age 6 months/180 days for those identified with a hearing loss (Centers for Disease Control and Prevention [CDC], n.d.c; Joint Committee on Infant Hearing [JCIH], 2019). These 1-3-6 goals are known as the National EHDI Goals (CDC, 2003; CDC, n.d.a; National Center for Hearing Assessment and Management [NCHAM], n.d.).

The benchmark goal for newborn hearing screening was set as 95% by one-month chronological age, with a follow-up target of 70% (JCIH, 2000). With little data available from which to gauge a realistic benchmark, the JCIH set 100% as the goal for verification of hearing loss by three months of age. Each step of the process brings with it a transition of services between healthcare providers, agencies, and systems, presenting ample opportunities for

loss-to-follow-up/loss to documentation (LTF/D). Although the EHDI process is a national initiative, its programs are implemented and administered at state and territory levels, with each entity contributing aggregate data through the CDC's annual Hearing Screening and Follow-Up Survey (HSFS; Nicholson et al., 2022) which is used to help assess progress in EHDI. Laws and regulations related to the reporting of screening and diagnostic data vary by state/territory. The HSFS data is voluntarily reported public health data collected annually by the CDC and is available via a public website (CDC, n.d.c). Unique strengths and weaknesses within each jurisdiction influence reported outcomes for the EHDI program.

Social Determinants of Health (SDoH)

Social determinants of health (SDoH) are non-medical variables or environmental conditions influencing health outcomes (Matiz et al., 2022). The circumstances in which people are born, grow, live, play, work, and age constitute the SDoH (World Health Organization [WHO] and Commission on Social Determinants of Health, 2008). Having sufficient financial resources linked to economic stability, accessibility to quality education and healthcare, safe home and school environments, and accessibility to play areas within the social and community context are primary domains of SDoH (U.S. Department of Health and Human Services [DHHS], n.d.). Together, these factors influence the health and well-being of all individuals, influencing differences in sociodemographic variables as well as contributing to health disparities and inequities. (e.g., Erikson et al., 2022).

Health Inequities and Health Disparities

It is important to understand the difference between health inequities and health disparities; ambiguity might lead to misdirection of resources (Braveman, 2014). Health **inequities** refers to *inequalities* or differences in treatment due to being marginalized or minoritized (e.g., those who are resource-constrained or not identified as white or residing in rural communities). On the other hand, health **disparities** refer to outcome differences largely due to the impact that SDoH have on specific populations, irrespective of service provider treatment (e.g., Florentine et al., 2022; Schuh & Bush, 2021).

Hearing health disparities among children contribute to poorer outcomes. Children with hearing loss from certain ethnic or impoverished backgrounds or from specific geographic regions have been significantly delayed in diagnosis and intervention (Barr et al., 2019; Boss et al., 2011; Bush et al., 2013; Bush, Bianchi, et al., 2014; Bush, Osetinsky, et al., 2014; 2017; Parker et al., 2020). Children with hearing loss are more likely to live in poverty and not take advantage of hearing health services (Boss et al., 2011; Emmett & Francis, 2014; Linton et al., 2019). Hearing health services seem either less likely to be sufficient or not provided at all to some children with hearing loss from marginalized or non-white groups (e.g., Bush et al., 2017; Ely & Driscoll, 2019; Linton et

al., 2019; Liu et al., 2020; Nieman, Marrone, et al., 2016; Nieman, Tunkel, et al., 2016; Okolie et al., 2020; Qian et al., 2021; Tolan et al., 2017; Zhang et al., 2019). The first two decades of this century often placed non-white American children at distinct disadvantages (Cooc & Kiru, 2018; Love & Beneke, 2021; McManus et al., 2010; Morgan et al., 2017; Park et al., 2021; Parker et al., 2020; Thorne et al., 2019). Hearing health disparities are linked to identification/diagnosis of hearing loss, use of hearing devices, and medical treatment of hearing-related issues that include cochlear implantation (e.g., Liu et al., 2020; Okolie et al., 2020; Peltz et al., 2021; Zhang et al., 2021).

Sociodemographic Factors

Sociodemographic data are the classifiable characteristics of a given population (e.g., age, gender, race, ethnicity), commonly used in public health surveys and reports. Sociodemographic characteristics may impact outcomes among young children with hearing loss by influencing a primary caregiver's ability to: (a) acquire knowledge about the value of early identification of hearing loss, (b) communicate effectively with hearing healthcare providers, and (c) obtain effective social support for securing audiological diagnosis. Researchers often consider sociodemographic factors as predictors or independent variables used in regression analyses (Salkind, 2010).

Sociodemographic Variables

A *sociodemographic variable* is any variable that relates to or involves a combination of social and demographic factors which can significantly influence mental and physical health or intervention outcomes. For example, research having to do with child development often associates child health, educational, or intervention outcomes with such variables as maternal age, child sex/gender identification, parental educational attainment, marital status, family composition/living arrangements, religious affiliation/practices, caregivers' ethnic background, maternal/child skin color, level of household income, parental employment status, geographic area of residence, neighborhood characteristics, language/s spoken at home, household routines, abuse or complex needs of family members, and/or availability of neighborhood/family resources (e.g., Behforouz et al., 2014; Crutchfield et al., 2022; Davis-Strauss et al., 2021). It is important to recognize that one of these variables can exacerbate the effects of another variable (e.g., poverty can unduly influence the effects of being marginalized due to skin color). Likewise, poverty can negatively influence household routines, neighborhood characteristics, and so on. As a variable, low-income level is particularly insidious.

Publicly reported EHDI hearing screening and follow-up outcomes collected from voluntary state and territory HSFS reports to the CDC are published on the CDC EHDI website. The sociodemographic variables collected and reported include maternal age, education, race, and ethnicity. These data provide a limited window into sociodemographic factors or variables that may impact outcomes.

Age. Maternal age, a significant sociodemographic variable influencing child diagnostic and developmental outcomes is considered a high-risk factor with teen pregnancies under 17 years and geriatric pregnancies over 35 years (Shanker et al., 2019). Although such high-risk maternal age groups involve more birth complications (Cavazos-Rehg et al., 2015), geriatric pregnancies are at lower risk for problematic child developmental outcomes (Duncan et al., 2018; Falster et al., 2018).

Education. Maternal education, one of the sociodemographic variables reported as EHDI outcomes by the CDC, is linked to language outcomes for both typically hearing children (Bruce et al., 2022; Hoff et al., 2018; Justice et al., 2020) and children using hearing technology (Ching et al., 2018; Tomblin et al., 2015; Yoshinaga-Itano et al., 2018). Maternal education is also linked to EHDI outcomes (Nicholson et al., 2022; Zeitlin et al., 2021).

