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A Systematic Review of the Prevalence of Late Identified Hearing Loss in Childhood

Karen Muñoz,[1, 2, 3] Dylan Chan,[4] Donald Goldberg,[5, 3] Diana Ortiz,[1] Valerie James Abbott,[6] Karl White[2]

[1]Department of Communicative Disorders and Deaf Education, Utah State University

[2]National Center for Hearing Assessment and Management, Utah State University

[3]Joint Committee on Infant Hearing

[4]University of California, San Francisco

[5]College of Wooster and Cleveland Clinic Foundation

[6] Infant and Toddler Connection of Virginia

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Address correspondence to:
Karen Muñoz, Department of Communicative Disorders and Deaf Education, Utah State University, 1000 Old Main Hill, Logan, UT 84321. Phone: (435) 797-3701; Email: karen.munoz@usu.edu

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Abstract

Objectives: The objective of this systematic review was to assess the evidence about the prevalence of permanent hearing loss for children not identified from newborn hearing screening (NHS).

Design: Articles were grouped into three categories based on the methodological approach: (1) all participants received diagnostic testing, (2) otoacoustic emission (OAE) or pure tone screening was completed and those not passing were referred for a diagnostic test, and (3) data were retrieved from archival records. Study characteristics, prevalence, and contextual factors were synthesized and narratively described.

Study Sample: 30 peer-reviewed articles.

Results: Prevalence of permanent hearing loss per 1,000 children ranged from 0.32 to 77.87 (M = 7.30; SD = 16.87). Variations in the criteria for inclusion contributed to prevalence differences. Prevalence was higher when unilateral and milder degrees of hearing loss were included, and older children had higher prevalence (M = 13.71; SD = 23.21) than younger children (M = 1.57; SD = 0.86).

Conclusion: There is scant research on prevalence of childhood hearing loss after NHS that utilized methods to accurately differentiate between permanent and temporary hearing loss. Rigorous research is needed on the prevalence of permanent childhood hearing loss to inform strategies for monitoring, identification, intervention, and management.

Keywords: prevalence, childhood, hearing loss, late identified

Introduction

Globally, there are an estimated 34 million DHH children (World Health Organization, 2023). Early identification and access to intervention services are critical to support child development and school readiness (Joint Committee on Infant Hearing [JCIH], 2019). Newborn hearing screening (NHS) is an important first step in early identification (Centers for Disease Control and Prevention [CDC], 2020); however, worldwide there are disparities in the availability of NHS (Neumann et al., 2022). Determining the prevalence of permanent hearing loss for younger children is challenging because there are few programs that provide hearing screening for children between the NHS and school entry, and hearing screening more typically occurs for school-aged children.

Early childhood is a critical period for auditory, language, speech, and cognitive development. Identification of infants and children with permanent hearing loss provides the opportunity for children to receive appropriate and timely hearing technology intervention, and educational services (JCIH, 2019). However, the gap between newborn and school entry hearing screenings, as well as an acute shortage of programs that do postnatal hearing screening, may contribute to delays in identification. In the U.S., after the newborn hearing screening, the next formal hearing screening test is not recommended by the American Academy of Pediatrics until the child is four years of age during the physician well-child check and it is not clear how often or by what method this recommendation is followed. When childhood hearing loss is not detected, children are at increased risk of permanent speech, language, and educational delays—a fact that, in the U.S., has led to the establishment of federal and state Early Hearing Detection and Intervention (EHDI) programs. Although these efforts initially focused on newborn hearing, the EHDI Act of 2017 extended the reach of

hearing screening programs to children from birth to 3 years of age (Public Law 115-71, 2017); however, such programs have not yet been widely implemented.

The lack of hearing screening between the NHS and school entry affects multiple stakeholders. Children with undetected hearing loss almost always experience delays in their development and negative academic consequences. For example, hard of hearing children aged 5 to 10 years were found to have greater deficits in receptive vocabulary and working memory compared to typically hearing peers, and this was more pronounced when they had lower auditory dosage, represented by how long a child had their hearing technology, how the technology was programmed, and how much they used their hearing devices (McCreery & Walker, 2021). Parents, clinicians, educators, and governments must bear and manage the increased costs and consequences of delayed identification and intervention. It is therefore incumbent on policy makers and healthcare professionals to consider systematic processes to identify permanent childhood hearing loss to ensure children receive timely intervention services and full access to language.

