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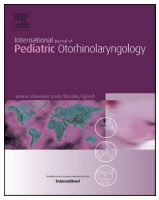

Estimated prevalence of permanent hearing loss among newborns and 6-year-olds: An evaluation of the three auditory screenings in Uppsala☆

Elsa Erixon *

Department of Surgical Sciences, Section of Otorhinolaryngology and Head and Neck Surgery, Uppsala University, Uppsala, Sweden

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ABSTRACT

Objectives: This study estimated the permanent hearing loss (PHL) prevalence among newborns and 6-year-olds in the Uppsala region (Sweden), compared how different definitions affected this estimation, and evaluated the outcome of the three hearing screening occasions for children.
Methods: A retrospective investigation of medical records and audiograms was conducted for children born in 2011–2012. Data extraction was performed when the children had reached 7 years of age. Hearing loss was defined as > 20 dB hearing level in at least one frequency (125–8000 Hz) in one or both ears (clinician's definition).
Results: A total of 1385 children were included, and 95 were diagnosed with PHL. The prevalence of bilateral PHL at 6 years was 5.50 per 1000 children based on the clinician's definition, 3.74 per 1000 children based on the World Health Organization (WHO) 2021 definition, and 2.64 per 1000 children based on the WHO 1991 definition. Adding unilateral PHL resulted in a total prevalence of 10.11 (clinician's definition) and 6.16 (WHO 2021) per 1000 children.
Conclusion: This study demonstrates the necessity of repeated hearing testing during childhood to identify PHL and suggests a higher prevalence in 6-year-olds than previously reported. The definition of PHL greatly impacted its estimated prevalence.

1. Introduction

The importance of early identification and rehabilitation of children with all grades of hearing loss has been highlighted by the Joint Committee on Infant Hearing [1] and the World Report on Hearing [2]. Even mild and unilateral hearing loss can affect childrens's development and require follow-ups and interventions when identified [3–6]. The World Report on Hearing, as well as the Hearing Screening Considerations for Implementations [2,7], advocate for repeated hearing screening throughout childhood and the entire lifetime since hearing loss can occur at any age and often remains undetected for several years in the absence of testing.

In the Uppsala region, as in most of the 21 self-governing regions in Sweden, preschool and school hearing screenings have been performed for decades, and neonatal newborn hearing screening was added in 2007, resulting in three auditory screenings for children. All children in the Uppsala region are offered hearing screening shortly after birth, at 4 years of age, and when they start school at 6 years of age. If a child is not eligible for the standard screening method for any reason, such as risk factors, comorbidities, or problems with concentration, they are directly referred to the Hearing and Balance Clinic at the Uppsala University Hospital for proper evaluation; of note, this is the only institution in the region that evaluates children with hearing problems. Fig. 1 demonstrates the timings and referral criteria for the three auditory hearings. In addition to the three screenings, parents can contact the Hearing and Balance Clinic directly or obtain a referral from a nurse or doctor if they suspect that their child has a hearing impairment. Moreover, if a child has a speech delay, the nurse at the well-baby clinic or the speech-and-language therapist can refer the child for an extra hearing test. Children diagnosed with PHL are offered regular follow-ups at the Hearing and Balance Clinic at least till 18 years of age and hearing rehabilitation if needed. Healthcare, hearing rehabilitation, and hearing aids for children are financed by taxes and free of out-of-pocket charge for the families.

The Swedish National guidelines for child healthcare include risk factors requiring referrals for extra hearing tests and describe the screening method and referral criteria for 4-year-old children [8,9], and

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* Department of Surgical Science, Uppsala University, Box 256, 751 05, Uppsala, Sweden.
E-mail address: elsa.erixon@akademiska.se.

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these are followed in Uppsala. Besides these recommendations, there is no national early hearing detection and intervention program with a standardized methodology or referral and diagnostic criteria for auditory screenings. Furthermore, no register for the screening coverage or outcome is available. Therefore, information on the outcomes of the three auditory screenings in the Uppsala region is limited. A screening program should be cost-effective and follow the WHO screening criteria [10]; however, the auditory screenings in Uppsala do not meet the WHO criteria.