Race. Race is a fluid social construct based primarily on perception of skin color (Monk, 2021). Skin color is a visual attribute assigned to African-Americans as well as non-white Latino-Americans, Asian-Americans, Pacific Islanders, and indigenous groups such as Native Americans/Hawaiians/Alaskans (Braveman et al., 2022). Race, linked with EHDI outcomes, warrants further analysis (Cunningham et al., 2018; Deng et al., 2022).

Ethnicity. Ethnicity is a social construct distinct from race/skin color (Breathett et al., 2021; Flanagin et al., 2021). Regardless of skin color or other visual attributes, people within many ethnic groups self-identify more so with their ethnic backgrounds (e.g., Vietnamese, Ethiopian, Hmong, Guatemalans, Filipinos, Haitians, Nigerians, Pakistani, Osceola, Inuit, Moroccan, Samoan; see, e.g., Holland & Palaniappan, 2012). Previously reported research demonstrated no relationship between Hispanic and non-Hispanic ethnicities and EHDI outcomes (Nicholson et al., 2022).

Purpose

The purpose of this study was to investigate differences in CDC EHDI HSFS reported data for maternal age, education, and race/ethnicity from 2016 to 2018. Specifically, we hypothesized significant differences: (a) in the percentage of states and territories reporting screening and diagnostic rates for 2016, 2017, and 2018 by maternal age, education, and race/ethnicity; (b) between the type of reason for LTF (documented reasons for lack of follow-up) or LTD (undocumented reasons for lack of follow-up or no report in screening and diagnostic testing during 2016, 2017, and 2018); and (c) by maternal sociodemographic and socioeconomic variables (age, education, and race/ethnicity) on screening, diagnostic, and LTF/D rates for 2016, 2017, and 2018. For this study, we refer to these variables as maternal demographic variables to maintain consistency with the CDC EHDI HSFS data reporting.

Method

Protocol #2022-132 was approved by the Nova Southeastern University Institutional Review Board. The data included in this study was reported to the CDC on the EHDI HSFS by participating state and territory jurisdictions and is publicly available on the CDC EHDI website (n.d.b).

Study Population

The participant cohort for this study was comprised of 11,382,997 infants who were born January 1, 2016 through December 31, 2018, as documented in the CDC EHDI HSFS annual report. At the time of this study, data through 2018 was available for analysis.

Data Collection

The CDC reported data by jurisdictions for screening, diagnostic, and intervention related variables from Part 1 of the HSFS while maternal demographic data was reported in the aggregate for all jurisdictions that provided these data. The jurisdictional de-identified data for LTF/D for screening and for diagnosis were exported into an excel spreadsheet for birth years 2016, 2017, and 2018 (CDC, n.d.b). The reasons for lack of follow-up data were coded as documented and undocumented for the purposes of further analysis. Aggregate maternal demographic data for age, education, and race/ethnicity were extracted from the CDC website for birth years 2016, 2017, and 2018 (CDC, n.d.b).

Measures

Number of Jurisdictions Reporting Demographic Data

The CDC listed the number of jurisdictions who reported maternal demographic data on the HSFS for each year. Jurisdictions reporting greater than 20% of the total demographics in the *unknown* category were excluded from the CDC analysis and demographic summary (CDC, n.d.b). The aggregate maternal demographic data available from the CDC consisted of those jurisdictions reporting less than or equal to 20% for each demographic variable which were included in the dataset for maternal demographics. To calculate the percentage of states and territories reporting for each service (i.e., screening or diagnosis) for each demographic variable (i.e., age, education, ethnicity, race/ethnicity) for each year (i.e., 2016, 2017, and 2018) served as the numerator. The total number of jurisdictions reporting demographic data and included in the data set served as the denominator. Percentages were calculated for each maternal demographic for each condition, demographic, and year.

LTF/D for Screening

The definitions for screening LTF/D were those standard HSFS definitions used by the CDC. The total number and percentage of infants, for whom maternal demographic data was reported, who did not complete the follow-up hearing screening after failing the initial screen for 2016, 2017, and 2018 were extracted from the CDC website. Infants considered LTF were those with reasons for lack of follow-up documented by the hospital (e.g., in an electronic medical record). Infants considered LTD were those who may have received services, but data were not reported, and the parents could not be contacted by the state EHDI follow-up team following the hearing screening.

Documented reasons listed on the HSFS for not receiving services included: infant died, moved out of jurisdiction, medical reason, parents declined, transferred, adopted, homebirth. Undocumented reasons listed on the HSFS for not receiving services included: parents unresponsive, unable to contact, unknown, and other. Numbers were recorded and percentages were calculated for each reason for each year in each category.

LTF/D for Diagnostics

The total number and percentage of infants who did not complete the follow-up diagnostic after failing the screening process for whom maternal demographic data were reported were extracted and recorded. Infants who had a documented status were considered as LTF. Infants who did not have a documented status and could not be contacted were considered LTD. Documented reasons included diagnostic in process, primary care physician (PCP) did not refer, non-resident or moved, medical reason, parents declined, transferred, or adopted. Undocumented reasons included parents unresponsive, unable to contact, and other.

Maternal Demographic Variables

Maternal Age. The percent of infants born to mothers by year (2016, 2017, 2018), condition (screening or diagnostic), and age group (< 15, 15–19, 20–24, 25–34, 35–50, and 50+ years) for whom maternal demographic data were extracted and plotted.

Maternal Education. The percentage of infants born to mothers by year (2016, 2017, 2018), condition (screening or diagnostic), and education level (less than high school, high school/GED, some college/associate degree, and college graduate+) were extracted and plotted.

Maternal Race/Ethnicity. The percent of infants born to mothers by year (2016, 2017, 2018), condition (screening or diagnostic), and race/ethnicity (white Non-Hispanic, white Hispanic, black Non-Hispanic, black Hispanic, Asian, Native Hawaiian or Pacific Islander, American Indian or Alaskan Native, or Other) were extracted and plotted.

Data Analysis

Data were combined across 56 jurisdictions for 2016 and 2017 and 57 jurisdictions for 2018 for analysis. Screening and diagnostic evaluation processes based on birth cohort for number of jurisdictions reporting, LTF/D, and demographic variables (maternal age, education, ethnicity, and race/ethnicity) were analyzed. Descriptive statistics consisted of group frequencies and/or percentages. Inferential analysis consisted of the univariate analysis of variance (ANOVA) to test hypotheses with follow-up post hoc multiple pairwise comparisons as needed.