The objective of this systematic review was to assess the global evidence about the prevalence of permanent hearing loss for children 0 to 12 years, not including children identified through NHS. Systems are needed for identifying and managing permanent hearing loss that is not identified from NHS. Information about prevalence can inform development of systems of care for this population of children. The age range for the review extended to 12 years to provide context in understanding the evidence of prevalence for younger children. Hearing loss onset varies and can be described as progressive, delayed or late onset, or acquired; each representing nuanced differences. For this paper, we use the term late identified hearing loss to describe any permanent hearing loss identified after the NHS. The

JCIH (2019) recommends using terminology that is inclusive, accessible, and clearly conveys the intended meaning. Depending on the message being conveyed in this paper, the term used varies (e.g., children who are deaf or hard of hearing [DHH]; hearing loss; hearing difference).

Methods

Search Strategy

A systematic literature review was completed using the Joanna Briggs Institute approach for systematic reviews of prevalence and incidence (Munn et al., 2017) for guidance. The following inclusion criteria were used: (1) general population sample, (2) sample size of 1,000 or more, (3) mean age of 12 years or younger, (4) type of hearing loss classified (temporary or permanent), (5) availability of data to calculate prevalence of permanent childhood hearing loss, and (6) published in English prior to June 1, 2022. For the review, permanent hearing loss identified through diagnostic assessment was defined as testing that included measures of middle ear function (tympanometry and/or bone conduction thresholds) and air conduction thresholds. The level of permanent hearing loss is described based on study definitions (e.g., slight, mild, etc.). Studies were excluded if the sample was not from the general population (e.g., clinically defined condition such as autism); if the recruitment method aimed to find people expressing concern about their child's hearing; if the population was from a newborn hearing screening program; if the data were insufficient to determine prevalence of permanent hearing level differences (e.g., temporary and permanent hearing differences could not be separated); if an informal or unvalidated screening method was used (e.g., noise-makers); if the study was a review or summary of other studies that did not include any new data.

Three databases were searched (PubMed, CINAHL Complete, and ERIC) to identify relevant studies using the following keywords: 1. (late identified OR progressive OR late onset OR delayed-onset OR post-natal OR peri-lingual); 2. (hearing loss OR hearing impairment OR deaf*); 3. (child* OR pediatric OR toddler OR infant). An example of how the search was performed is available in Supplemental Information 1. The database search yielded 9,871 articles. Three authors searched PubMed. They independently screened titles and abstracts for the first 200 articles and then met to discuss discrepancies and align application of inclusion criteria. Following this step, they each screened a separate set of 500 articles, then they each screened the same set of 100 articles, and then met to re-check alignment. This process continued until all the articles were screened. Two authors independently screened titles and abstracts for the other databases and met to resolve discrepancies. Next, all authors were paired and the full text was screened independently by two authors; discrepancies were discussed and resolved. One author reviewed the reference lists of these articles and nine articles that were not previously screened were identified for full text review and subsequently evaluated through the same process described above.

Methodological Quality

The same five authors then reviewed articles included after the full text screening using coding conventions (see Supplemental Information 2) and extracted data to a spreadsheet, to further assess eligibility for inclusion. Articles were then re-reviewed using the Joanna Briggs checklist for prevalence studies (2017) to make final inclusion decisions. The checklist consists of nine questions to assess the methodological quality of each study and an overall question about whether to recommend inclusion, exclusion, or further discussion with team members. To complete this step, the authors were paired and the checklist was completed independently

by two authors. Reviewer responses were documented, discrepancies discussed, and final decisions were made on inclusion for analyses (see Supplemental Information 3 for checklist ratings).

Data Extraction and Synthesis

The included articles were grouped into three categories based on the methodological approach used to estimate prevalence: (1) all members of the sample received diagnostic testing, (2) all members of the sample were screened using otoacoustic emissions (OAE) or pure tone screening and those not passing were referred for a diagnostic test, and (3) data about infants or young children who were diagnosed as DHH were retrieved from archival records. Archival records were a regional or national database where it was assumed all children would be included. The study characteristics, prevalence, and contextual factors were synthesized within categories, narratively described, and data tables are provided for each group. Prevalence in this article is reported for two age groups, under seven years and seven to twelve years, based on the mean age or the mid-point of the age range reported in each study. This study was not pre-registered before conducting the review.