This study aimed to evaluate the three auditory screenings by establishing when and at which screening occasion children with different grades of hearing loss were identified, though the goal of newborn screening is early identification of children with disabling hearing loss and the preschool and school screening should identify mild hearing loss and hearing loss with later onset. Furthermore, a comparison of the prevalence of hearing loss in Uppsala and other countries can clarify whether an accurate number of children with hearing loss were identified by the screenings in Uppsala.

In this study, different definitions were compared to see how they affected the prevalence of hearing loss within the same cohort. In 1991, the WHO introduced a grading system for hearing impairment [11], recommending the use of the pure-tone average of the air conduction thresholds at frequencies of 500, 1,000, 2,000, and 4000 Hz (PTA4) using decibel hearing level (dB HL) as the unit. Disabling hearing loss was later defined as a hearing loss of >40 dB HL in the better ear in adults and of >30 dB HL in the better ear of children [12]. This definition is herein referred to as WHO 1991. In 2008, the Global Burden of Disease Expert Group on Hearing Loss modified the grading system [13, 14], and this update was adopted and presented by the WHO in the World Report on Hearing in March 2021 [2] and is herein referred to as WHO 2021. The WHO 2021 classification differs from WHO 1991 because it includes unilateral hearing loss (UHL), modifies the limit used to define mild hearing loss from 26 to 20 dB HL, includes more hearing loss categories, and defines hearing loss as disabling at ≥ 35 dB HL in the better ear.

1.1. Study aims

This study aimed to estimate the prevalence of permanent hearing loss among newborns and 6-year-olds, to compare how different definitions of hearing loss affected the estimated prevalence of this condition and to evaluate the outcome of the three auditory screenings for children in the Uppsala region.

2. Materials and methods

A retrospective investigation of the medical records and audiograms was performed for all children born in 2011–2012 and living in the Uppsala region. The personal security numbers of children who had visited the Ear, Nose, and Throat department at the Uppsala University Hospital before the age of 6 months or had an audiogram in the audiogram database were extracted at least 1 year after the child had started school (January 26, 2019, for children born in 2011, and September 18, 2019, for children born in 2012). The medical records of the children born in 2011 and 2012 were reviewed in the spring of 2019 and 2020, respectively. Furthermore, the medical records of children with an uncertain diagnosis of hearing loss were examined until a confident diagnosis of hearing loss was established or excluded. The date of the last data extraction was August 14, 2021. The medical records were searched for the time and reason for referral (newborn, age of 4 or 6 years at screening, or other reasons), age of diagnosis, and hearing assessment results (normal hearing, permanent or temporary hearing loss). Moreover, for children diagnosed with permanent hearing loss (PHL), the medical records were also searched for PTA4, type of hearing loss (conductive, sensorineural, or mixed), aetiology, and kind of interventions (referral to hearing rehabilitation and type of hearing aid in each ear). The most recent audiogram was used to determine the type and grade of PHL, regardless of whether the hearing loss was identified at birth or later; thus, for most children, that hearing test was performed at 6 or 7 years of age. When calculating the PTA4, the value of 120 dB HL was used if the pure-tone threshold exceeded the maximum output level of the audiometer.