Results

The purpose of this study was to (a) investigate jurisdictional reporting patterns in CDC EHDI HSFS data by year, condition, and maternal demographic variable,
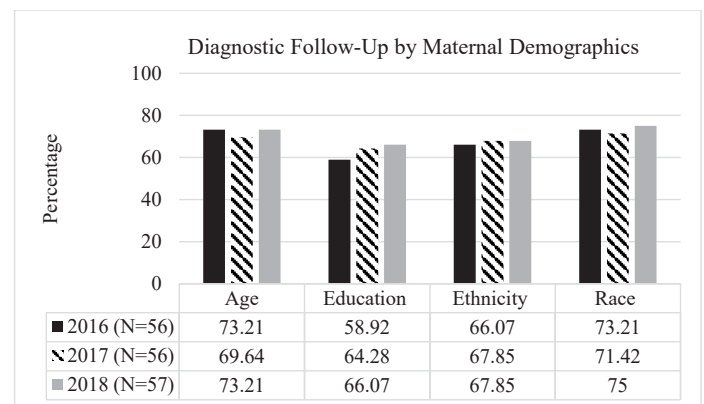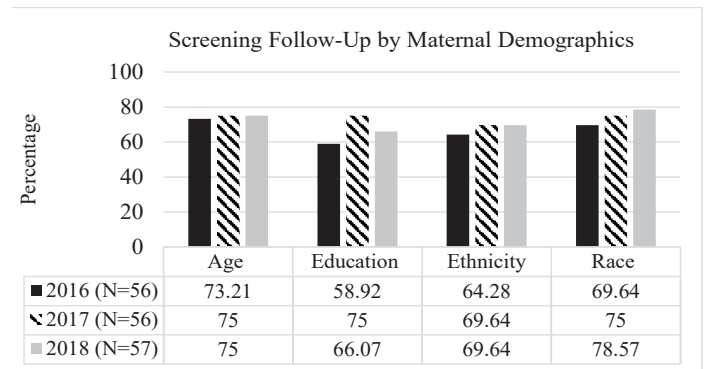
(b) explore type of LTF/D by year, specific reason, and condition, and (c) examine differences in screening and diagnostic completion rates by year and maternal sociodemographic factor.

Number of Jurisdictions Reporting Demographic Data

The first research question: Was there a significant difference in jurisdictional reporting patterns in CDC EHDI HSFS data by year for condition or for maternal sociodemographic variable? An Analysis of Variance (ANOVA) revealed no significant differences between screening and diagnostic reporting by year or with interaction of year and maternal demographic. There was a significant effect on reporting by maternal demographic [$F(2, 9) = 14.55$, $p = .002$]. The number of jurisdictions reporting maternal age and race/ethnicity were significantly higher than those reporting education ($p < .05$). See Figure 1.

Figure 1

Number and Percent of Jurisdictions Reporting Maternal Demographics for Screening and Diagnostic Follow-Up Outcomes 2016–2018

Screening Follow-Up by Maternal Demographics

	Age	Education	Ethnicity	Race
2016 (N=56)	73.21	58.92	64.28	69.64
2017 (N=56)	75	75	69.64	75
2018 (N=57)	75	66.07	69.64	78.57

Diagnostic Follow-Up by Maternal Demographics

	Age	Education	Ethnicity	Race
2016 (N=56)	73.21	58.92	66.07	73.21
2017 (N=56)	69.64	64.28	67.85	71.42
2018 (N=57)	73.21	66.07	67.85	75

Note. The number and percentage of jurisdictions reporting to the Centers for Disease Control and Prevention (CDC) on the Early Hearing Detection and Intervention (EHDI) Hearing Screening and Follow-Up Survey (HSFS) is shown for screening follow-up outcomes (top panel) and diagnostic follow-up outcomes (bottom panel). Fifty-six jurisdictions responded to the survey in 2016 and 2017; 57 responded in 2018. See https://www.cdc.gov/ncbddd/hearingloss/ehdi-data.html by year for more information.

LTF/D for Screening and Diagnosis

The second research question posed: Was there a significant difference for LTF/D outcomes by year or classification of reason (documented vs. undocumented)? Screening results are presented separately from diagnostic results. Table 1 shows screening data by year, classification of documented versus undocumented, and specific reason for LTF/D. The three highest documented reasons for loss to screening follow up consistent across years were "infant dies", "parents declined", and "homebirth", each receiving approximately 25–33% of responses. The largest undocumented category was "unknown" at about 75%. Similar data for diagnostics is visible in Table 2, although the list of specific reasons is slightly different. For the documented reasons, "parents declined" and "non-resident or moved" have response levels between 25–35%. A third documented reason, "in process" (i.e., the jurisdiction is working to finalize and submit the data), shows a 10% downward trend, 27% to 17%, across the three years, suggesting that processes and/or reporting improved in many jurisdictions. Multiple regression analyses on the screening and diagnostic data indicated that year and documented/ undocumented type predicted 90.3% (screening) and 98.7% (diagnostics) of the variances. Results show that documented vs. undocumented was significant in predicting the outcomes (screening: ß = -.91, p = .007; diagnostic: ß = .99, $p < .001$), but year was not.

Maternal Demographics

The third research question: Was there a significant difference in reported procedure completion rates by condition (screening versus diagnostic) or for each maternal demographic (age, education, race/ethnicity)? To assess this question, screening and diagnostic data were analyzed separately, and a univariate ANOVA was conducted for each demographic variable. Data are shown for maternal age, education, ethnicity, and race on Figures 2–3.

Table 1

Number and Percentage of Infants Not Completing Screening Process for Birth Years 2016, 2017, and 2018 by Reason (CDC EHDI HSFS Data)

	Reason	2016	2017	2018
Loss to Follow-Up	Infant dies	11,988 (28%)	11,708 (29%)	12,222 (31%)
(LTF)	Moved out of Jurisdiction	988 (2%)	948 (2%)	1,204 (3%)
Documented Reasons for LTF	Medical Reason	2,284 (5%)	2,769 (7%)	3,304 (8%)
	Parents declined	9,955 (24%)	10,878 (27%)	9,793 (25%)
	Transferred	4,691 (11%)	1,396 (3%)	1,702 (4%)
	Infant Adopted	20 (<1%)	7 (<1%)	203 (<1%)
	Homebirth	12,185 (29%)	12,962 (31%)	11,263 (28%)
Subtotal # LTF		**42,111**	**40,668**	**39,691**
Subtotal Percent LTF		56%	63%	63%
Loss to Documentation	Unresponsive	1,489 (4%)	1,169 (5%)	1,023 (4%)
(LTD)	Unable to contact	1,051 (3%)	1,035 (4%)	2,484 (11%)
Undocumented re: follow-up	Unknown	26,067 (71%)	18,820 (77%)	16,145 (69%)
	Other	4,005 (11%)	3,356 (15%)	3,696 (16%)
Subtotal # LTD		**32,612**	**24,380**	**23,348**
Subtotal Percent LTD		44%	37%	37%
Total # LTF/D		74,742	65,048	63,039
Total # Births		3,830,526	3,807,656	3,744,815
Total Percentage LTF/D		**2%**	**2%**	**2%**