Results

The database search identified 9,810 articles after duplicates were removed. Title and abstract screening excluded 9,409. Following full text screening and quality reviews, an additional 380 articles were excluded. Thirty articles met the inclusion criteria, and within these articles there were 36 samples. See Figure 1 for the PRISMA flowsheet, Supplemental Information 4 for the list of included articles. The studies were categorized based on the research design. Category 1 includes studies that completed diagnostic testing on all children in the sample (n = 3). Category 2 includes studies that screened using distortion product OAEs

(DPOAE) or pure tone audiometry and attempted to complete diagnostic testing on children that did not pass the screening (OAE: $n = 5$; pure tone: $n = 11$). Category 3 includes studies that used archival data to estimate prevalence within a population ($n = 11$).

Prevalence of permanent hearing loss per 1,000 children ranged from 0.32 to 77.87 (M = 7.30; SD = 16.87), and was higher for older children than younger children. Prevalence for 17 samples of children seven to twelve years (M = 13.71; SD = 23.21) compared to 19 samples of children under age seven (M = 1.57; SD = 0.86) demonstrated significantly higher prevalence per 1,000, $t(34) = -2.281$, $p = .029$. Differences in hearing level cut-off, and whether or not unilateral hearing loss was included contributed to variations in prevalence (see Table 1). When considering the cut-off level used, the average prevalence per 1,000 children was 20.28 (15 or 20 dB HL or greater), 4.90 (25 or 30 dB HL or greater), 1.94 (35, 40, or 45 dB HL or greater), and 0.58 (55 dB HL or greater).

Category 1: Diagnostic Testing on all Participants

Three studies examined prevalence by completing diagnostic testing on all of the children in their sample (see Table 2). The studies, conducted in Nepal (Maharjan et al., 2021), Ethiopia (Birhanu et al., 2021), and the Netherlands (le Clercq et al., 2017), included children with a mean age of over seven years, had prevalences of 11.76, 67.36, and 77.87 per 1,000, respectively, and used different cut-off levels, 25, 20, and 15 dB HL, respectively. Each study included unilateral or bilateral hearing losses, and none reported if children with previously identified permanent hearing losses were excluded.

Category 2: Physiologically-based Screening, Followed by Diagnostic Testing

Sixteen studies, from 10 different countries, examined prevalence by completing OAE

or pure tone screening and referring children that did not pass the screening for a diagnostic assessment. Five studies used OAEs (Abdel-Hamid et al., 2007; Eiserman et al., 2008; Chen et al., 2013; Ramkumar et al., 2018; Cedars et al., 2018), and 11 studies used pure tone audiometry (Nelson & Berry, 1984; Augustsson et al., 1990; Swart et al., 1995; Flanary et al., 1999; Hornby et al., 2000; Wake et al., 2006; Lü et al., 2011; Al-Rowaily et al., 2012; Wenjin et al., 2014; Mahomed-Asmail et al., 2016; Hussein et al., 2018).

OAE Screening

Table 3 provides information on the OAE studies. Four of the studies included children under seven years, had prevalence from 0.84 to 3.00 per 1,000 children, and loss to follow-up from screening to diagnosis was 0 to 38%. One study had a mean age over seven years, had prevalence of 19.41, and loss to follow-up was not available (Abdel-Hamid et al., 2007). All of the studies used DPOAEs and included both unilateral and bilateral hearing losses. Two studies reported that children with previously identified permanent hearing losses were excluded, and three studies did not report this information.

Pure Tone Screening

Table 4 provides information on the studies in which children were screened using pure tone audiometry. There were five samples of children under the age of seven, six samples of children over seven years, and one study that included samples of children in both age categories. For the samples of children under the age of seven, prevalence ranged from 0.75 to 3.00, loss to follow-up from screening to diagnosis was 3 to 55%, and the cutoff for reporting hearing level difference was from 20 to 40 dB HL. For samples over age seven, prevalence ranged from 0.81 to 24.36, loss to follow-up was 0 to 35% (four not reported), and the cutoff

for reporting hearing level differences was from 15 to 35 dB HL. All of the studies included unilateral and bilateral hearing losses; one study did not report this information. Three samples reported that children with previously identified permanent hearing losses were excluded (2 for younger children, 1 for older children); most studies did not report this information.