The definition of hearing loss adopted for this study was at least one

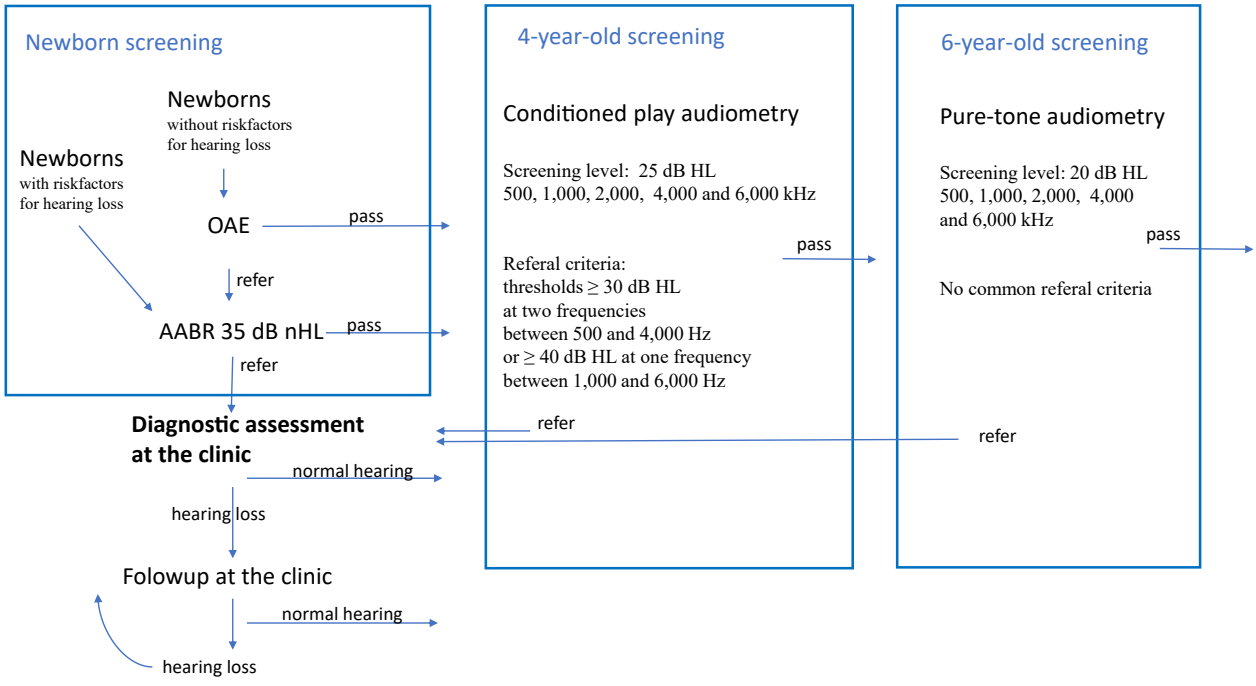

Fig. 1. Flow chart of the three auditory screenings for children in the Uppsala region. OAE: automatic transient otoacoustic emissions; AABR: automatic auditory brain stem responses.

frequency (125–8000 Hz) with air conduction of >20 dB HL in at least one ear. UHL was defined as air conduction of ≤20 dB HL at all frequencies (125–8000 Hz) in the better ear and at least one frequency of >20 dB HL in the worse ear. Bilateral hearing loss (BHL) was defined as air conduction of >20 dB HL for at least one frequency (125–8000 Hz) in both ears. These definitions of hearing loss are referred to herein as "the clinician's definition." The children with PHL according to the clinician's definition were graded according to the WHO 1991 and WHO 2021 grading systems. PHL is herein defined as a sensorineural or conductive hearing loss that is expected to last for the rest of the patient's lifetime. In contrast, temporary hearing loss (THL), which is caused by various short-term conditions, such as secretory otitis media, ear infection, or eardrum perforation, may be treated by surgery or medication, or it resolves on its own. The data were pseudo-anonymized, and Excel (Microsoft; Redmond, WA, USA) was used for data storage and statistical analysis.

2.1. Ethical considerations

This study was approved by the Regional Ethical Review Board in Uppsala (2017/111).

3. Results

3.1. Prevalence

Initially, 1584 children were identified. After the exclusion of children not living in the region and those who passed their preschool or school screening at the clinic, 1385 remained and were included in the study. Among them, 95 were diagnosed with PHL, of whom 40 were identified at newborn screening. However, one child with profound bilateral hearing loss identified at the newborn screening had moved into the region later; hence, the number of children identified at the newborn screening living in the region at the time of the screening was 39. Furthermore, three children relocated from the region or died before the age of 6 years: one with single-sided deafness, one with profound bilateral hearing loss, and one with moderate hearing, reducing the number of 6-year-olds with PHL living in the Uppsala region to 92. The number of inhabitants was extracted from the Kolada database of statistics [15]. The population of 2011 and 2012 together included 8088 newborns. Six years later, when the cohort had started school, the population had grown to 9098 6-year-olds. The prevalence of PHL in children identified at the newborn screening and of 6-year-olds according to the different definitions of hearing loss is presented in Table 1.