Note. Total Percent LFU / LTD: ((# Contacted but Unresponsive + # Unable to Contact + # Unknown) / # Total Occurrent Births) * 100. LTF/D = Loss-To-Follow-up/Documentation. The number of jurisdictions reporting to the Centers for Disease Control and Prevention (CDC) on the Early Hearing Detection and Intervention (EHDI) Hearing Screening and Follow-Up Survey (HSFS) was 56 for 2016 and 2017; however, 57 reported for 2018.

Table 2

Number and Percentage of Infants Not Completing Diagnostic Process for Birth Years 2016, 2017, and 2018 by Reason (CDC EHDI HSFS Data)

	Reason/Birth Year	2016	2017	2018
Documented	In process	1,607 (27%)	1,201 (21%)	898 (17%)
(LTF)	PCP did not refer	67 (1%)	61 (1%)	104 (2%)
	Infant died	403 (7%)	410 (7%)	437 (8%)
	Non-resident or moved	1,676 (28%)	1,758 (31%)	1,755 (33%)
	Medical Reason	418 (7%)	211 (4%)	256 (5%)
	Parents declined	1,666 (28%)	2,051 (36%)	1,878 (35%)
	Infant Adopted	106 (2%)	18 (<1%)	35 (1%)
Subtotal # LTF		**5,943**	**5,710**	**5,363**
Subtotal Percent LTF		24%	26%	25%
Undocumented	Unresponsive	4,708 (26%)	5,778 (36%)	5,229 (32%)
(LTD)	Unable to contact	2,675 (15%)	2,714 (17%)	3,828 (24%)
	Unknown	9,139 (50%)	6,957 (43%)	6,524 (40%)
	Other	1,856 (10%)	713 (04%)	680 (4%)
Subtotal # LTF		**18,378**	**16,162**	**16,261**
Subtotal Percent LTD		76%	74%	75%
Total # LTF/D		24,321 (37%)	21,872 (35%)	21,624 (36%)
Total # Failed Screening		65,157	62,859	60,258

Note. Total Percent LFU / LTD: ((# Contacted but Unresponsive + # Unable to Contact + # Unknown) / # Total Occurrent Births) * 100. LTF/D = Loss-To-Follow-up/Documentation. The number of jurisdictions reporting to the Centers for Disease Control and Prevention (CDC) on the Early Hearing Detection and Intervention (EHDI) Hearing Screening and Follow-Up Survey (HSFS) was 56 for 2016 and 2017; however, 57 reported for 2018.

Maternal Age

Categories for maternal age in years were (a) less than 15, (b) 15 to 19, (c) 20 to 24, (d) 25 to 34, (e) 35 to 50, (f) 51 and above (see Figure 2). The ANOVA showed no significant difference by year for screening or diagnostics. Analysis for all three years revealed a significant difference by maternal age for diagnostics [$F(5,12) = 5.31$, $p = .008$] but none for screening. Figure 2 shows that the reporting pattern for age is similar for the youngest and oldest groups, low-high-low for 2016–2018. By contrast the remaining age groups all had a similar pattern of age reporting, with a decreasing trend across the three years. An additional ANOVA of the maternal age diagnostic data collapsed across the three years was completed, which indicated no differences among any age groups [$F(5,12) = 1.81$, $p = .184$]. This finding suggests that the individual group differences reported for the < 15 and > 50 age groups are likely due to anomalous reporting in one or more years.

Maternal Education

Categories for maternal education were (a) less than high school, (b) high school/GED, (c) some college, and (d) college graduate (see Figure 3, top panel). Although results of the univariate ANOVA showed a significant difference for education level in screening condition by year [$F(2,11) = 4.32$, $p = .048$], the Bonferroni post hoc analysis indicated no significant differences between any pairs of years, and the data were collapsed. Subsequent analysis of screening data yielded no significant differences by maternal education.

ANOVA results showed a significant effect for diagnostics collapsed across years [$F(3,8) = 116.98$, $p < .001$]. Bonferroni post hoc pairwise comparisons indicated significant differences for all comparisons. See Table 3 for mean differences, level of significance, and confidence intervals. Figure 3 indicates that, in general, the higher the level of maternal education, the higher percentage of reported diagnostics results. That trend appears to be roughly 10% higher for each category of education level. Across individual years there is a trend, albeit small, for a lower level of reporting for all categories except less than high school.

Maternal Race/Ethnicity

Categories for race/ethnicity used in this study were (a) white Non-Hispanic, (b) white Hispanic, (c) black Non-Hispanic, (d) black Hispanic, (e) Asian, (f) Native Hawaiian or Pacific Islander, (g) American Indian or Alaskan Native, or (h) Other. No significant difference was found by year for screening. There were statistical differences between and among the race/ethnicity categories for

Figure 2

Hearing Screening and Diagnostic Follow-Up Outcomes for Maternal Age for 2016–2018

Diagnostic Follow-Up Outcomes for Maternal Age

Hearing Diagnostic Follow-Up Outcomes by Maternal Age (2016-2018)

Figure 3

Hearing Diagnostic Follow-Up Outcomes for Maternal Education (top panel) and Maternal Race/Ethnicity (lower panel) for Years 2016–2018