Category 3: Analysis of Archival Records

Eleven studies (16 samples) from nine different countries, estimated prevalence by extracting diagnostic data from an archival source and calculating prevalence based on the population in the same geographical area (see Table 5). Five studies had samples of children under seven (Vartiainen et al., 1997; Dietz et al., 2009; Kvestad et al., 2014; Lü et al., 2014; Kataoka et al., 2020), four had samples of older children (Parving, 1983; Boyle et al., 1996; Bhasin et al., 2006; Watkin & Baldwin, 2011), and two studies had samples in both age groups (Lin et al., 2018; Uhlén et al., 2020).

For samples of younger children, prevalence was 0.32 to 2.20 per 1,000 children, six included only bilateral hearing losses and two included both unilateral and bilateral, and the cutoff for reporting hearing level differences ranged from 20 to 55 dB HL. For samples of older children, prevalence was 0.65 to 3.37, six samples included bilateral hearing losses only and two included both unilateral and bilateral, and the cutoff for reporting was from 20 to 55 dB HL.

Discussion

The purpose of this systematic literature review was to identify the prevalence of permanent hearing loss for children who were not identified from NHS with an average age up to 12 years. Thirty studies met the inclusion criteria, and importantly, one criterion was that tests

were conducted to differentiate between permanent and temporary hearing loss. Because of variations in other design factors, we found a wide range of prevalence. As would be expected, prevalence findings were higher when unilateral and milder degrees of hearing loss were included, and older children had a higher prevalence of hearing loss than younger children.

Even though national surveys and census data are often cited for prevalence estimates, they were not included in this review because of the approach used to subjectively determine the presence of hearing loss. Findings from these data sources often rely on parent report by asking about hearing ability. For example, in the US the National Health Interview Survey (NHIS) for children ages 3-17 asked if the child had "a lot of trouble" hearing and less than 1% were identified with a moderate to profound hearing loss (Zablotsky & Black, 2019). Information that provides accurate estimates of prevalence are important in determining systematic solutions for identifying DHH children as early as possible and for facilitating access to appropriate intervention.

For the studies in this review, there are additional factors that may have contributed to the variation in prevalence findings. There were differences in how studies considered the influence of ambient noise during testing. For example, testing in a quiet room and using a biologic check to determine acceptable noise levels (Maharjan et al., 2021) versus testing in a sound-proofed booth (le Clercq et al., 2017). Noise interfered with testing; for example, Birhanu et al. (2021) reported challenges with ambient noise levels being too high but did not measure the noise level, and ultimately excluded thresholds at 500 and 1,000 Hz in their analysis because of ambient noise. Swart et al (1995) reported noise interfered with screening conducted in a vacated classroom. Studies also varied in the hearing level considered, with some studies including slight hearing loss (Wake et al., 2006; le Clerq et al., 2017) and others

only higher levels of hearing loss (e.g. 55 dB HL or greater; Lin et al., 2018). Additionally, some studies only included bilateral hearing loss (e.g., Kataoka et al., 2020).

To effectively determine prevalence of permanent childhood hearing loss and to appropriately advocate for children, there are considerations that need to be addressed in future research. For example, children with unilateral hearing loss and milder degrees of hearing loss can experience negative consequences and decisions about management need to be considered (e.g., Zussino et al., 2022), yet approximately one-third of the samples in this review only considered bilateral hearing loss and children with hearing losses greater than 35 dB HL. To accurately determine if a hearing loss is permanent, it is necessary to obtain bone conduction thresholds, and a quiet environment is needed to determine hearing levels (American Speech-Language-Hearing Association [ASHA], n.d.), yet only half of the studies reported obtaining bone conduction thresholds and described the setting where testing was done. Information on whether children in the sample were previously identified with permanent hearing loss (e.g., as a result of newborn hearing screening) needs to be known because it influences understanding of prevalence in the general population during childhood; 79% of the studies did not report this information (15/19 studies in Categories 1 and 2).