Table 1
Prevalence of permanent hearing loss in children identified at the newborn screening and in 6-year-olds based on different definitions of hearing loss.

	Children identified at the newborn screening (n = 39)		6-year-olds (n = 92)	
Total population	8088		9098	
	n	Prevalence/1000	n	Prevalence/1000
Bilateral hearing loss				
Clinician's definition	23	2.84	50	5.50
WHO 2021	22	2.72	34	3.74
WHO 1991	19	2.35	24	2.64
Unilateral hearing loss				
Clinician's definition	16	1.98	42	4.62
WHO 2021	14	1.73	22	2.42
WHO 1991	0	0	0	0
Total				
Clinician's definition	39	4.82	92	10.11
WHO 2021	36	4.45	56	6.16
WHO 1991	19	2.35	24	2.64

Clinician's definition: at least one frequency (125–8000 Hz) > 20 dB HL in one or both ears; WHO 2021: pure-tone average ≥ 20 dB HL in the better ear in bilateral hearing loss or < 20 dB HL in the better ear and ≥35 dB HL in the worse ear in unilateral hearing loss; WHO 1991: pure-tone average > 25 dB HL in the better ear.

3.2. Screening outcome

The 1385 children were referred to the clinic 1469 times because of suspected hearing loss. Among the 1469 referrals, 403 (27 %) were referred after not passing the newborn screening, 362 (25 %) did not pass the fourth-year screening, 132 (9 %) the school screening, and 572 (39 %) were referred for other reasons. The most common reason for these extra referrals was a delay in language development among children under 3 years of age. The number of referrals from each screening and the outcomes of the hearing assessments at the clinic are presented in Table 2. Concerning the 5 children lost to follow-up, the child identified at the fourth-year screening and lost to follow-up, was later referred from the school screening and diagnosed with PHL. Nothing is known about the remaining lost children.

Ninety-five children were diagnosed with PHL based on the clinician's definition of hearing loss, including 42 girls and 53 boys. Among them, 40 (42 %) were diagnosed at the newborn screening, 24 (25 %) at the fourth year one, 15 (16 %) at the school screening, and 16 (17 %) through a referral outside of the screening programs.

Table 2
Number of referrals from different screening and testing occasions and the outcome of diagnostic testing, classified as normal hearing (Normal), temporary hearing loss (THL), and permanent hearing loss (PHL).

	Referrals	Normal	THL	PHL	Lost to follow-up
Newborn screening	403	326	35	40	2
		81 %	9 %	10 %	0 %
Screening at 4 years of age	362	231	106	24	1
		64 %	29 %	7 %	0 %
School screening	132	74	41	15	2
		56 %	31 %	11 %	2 %
Referrals outside the screening program	572	368	188	16	0
		64 %	33 %	3 %	0 %
Total	1469	999	370	95	5

The data are expressed as the total number and percentage of the referrals.

3.3. Grades and types of hearing loss and rehabilitation

Based on the clinician's definition, 52 children had BHL and 43 had UHL. Irrespective of the definition of hearing loss, most children with severe or profound BHL were identified at the newborn screening, and the children that were diagnosed later were more likely to have mild, slight, or moderate BHL or UHL. The numbers of children with PHL divided into different grades and subgroups according to the clinician's definition and the WHO 2021 and WHO 1991 definitions are presented in Table 3.