Diagnostic Follow-Up Outcomes for Maternal Education

Diagnostic Follow-Up Outcomes for Maternal Race
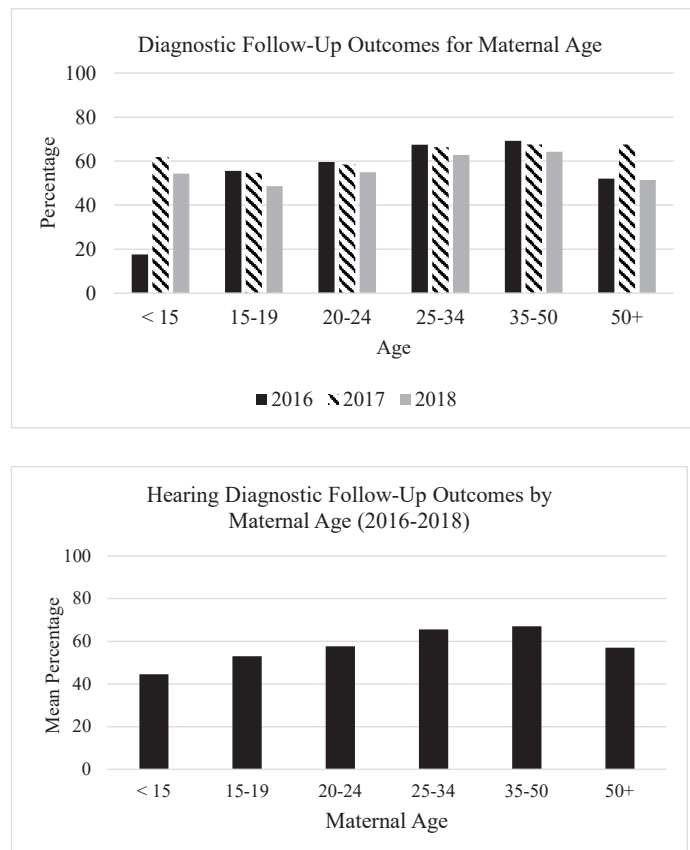
Note. Hearing diagnostic follow-up outcomes for maternal age by year are shown in the top panel and mean percentage of hearing diagnostic follow-up outcomes for maternal age (2016–2018 averaged) are shown in the lower panel. Data represents maternal demographic variables reported by the Centers for Diseases Control and Prevention (CDC) for the Early Hearing Detection and Intervention (EHDI) Hearing Screening and Follow-Up Survey (HSFS) for 2016, 2017, and 2018. See https://www.cdc.gov/ncbddd/hearingloss/ehdi-data.html by year for more information.

Note. Hearing diagnostic follow-up outcomes for maternal education are shown by year in the top panel. Hearing diagnostic follow-up outcomes are shown by race/ethnicity by year in the lower panel. Data represents maternal demographic variables reported by the Centers for Diseases Control and Prevention (CDC) for the Early Hearing Detection and Intervention (EHDI) Hearing Screening and Follow-Up Survey (HSFS) for 2016, 2017, and 2018. See https://www.cdc.gov/ncbddd/hearingloss/ehdi-data.html by year for more information.
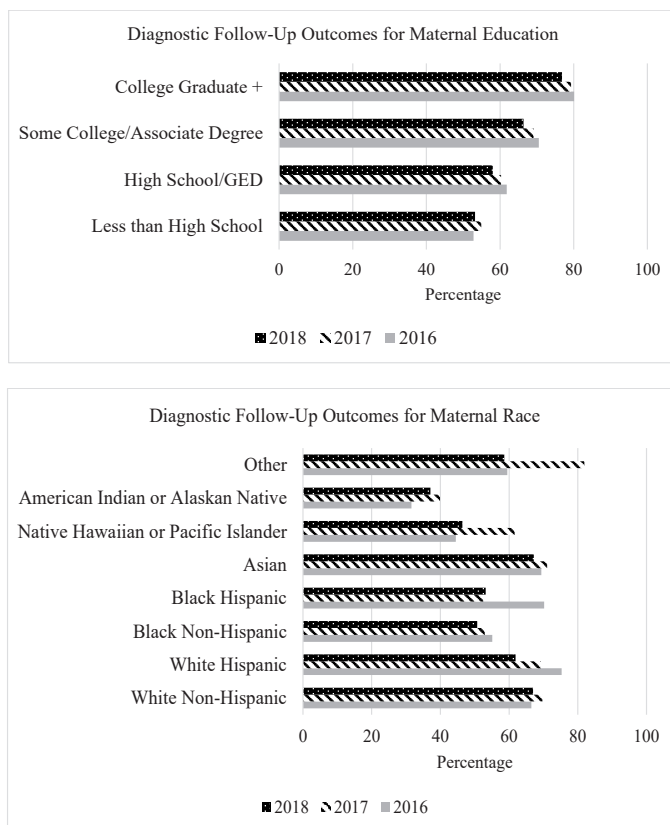
screening across years. However, we suggest they are not meaningful, given the quite similar values across categories shown in Figure 3 (lower panel) and we do not report those here.

The across-year ANOVA on maternal race/ethnicity showed significant differences for diagnostics [F(7,16) = 7.533, *p < .001*]. The subsequent post hoc pairwise comparisons using Dunnett T3 [Levene = 4.523, *p = .006*] indicated significantly lower follow-up rates for black Non-Hispanics compared to (a) white Non-Hispanics and (b) Asians, and significantly lower follow-up rates between American Indians or Alaskan Natives and (a) white Non-Hispanics, (b) white Hispanics, (c) black Non-Hispanics, and (d) Asians (see Table 4 for the mean differences and significant results matrix). All other pairs were statistically similar.

Our results suggest that the number of jurisdictions reporting demographic data has remained stable over the

past three years. Year did not predict LTF/D screening or diagnostic outcomes. To tease out variables related to SDoH, we categorized LTF/D variables by those that have valid documented reasons why screening and/or diagnostics could not be completed and those that did not have valid documented reasons. We found that documented versus undocumented categories of reasons for LTF/D did not predict LTF/D outcomes for screening or diagnostics. We then evaluated the impact of maternal demographics on completion rates for screening and diagnostic processes and found that there are no significant differences for age; however, education and race/ethnicity play a significant role.

Discussion

The goal of this study was to explore how SDoH is related to hearing health disparities. Specifically, we sought to examine CDC EHDI HSFS screening and diagnostic outcomes, maternal demographic variables, and LTF/D for years 2016, 2017, and 2018; at the time of the analysis, this was the available data. For newborn hearing

Table 3

Mean Differences for Education Level, Standard Error, Level of Significance, 95% Confidence Intervals (Lower Bound and Upper Bound) for Bonferroni Post Hoc Pairwise Comparisons for Diagnostics

Education Level	Comparison	Mean Difference	Significance	95% Confidence Interval	
				Lower Bound	Upper Bound
Less than High School	HS/GED	-.063	.012	-.127	.000
	AA/AS/Some	-.150	< .001	-.220	-.079
	Coll Grad	-.250	< .001	-.307	-.193
High School Diploma/GED	< HS	.063	.012	-.000	.127
	AA/AS/Some	-.086	.002	-.158	-.015
	Coll Grad	-.187	< .001	-.252	-.122
AA/AS/Some College	< HS	.150	< .001	.079	.221
	HS/GED	.086	.002	.015	.157
	Coll Grad	-.100	< .001	-.170	-.031
College Graduate	< HS	.250	< .001	.194	.307
	HS/GED	.187	< .001	.121	.252
	AA/AS/Some	-.100	< .001	.031	.170

Note. < HS = Less than high school; HS/GED = High School degree or Graduate equivalent degree; AA/AS/Some = Associate of Arts, Associate of Science, Some college; Coll Grad = College Graduate. *The mean difference is significant at the .05 level.