A minimum standard for reporting prevalence of permanent hearing loss is needed to improve the quality of information health care providers and systems of care use for making decisions that impact early identification and management of childhood hearing loss. For prevalence information to be meaningfully useful, purposeful decisions need to be made in the study design and transparently reported. For example, reporting on decisions and methods for the following aspects of the study: (a) test used to determine the type of hearing loss, (b) test parameters (e.g., hearing level cut-off, laterality, test frequencies), (c) inclusion/exclusion criteria

(e.g., sample selection, age, previously identified hearing loss, presence of other conditions), (d) test environment characteristics, including noise management and/or measurement, (e) procedures for tracking and reporting loss to follow-up (if applicable for the design), (f) procedures for determining fidelity of testing, and (g) description of how permanent hearing loss is defined in the study (e.g., how degree determined, hearing loss types, frequencies included) and methods for calculating degree of hearing loss. Variance among studies in measurement and calculation of hearing loss, and inclusion criteria create barriers to being able to draw conclusions about prevalence of hearing loss.

Even though prevalence data from the studies included in this review is imprecise, it demonstrates that many children are not identified through NHS systems. For this reason, practical implications for identification and management need to be considered. Management of hearing loss identified in childhood requires the involvement of multiple stakeholders (ASHA, n.d.), and it begins with awareness and education. Caregivers, healthcare providers, audiologists, early interventionists, among others, need to be aware that hearing loss can occur at any age, even if an infant passed their newborn hearing screening. Information dissemination is needed on the increase in prevalence of permanent hearing loss during childhood, the importance of vigilance for signs of hearing difficulty, and steps to take when there are concerns. Recommendations for information dissemination include:

- Hospital newborn hearing screening materials for parents
- Primary care physician well-child check appointment discussion
- Early intervention services for speech-language delay
- National public service campaigns

The JCIH (2019) statement provides guidance on accessible education that supports understanding, evidence-based hearing assessment, and approaches for intervention needed for child development and school readiness. Timely action and coordinated care are critical to help children achieve optimal outcomes.

Currently, there are no systems of care to effectively identify children with permanent hearing loss between the NHS and school entry. Children can easily be missed if they pass the NHS, or if they have a condition associated with later onset hearing loss, such as certain genetic variants and congenital cytomegalovirus. Often times these conditions are not known to the parent or healthcare providers, and are a silent risk factor that is not being monitored. The limited data that are available suggest that hearing screening during early childhood occurs infrequently and inconsistently (Halloran et al., 2005; Selden, 2006). Some screening occurs during well child checks by primary care physicians, in Head Start programs, and other early childhood settings; however, many children do not receive regular screening. Identification relies primarily on someone recognizing signs of difficulty and raising their concern. In the U.S., the EHDI Act of 2017 extended the reach of EHDI programs to include children from birth to 3 years of age which is an important step, but increased attention by policy-makers and healthcare professionals is needed to determine how to systematically educate stakeholders and screen the hearing of children in early childhood. Regular monitoring of hearing and increased awareness can mitigate developmental delays. Parental concern about speech, language, or hearing is a risk factor (JCIH, 2019) necessitating prompt referral for hearing assessment.

Conclusion

This systematic review revealed scant research on prevalence of childhood hearing loss not identified from NHS that utilized testing methods that can accurately differentiate between

permanent and temporary hearing loss. Based on the studies in this review, prevalence of permanent hearing loss in childhood that is not identified from NHS is at least as high as the number of children identified through NHS. Importantly, prevalence identified depends on how hearing loss is defined as it relates to degree level and laterality included. When slight, mild, and unilateral hearing loss is included, prevalence is much higher. There is a need for rigorous research about the prevalence of permanent hearing loss in childhood, and how that might differ across geographical and demographic groups, to inform strategies for identification, intervention, and management. Systems are needed for identifying DHH children after the NHS.