For six of the 95 children with PHL, a reliable pure-tone audiogram could not be obtained by the end of the data collection period, and their PTA4 was estimated from ABR or visual reinforcement audiometry. Therefore, owing to limited diagnostic assessments, the type of hearing loss could not be classified in three children (3 %). Seventy-five children (79 %) had sensorineural hearing loss, fourteen (15 %) had conductive hearing loss, and three (3 %) had mixed hearing loss. The aetiology was not mentioned in several medical records and when mentioned was undetermined in most cases. A syndrome was the most common cause when the aetiology was known. Other mentioned causes were atresia and congenital cytomegalovirus infection. Among the 43 children with UHL, the PTA4 was <20 dB HL for the impaired ear in ten children, 20–34 dB HL in ten children, 35–49 dB HL in seven children, 50–64 dB

Table 3
Number of children with permanent hearing loss and subgroups based on different definitions.

		Identified at newborn screening n = 40	All 6-year-olds n = 95
Clinician's definition			
Bilateral hearing loss	At least one frequency (125–8000 Hz) > 20 in both ears	24	52
Unilateral hearing loss	At least one frequency (125–8000 Hz) > 20 in one ear, and the other, all frequencies ≤20	16	43
WHO 2021	PTA4 (dB HL)		
Normal hearing	<20 in the better ear	17	59
Mild hearing loss	20–34 in the better ear	7	17
Moderate hearing loss	35–49 in the better ear	8	10
Moderately Severe hearing loss	50–64 in the better ear	0	0
Severe hearing loss	65–79 in the better ear	3	3
Profound hearing loss	80–94 in the better ear	2	3
Complete or total hearing loss	≥95 in the better ear	3	3
Disabling hearing impairment	≥35 in the better ear	16	19
Unilateral hearing loss	<20 in the better ear; ≥35 in the worse ear	14	23
WHO 1991	PTA4 (dB HL)		
No impairment	≤25 in the better ear	20	69
Slight impairment	26–40 in the better ear	9	13
Moderate impairment	41–60 in the better ear	3	4
Severe impairment	61–80 in the better ear	3	4
Profound impairment	>80 in the better ear	5	5
Disabling hearing impairmentin children	≥30 in the better ear	18	22
Swedish Quality Register	At least one ear PTA4 > 29	36	56

The data are expressed as absolute numbers. WHO 2021: definition of hearing loss proposed by the World Health Organization in 2021; WHO 1991: older definition by the World Health Organization in 1991; PTA4: pure-tone average for the frequencies of 500, 1,000, 2,000, and 4000 Hz; dB HL: decibel hearing level.

HL in four children, 65–79 dB HL in two children, and ≥95 dB HL in ten children, with no children presenting PTA4 in the 80–94 dB HL range. Among the children identified as experiencing hearing loss at the newborn screening, 40 % and 38 % had UHL based on the clinician's definition and the WHO 2021 definition, respectively. By the age of 6 years, these percentages increased to 45 % and 39 %, respectively.

Among the 95 children with PHL, 70 were referred to the hearing rehabilitation centre, where they received family-centred interventions, and 57 were fitted with hearing technology. Regarding the 52 children with BHL, 4 received bilateral cochlear implants, 27 received bilateral conventional hearing aids, 1 received bilateral bone-conducting hearing aids, and 1 received a unilateral conventional hearing aid. Among the 43 children with UHL, 18 received a conventional hearing aid, 3 received contralateral routing of signals (CROS) hearing aids, and 3 received a bone-conducting hearing aid (1 child with atresia and 2 with single-sided deafness). However, one child was recommended hearing aids, but this was declined by the parents, and three children fitted with hearing aids stopped using the devices.

4. Discussion

The different methods to screen or assess hearing ability in children of varying ages limit the use of a common definition of hearing loss that is valid for all ages. Children are mentioned in the preparatory work of the WHO 2021 classification system [14,16]; however, the World Report on Hearing states that "the classification and grades are for epidemiological use and applicable to adults" and fails to mention how to evaluate children. In this study, this issue was solved by using an audiogram at the age of 6 years when classifying hearing loss. However, the usage of PTA4 reduces or misses higher-frequency hearing loss. The clinician's definition of hearing loss was chosen because in a clinical setting, every frequency measured >20 dB HL suggests that the clinician should consider hearing loss. Since PHL may be progressive, children diagnosed with PHL need to be followed up throughout childhood. The choice to define hearing loss at a single frequency of >20 dB instead of ≥20 dB was to define it based on clinical practise; when a child is referred with suspected hearing loss, the audiologists in Uppsala often do not test hearing thresholds <20 dB HL to make the hearing test more feasible in young children.