Table 4

Mean Difference and Significant Results Matrix for Diagnostics—Dunnett T3 Post Hoc Pairwise Comparisons for Race/ Ethnicity

	White Non-Hispanic	White Hispanic	Black Non-Hispanic	Black Hispanic	Asian	Native Hawaiian or Pacific Islander	American Indian or Alaskan Native	Other
White Non-Hispanic	.000	-.011	.148*	.091	-.015	.169	.315*	.011
White Hispanic			.159	.102	-.004	.180	.326*	.022
Black Non-Hispanic				-.057	*.163	.021	.167	-.138
Black Hispanic					-.106	.078	.224	-.080
Asian						.184	.330*	.026
Native Hawaiian or Pacific Islander							.146	-.158
American Indian or Alaskan Native								.304
Other								.000

Note. Matrix for Dunnett's T3 post hoc analysis for race/ethnicity for the diagnostic condition. Mean differences are shown. *indicates significance at the .05 level.

screening, there was no significant difference by year; however, the number of jurisdictions reporting maternal age and race/ethnicity variables was significantly higher than those reporting maternal education.

Screening Outcomes

Year did not predict LTF/D hearing screening outcomes; however, reasons reported by the CDC accounted for 90.3% of the variation in screening follow-up outcomes. Reasons categorized as LTF (documented in the electronic health record) accounted for a higher predictive value than reasons categorized as LTD (could not reach parents for follow-up). Results showed no significant difference in follow-up outcomes for maternal age, education, or race/ethnicity for screening.

Diagnostic Outcomes

For diagnostic follow-up outcomes, when years were collapsed there was a significant difference for education, and race/ethnicity. For education, the higher the level of educational attainment, the higher the likelihood of follow-up. In general, diagnostic follow-up outcomes were significantly lower for infants of mothers of color (black Non-Hispanics, American Indian or Alaskan Natives) than for other race/ethnicity categories.

CDC EHDI HSFS Data Quality for Demographic Variables

Recent studies have brought attention to or identified issues regarding the quality in CDC EHDI HSFS data for demographic variables (Alam et al., 2016; Alam et al., 2018; Gaffney et al., 2014; Sanchez-Gomez et al., 2019). Salvidar (2012) suggests that U.S. government surveys such as the CDC EHDI HSFS are expected to have a response rate of at least 75%. Response rates (number and percentages) for jurisdictions are shown in Figure 1. These response rates fall slightly below the expected 75% response rate for government surveys; therefore, we suggest that data for maternal demographics be interpreted with appropriate caution.

LTF/D Rates by Year, Condition, and Classification

Regression analysis results showed there was no significant effect for year on screening or diagnostic follow-up outcomes; however, there was a significant effect for classification for type of reasons (LTF documented versus LTD undocumented) for both screening and diagnostics. Some suggest several additional family variables that may influence LTF/D (Holte et al., 2012; Zeitlin et al., 2021) such as parental decision-making or cultural factors/biases (Chung et al., 2017; Gaffney et al., 2014; Gonzalez et al., 2017; Kenna, 2021; Landon et al., 2021; Linton et al., 2019). Other variables identified include (a) transportation issues, (b) health insurance coverage, (c) language differences, (d) health literacy issues, and (e) communication skills (Shulman et al., 2010). The reasons used to classify LTF/D provide insight into the social and cultural variables that may influence outcomes (e.g., parents declined, infant in the foster care system

or adopted, homebirths, parents unresponsive to contact attempts, unable to contact).

Impact of SDoH on Screening LTF/D Rates

Although there was no significant difference by year for screening follow-up outcomes, there was a significant difference in categories for LTF/D (see Table 1). Of infants categorized as LTF/D, 61% had an identifiable cause. Of these, approximately 29% were due to infant deaths; however, about 29% were due to home births, and about 25% were due to parent denials. In each of these cases, an educational intervention could be designed and implemented to mitigate loss to follow-up. For the cases categorized as LTD (39%), we do not know the *why* for unresponsiveness, lack of accurate contact information, or the other unknowns. Importantly, the overall LTF/D rate for newborn hearing screening is very small for the total population (2%).

Impact of SDoH on Diagnostic LTF/D Rates

Previously reported data suggested a decreased likelihood of diagnostic follow-up for: (a) mothers with less than a high school education (Crouch et al., 2017); (b) in rural areas with limited access to services (Bush, Osetinsky, et al., 2014; Crouch et al., 2017); and (c) for those on public insurance versus private insurance (Crouch et al., 2017; Deng et al., 2022). Child variables that increase the likelihood of delayed diagnostic testing include low birthweight (Tran et al., 2016) and multiple audiology appointments (Shanker et al., 2019; Tran et al., 2017). Our data shown in Table 2 indicates that, on average, 33% of the time LTF is due to decline to follow-up by the parents, 31% of the time it is due to the family moving or being a nonresident of the state, and 22% of the time, the diagnostic is still in process. The Action Kit for Audiologists developed by the National Institute for Children's Health Quality (NICHQ) provides suggestions to facilitate follow-up. Several identified system challenges may also contribute to a decrease in LTF/D for diagnostic evaluations (NICHQ, 2016; Williams et al., 2015). These data indicate the possibility that additional SDoH, and other cultural variables played a significant role in LTF/D. Our results are consistent with previously reported data except for the impact of maternal age on diagnostic follow-up outcomes.

Impact of Maternal Demographics

Sociodemographic data are the classifiable characteristics of a given population and are commonly used in public health reports. SDoH are the conditions in the environment in which people are born, live, learn, and play that predict quality of life outcomes and risks (National Center for Health Statistics, 2001). Two of the maternal demographics reported by the CDC fall into the category of sociodemographic variables (i.e., age and race/ethnicity) whereas others are considered SDoH (i.e., education). The EHDI maternal demographic data are readily available from the CDC HSFS annual report and are important factors when assessing disparities in health services. Our data show no significant difference in maternal age, education, or race/ethnicity for screening follow-up outcomes, but a significant difference for education and race/ethnicity for diagnostic follow-up outcomes. Follow-up

rates for screening and diagnostics are integrally related to LTF/D rates, representing the inverse. Some research on maternal demographics uses follow-up outcome rates whereas other research uses the inverse, presenting LTF/D outcome data. This is something to be aware of when examining and interpreting the data.