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Table 1. Prevalence of permanent hearing loss per 1,000 children by age, severity, and laterality

Age Group and Laterality	Hearing loss dB cut-off at greater than or equal to:							
	15 or 20		25 or 30		35 or 40 or 45		55	
	n	M	*n*	M	*n*	M	*n*	M
0-6 years								
Bilateral only			2	1.35	1	0.83	2	0.49
Unilateral and bilateral	2	2.15	9	1.94	2	0.74		
7-12 years								
Bilateral only	1	2.10			4	1.24	1	1.00
Unilateral and bilateral	5	31.17	6	10.52	1	8.23		

Abbreviations: *n* = number of studies; M = mean prevalence

Table 2. Prevalence of permanent hearing loss: diagnostic testing completed for all children in the sample

Source			HL Prevalence			HL Determination (dB)			Included in Analysis		
ID	**Year Author**	**Country Years**	**Age range M(SD)**	**N**	**Per 1000**	**HL level**	**Degree ranges**	**Degree based on**	**Laterality**	**Type**	**Known HL (excluded)**
1	2021 Maharjan	Nepal 2015-19	5-10 NR	21,514	11.76	> 25	NR	PTA	Bilateral, unilateral	SN, mixed	NR
2	2021 Birhanu	Ethiopia 2019-20	6-14 10 (1.94)	1,351	67.36	> 20	25-35; 40-50; 55+	BC (2,4)	Bilateral, unilateral	SN, mixed	NR
3	2017 le Clercq	Netherlands 2012-15	9-11 9.9	5,368	77.87	> 15	16-25; 26-40; 41-55; 56-70; 71-90; 91+	LFPTA and/or HFPTA	Bilateral, unilateral	SN	NR

Abbreviations: HL = hearing loss; SN = sensorineural; dB = decibel; NR = not reported; kHz = kiloHertz; BC = bone conduction; LFPTA = low frequency pure tone average; HFPTA = high frequency pure tone average

Table 3. Prevalence of permanent hearing loss: DPOAE screening followed by diagnostic testing on referrals

Source			HL Prevalence			HL Determination			Included in Analysis		
ID	**Year Author**	**Country Years**	**Age range M(SD)**	**N**	**Per 1000**	**Degree ranges**	**Degree based on**	**LTF**	**Laterality**	**Type**	**Known HL (excluded)**
4	2007 Abdel-Hamid	Egypt NR	0-15	1,597	19.41	25–40; 40–55; 55–70; 70–90; >90	NR	NR	Bilateral, unilateral	SN, mixed	NR
5	2008 Eiserman	U.S. NR	NR 22 mo (13)	4,511	1.55	NR	NR	38%	Bilateral, unilateral	SN, mixed	No
6	2013 Chen	China 2010-11	3-6 4.86 (1.67)	28,546	0.84	26-40; 41-70; 71-90; >90	PTA	0%	Bilateral, unilateral	SN, mixed	No
7	2018 Ramkumar	India 2011-13	4 days – 4.11 yrs 1.5	1,335	3.00	NR	NR	15%	Bilateral, unilateral	SN	NR
8	2018 Cedars	U.S. 2014-15 2015-16	2-6	1,821	1.65	NR	NR	4%	Bilateral, unilateral	SN	NR

Abbreviations: DPOAE = distortion product otoacoustic emissions; HL = hearing loss; SN = sensorineural; PT = pure tone (air); dB = decibel; LTF = lost to follow-up; NR = not reported; PTA = pure tone average

Table 4. Prevalence of permanent hearing loss: pure-tone screening followed by diagnostic testing on referrals