Maternal Age

Teen mothers tend to be over-represented by low socioeconomic status or low maternal education (Hunter, 2012) or come from families with similar backgrounds (e.g., a cycle of intergenerational hardship referred to as a *culture of despair*; Basch, 2011; DeBacker & Routon, 2021). Restated, social context plays a role in teenage pregnancy and childbearing (Hunter, 2012). The incidence of birth complications is much more significant among non-white women, largely due to environmental stressors and health care disparities (Anifantaki et al., 2021; Braveman et al., 2021; Petersen et al., 2019).

Given that children of teen mothers are at greatest risk for a host of health, social, and economic issues (Agnafors et al., 2019), one might expect a relationship between maternal age, hearing screening, and follow-up outcomes (Deng et al., 2022; Shanker et al., 2019). Meyer and colleagues (2020) reported a higher risk of delayed diagnosis in infants of mothers younger than 25 years of age for 2012 to 2016 in Minnesota. Our data, however, does not support this finding. Differences could be attributed to several variables such as population source and number, age categories, choice of statistical analyses, and/or data quality. Meyer et al. (2020) reported a significant difference for maternal age less than 25 years, and our lowest age category was less than 15 years.

Maternal Education

Historically, research-based evidence typically includes at least one of three key variables that constitute *socioeconomic status* (SES), sometimes referred to as *social class*: (a) parental educational attainment, (b) parental occupational status/job prestige/subjective perceptions of social class; (c) household or family income/financial security. These three factors, designated to establish an individual's social standing, are intended to encompass quality of life attributes as well as opportunities and privileges afforded people within society (Darin-Mattsson et al., 2017). Although some consider SES to be a reliable predictor of physical and mental health across the life span, others question the validity of what it measures (e.g., Navarro-Carrillo et al., 2020; Zang & Bardo, 2019). Questions have been raised about the quality of such data, the narrowness of the measures, and the lack of a composite SES measure (Cowan et al., 2012; Dickinson & Adelson, 2014). Maternal education continues to be used as a substitute for SES when data on income and occupation is not available. Such is the case with the CDC HSFS EHDI data.

Education/SES Indicator. Maternal education is the only one of the three SES indicators reported by the CDC on the EHDI HSFS. Limitations in using a level of formal education attained by a parent have been reported.

For example, a parent may or may not have attained a secondary/high school diploma yet have attained considerable distance and technology-based informal learning (Latchem, 2014). Informal education may be insufficiently represented in the sociodemographic variable of maternal education; the quality of this sociodemographic variable has long been called into question (Alderman & Headey, 2017; Harding et al., 2015). Rather than formal education, the executive functioning or cognitive capacities of parents may sometimes be a better proxy for SES (Cuevas et al., 2014; Walhovd et al., 2022). Although this is true, cognitive capacity or measures of executive function are not easily accessible or included in publicly reported data.

Villalba (2014) cautions against the use of maternal education as the sole or primary determinant of SES, suggesting it to be meaningless and statistically invalid. SES is really a much larger issue than that of education alone; it is typically based on several variables such as occupation, number of years of education, income, and place of living (Aarø et al., 2009). Deng and colleagues (2022) used an approach to improve the validity of the SES component by coupling material education with family participation in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC). They found the rate of diagnostic follow-up to be lower among infants enrolled in the WIC program than those not enrolled and occurring at an increased rate with higher maternal education. This finding has potential intervention implications for EHDI programs.

Our results concur with previously reported findings demonstrating significantly higher follow-up rates with higher maternal education. The relationship between education and SES is noteworthy as maternal education may be a confounding factor when considering resource constrained families. Regardless of maternal education, resource constrained families are in desperate need of immediate social supports and diagnostic follow-up, identification has the potential to connect families with a holistic approach to intervention (Rendall et al., 2022).

Occupation. Although economic resources matter, income can fluctuate and does not necessarily equal wealth (e.g., work-related benefits may be excluded; Thompson & Dahling, 2019). Moreover, income can vary dramatically as in the case of well-educated students who are unemployed. Similarly, using occupation as a data collection point can exclude a good part of a population, such as retirees, students, or temporarily unemployed parents who may be transitioning to other occupations. Occupations are not necessarily indicative of social class (Svedberg et al. 2016). Income, education, and occupation are not interchangeable SES characteristics; efforts to equate these variables can result in validity issues (e.g., Darin-Mattsson et al., 2017; Galobardes et al., 2006). Our data did not include consideration of occupation; however, it is included here as one of the *big three* SES indicators.

Income. It is well known that insufficient or unstable household income/economic resources can have

deleterious effects on child development (e.g., Beech et al., 2021). Nearly one in six children under the age of six in the United States lives in poverty; these children reside in food-insecure homes and are the poorest age group in America (Children's Defense Fund, 2021; Wight et al., 2014). Poverty disproportionately affects children of color; indeed, more than 70% of America's impoverished children are from marginalized non-white groups (Children's Defense Fund, 2021; Haider, 2021). The effects of childhood poverty are pervasive, including its lifetime link to injuries, chronic illness, hearing health, and mental health difficulties (e.g., Gupta et al., 2007; Schmidt et al., 2021).

More importantly, research that considers just the three SES variables of education, occupation, and income is often deemed insufficient in the use of statistical controls (Dickinson & Adelson, 2014; Williams & Mohammed, 2013). How data are collected for measuring these three variables is often not consistent across research studies (Cowan et al., 2012). It is now widely understood that many more factors affect intervention outcomes (e.g., Adams & Beeble, 2019; Park et al., 2021; Rollè et al., 2019). It is important to know if all the subgroups in any target audience are fairly represented and which factors might be associated with specific outcomes (Deaton & Cartwright, 2018). Simply stated, poverty exacerbates the effects of race and age and education.

Maternal Race/Ethnicity

Deng and colleagues (2022) assessed the impact of race/ethnicity on follow-up outcomes and found non-Hispanic black mothers with the lowest rate of follow-up for screening and non-Hispanic black and American Indian/Alaska Natives with the lowest rates of diagnostic outcomes. We found no significant difference for screening outcomes; however, our diagnostic outcomes support the results of Deng et al. (2022). The CDC EHDI HSFS guidance documents do not specifically address the reasons why information about race/ethnicity is so important. Providing respondents (e.g., hearing screeners and oversight personnel) with more specific information about the importance of demographic variables may facilitate better data collection procedures and outcomes (Avvisati, 2020; Williams-Roberts et al., 2018). Our findings indicate that maternal race predicts diagnostic follow-up outcomes. Specifically, Asian diagnostic follow-up outcomes are the highest for maternal race/ethnicity while American Indian and Alaskan Native, followed by Native Hawaiian and Pacific Islander, and then Black Hispanic and Black Non-Hispanic are notably lower than white. These results suggest that race or skin color plays a role in diagnostic follow-up outcomes. Additional research is needed to further delineate.

Reporting Sociodemographic Variables

The CDC identified one maternal demographic category as race/ethnicity, which may cause some confusion. The separation of these categories, and inclusion of more ethnic categories than Hispanic versus non-Hispanic may

provide relevant data. The CDC practice of collecting race and ethnicity as combined variables should be reconsidered. It may also be important to note whether race was self-identified by the mother or by the data collector. Deng and colleagues (2018) suggest that many states apparently do not consider these data essential for appropriate and timely EHDI care, thus they apparently are not considered critical from a reporter perspective. This lack of data impedes research regarding the influence of SDoH on EHDI outcomes (Deng et al., 2018). Deng and colleagues (2018) concluded that the paucity of race/ethnicity data reported for the three states they studied necessitates an increased awareness and emphasis on the importance of reporting demographic variables.

Despite clinical and research advances in hearing health, there is mounting evidence of long-standing hearing health disparities across the United States and its territories. Disparities persist by skin color, ethnicity, household income, and other sociodemographic variables among young American children with hearing loss (e.g., Juarez et al., 2020; Kingsbury et al., 2022; Lantos et al., 2020; Mohapatra & Mohan, 2021). Therefore, race/skin color *and* ethnicity should be considered as two distinct variables to be disaggregated. These two variables should be included with other sociodemographic variables collected and analyzed in EHDI research. Identification of such critical factors enables segmentation of subjects and improved accuracy in interpretation of results that, in turn, can facilitate improvement in the timely delivery of intervention services (Orkin et al., 2021).

It is widely recognized that ethno-racial data collection is both challenging and wanting in research studies within the United States (Chaiya-chati et al., 2022; Davis & Jones, 2022; Kader et al., 2022; National Research Council, 2013; Rees et al., 2022). Federal research and regulatory authorities as well as medical journals seek to increase the number of people from underrepresented ethno-racial populations in clinical research and to disaggregate that ethno-racial data (Blumenthal & James, 2022; Chaiya-chati et al., 2022; Davis & Jones, 2022). Even with the recognition that many barriers exist, more agencies and funding sources are necessitating an increase in the inclusion of marginalized people as pertains to data collection (Blumenthal & James, 2022). It behooves all those involved with EHDI to develop consistent protocol for equalizing the identification of ethno-racial demographics.

The United States has undergone enormous changes since the advent of the 20th century, particularly those marked by size and diversity (Cohn & Caumont, 2016). Some sociodemographic variables, particularly those having to do with race and ethnicity, are referred to as real world data and considered predictors of a vast array of outcomes in such Westernized democracies as the United States (Concato et al., 2020; Tarver, 2021). Indeed, whether self-identified or other-identified, race and ethnic background should always be considered when analyzing intervention outcomes to produce real-world evidence (e.g., Chodankar, 2021; National Research Council, 2013;

Valdez & Langellier, 2015). Although race and ethnicity are often used interchangeably, it is critical that these two social constructs be (a) disentangled and (b) included in outcome findings (Kauh et al., 2021; Tarver, 2021). It is also important that ethno-racial data be accurate and complete; such detail can identify the nature and extent of disparities in health care, target quality improvement efforts, and monitor progress (Concato & Corrigan-Curay, 2022; National Research Council, 2013). This is vital if we are to improve hearing health care for families and their children with hearing loss.

Limitations

There are several limitations inherent in this study. First, the original source of data used in this study was provided via jurisdictional EHDI Information Systems (IS) in the form of responses to the CDC HSFS questions. Some of the EHDI IS are more sophisticated and robust than other systems; however, the details regarding the characteristics of various EHDI IS are not publicly available. All analyses were conducted on the entire data sets available for 2016, 2017, and 2018 as reported by individual jurisdictions and are thus subject to a wide variety of different tracking, reporting, and other surveillance methodology and may have different population characteristics and conventions. The data is incomplete in that not all states participated in data collection. The reliability and validity and completeness of the parental ethno-racial identities are unknown, subject to response-bias, and may differ between hospitals as well as jurisdictions. Furthermore, some non-respondent demographic characteristics were unavailable, potentially introducing sampling variance. We previously described the limitations of the CDC data in terms of quality, incomplete data, and risk for participation and nonresponse bias.

Implications for Future Research, Policy, and Practice

The results of this study are consistent with the findings of previous studies regarding hearing screening follow-up and diagnostic audiologic follow-up outcomes. Depending on the sociodemographic profile of pregnant mothers, researchers can better understand one sociodemographic factor with respect to another, thus improving the effectiveness of EHDI efforts. Further exploratory research examining LTF/D variables may provide additional insight into SDoH variables contributing to difference in screening and diagnostic follow-up outcomes. Suggestions to improve the effectiveness of EHDI efforts include the following:

- Developing more specific data collection protocol/procedures and guidelines for the CDC EHDI HSFS that will be consistently implemented across all 50 of the United States and American territories.

- Implementing a nationwide training program pertaining to the need for consistent and standardized reporting of sociodemographic variables; this training program will include EHDI coordinators, pediatric audiologists, hearing screeners, and hospital employees involved with data collection.

- Broadening the data collection protocol so that service providers attain an improved understanding of each family's social landscape (e.g., number of children in the household, additional medical/developmental problems within the family, or transportation issues).

- Development of specific sociodemographic profiles could permit some mothers and their newborns to be red-flagged for more intensive follow-up or personalized attention.

- Linking child level data to disaggregated sociodemographic variables in future research to allow for better analysis and interpretation (e.g., exploring the LTF/D reasons relative to race/ethnicity to improve the identification of at-risk groups.

- Implementing an intervention protocol that is holistic in nature, targeting at-risk groups to further minimize LTF/D.

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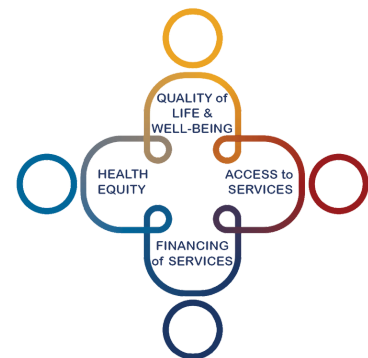
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