Source			HL Prevalence			HL Determination				Included in Prevalence		
ID	**Year Author**	**Country Data Years**	**Age range M(SD)**	**N**	**Per 1000**	**Screen level**	**Degree ranges**	**Degree based on**	**LTF**	**Laterality**	**Type**	**Known HL (excluded)**
9	1984 Nelson	U.S. 1978-80	4-14	15,890	3.84	> 20	21-30; 31-40; 41-50; 51-60; 61-70; 71-80; 81-90, 90+	SRT or 2 best thresholds .5-2	NR	Bilateral, unilateral	SN, mixed	NR
10	1990 Augustsson	Sweden 1984-85 1987-88	4.5 (NR) 6.7-8.3	2,330 2,482	3.0 0.81	≥ 25	NR	NR	3% 35%	Bilateral, unilateral	SN	No
11	1995 Swart	Swaziland 1992	5-15 NR	2,430	8.23	> 30/35	NR	NR	NR	Bilateral, unilateral	SN	NR
12	1999 Flanary	U.S. 1996-97	5-6 NR	8,220	1.58	> 20	NR	NR	35%	Bilateral, unilateral	SN	NR
13	2000 Hornby	Barbados 1996-97	5-11 NR	17,902	5.25	> 20	n/a	NR	0%	NR	SN, mixed	NR
14	2006 Wake	Australia 2003-04	7.2 (0.43) and 11.1 (0.43)	6,240	24.36	> 15	NR	PTA, LPTA, HPTA	NR	Bilateral, unilateral	SN	NR
15	2011 Lü	China 2009-10	3-6 4.89 (1.11)	21,427	0.75	> 40	25-40; 41-60; 61-90; >90	PTA	31%	Bilateral, unilateral	SN, mixed	No
16	2012 Al-Rowaily	Saudi Arabia 2009-10	4-8 NR	2,574	2.72	> 20	26–40; 41–55; 56–70; 71–90; >91	NR	NR	Bilateral, unilateral	SN	NR
17	2014 Wenjin	China NR	3.01-6.92 5.1	6,288	1.91	≥ 25	26-40; 41-60; 61-80; >80	PTA	20%	Bilateral, unilateral	SN, mixed	NR
18	2016 Mohamed-Asmail	South Africa NR	6-12 8 (1.1)	1,070	4.67	> 25	NR	NR	NR	Bilateral, unilateral	SN	NR
19	2018 Hussein	South Africa NR	3-7	6,424	2.49	> 25	NR	NR	55%	Bilateral, unilateral	SN, mixed	NR

Abbreviations: OAE = otoacoustic emissions; DP = distortion product; HL = hearing loss; SN = sensorineural; PT = pure tone (air); dB = decibel; LTF = lost to follow-up; NR = not reported; ME = middle ear; PTA = pure tone average; LPTA = low frequency pure tone average; HPTA = high frequency pure tone average; dx = diagnostic

Table 5. Prevalence of permanent hearing loss: retrospective population-based studies

Source			HL Prevalence			HL Determination		Included in Analysis	
ID	**Year Author**	**Country Years**	**Age Range**	**Population**	**Per 1000**	**Degree based on**	**Degree ranges**	**Laterality**	**Type**
20	1983 Parving	Denmark 1970-79	2-12	82,265	1.36	≥ 35 PTA	NR	Bilateral	SN, mixed
21	1996 Boyle	US 1985-87	3-10	249,500	0.93	≥ 40 PTA	40-64 dB; 65-84 dB; 85+	Bilateral	SN, mixed
22	1997 Vartiainen	Finland 1974-87	0-9	46,240	2.10	>25 PTA	26-40; 41-70; 71-95; >95	Bilateral	SN, mixed
23	2006 Bhasin	US 1996 and 2000	8	36,753 43,593	1.44 1.21	≥ 40 PTA	40-64 dB; 65-84 dB; 85+	Bilateral	NR
24	2009 Dietz	Finland 1988-2002	5.1	43,711	2.12	> 20 PTA	21-39; 40-69; 70-94; 95+	Bilateral	SN
25	2011 Watkin	UK Not reported	7	35,668	1.60	≥20 PTA	20-39; ≥ 40	Bilateral, unilateral	NR
26	2014 Kvestad	Norway 1978-1999	0-5	392,044	0.83	≥ 35 PTA	NR	Bilateral	SN
27	2014 Lü	China 2009-11	3-6	35,684	0.73	>40 PTA	25-40; 41-60; 61-90; >90	Bilateral, unilateral	SN, mixed
28	2018 Lin	Taiwan 2004-2010	0-3 3-5 6-11	4,288,674 4,989,124 12,125,139	0.32 0.65 0.78	> 55	> 55-69 dB; 70-89; 90+	Bilateral	NR
29	2020 Kataoka	Japan 2006-2018	0-7	168,104	0.57	>25 PTA	25-40; 41-70; 71-90; >90	Bilateral	SN, mixed
30	2020 Uhlén	Sweden 1999-2017	<1 2.5 7	24,740 119,072 147,059	0.97 1.89 3.37	>25 PTA	21-40; 41-60; 61-90; >90	Unilateral, bilateral	SN, mixed

Abbreviations: US = United States; UK = United Kingdom; HL = hearing loss; PTA = pure tone average; NR = not reported

Figure 1. PRISMA inclusion flowchart