The method of grading hearing loss from the most recent and accurate pure tone audiogram has advantages and disadvantages. When children do not pass the newborn hearing screening, electrophysiological methods are used to estimate the grade and type of hearing loss. Alternatively, in most 6-year-olds, a pure tone audiogram, with details on bone and air conductions, can be obtained, and PTA4 can be calculated. Moreover, repeated audiograms and examinations on the diagnosed children allow reliable identification of the grade and type of hearing loss. This provides control over the potential presence of secretory otitis media and fluctuating hearing thresholds, resulting in a more reliable PTA of the PHL. One-third of the 95 children with PHL in this study had complications because of secretory otitis media, which healed or was cured with ventilation tubes before grading the PHL. Concerning the prevalence of hearing loss among 6-year-olds, defining the condition as permanent or temporary and understanding whether THL may complicate PHL are crucial issues.

A disadvantage of using the audiograms from the age of 6 years is that hearing in some of the children identified at the newborn screening deteriorated since the initial diagnosis. The hearing deteriorated in 18 % of the children with PHL, and the use of audiograms at 6 years of age to grade the hearing loss retrospectively is likely to have contributed to the higher prevalence among newborns in this study.

The prevalence of hearing loss presented in a study is an estimation of the actual prevalence and depends on several factors, including the definition of hearing loss, the method to measure hearing, and the study population and design. For example, lowering the criteria for normal hearing (<20 dB HL instead of ≤25 dB HL) in the updated WHO definition resulted in 42 % more cases of BHL being diagnosed among the 6-year-olds in this study (2.64–3.74 per 1000). Moreover, with the inclusion of UHL, the prevalence of PHL increased by 133 %, from 2.64 (WHO 1991) to 6.16 (WHO 2021) per 1000. For children diagnosed with

BHL in this study, the variation in the prevalence for children identified at the newborn screening using different definitions was minor (between 2.35 and 2.84 per 1000 children) compared to that in 6-year-olds (between 2.64 and 5.50 per 1000 children). The reason for this is that mild BHL is rarely identified in newborn screening because of the screening method. According to the WHO, the global prevalence of moderate or higher grade (≥35 dB HL) BHL is 2 per 1000 infants within a month of life [2], which is similar to the prevalence of 1.85 per 1000 estimated in this study. A systematic review [17] of the neonatal prevalence of PHL reported a rate of 1.33 (1.01–1.63) per 1000 infants for BHL (≥40 dB HL) and 0.78 (0.51–1.07) for UHL (≥40 dB HL). Thus, the rate of BHL (1.36) in this study was consistent with that reported in the review, whereas the UHL rate in this study (1.61) was markedly higher than that reported there. Another systematic review [18] reported the prevalence of permanent BHL (≥26 dB HL) identified at newborn screenings in highly developed countries as 1.1 per 1,000, a lower value compared to the prevalence of 2.34 per 1000 estimated in this study. It appears that the number of children identified at newborn screening in Uppsala is in accordance with or higher than in other countries.

In a study of children referred for hearing rehabilitation in the Stockholm region, the prevalence of permanent UHL and BHL >20 dB HL was found to be 0.97 per 1000 among children under one year of age and 3.16 per 1000 among 6-year-olds [19]. In contrast, in this study, based on the WHO 2021 definition of hearing loss, which is less inclusive of UHL, the corresponding rates were higher (4.45 and 6.16 per 1,000, respectively). No obvious demographic or socioeconomic differences are present between the neighbouring regions of Uppsala and Stockholm; therefore, the higher prevalence in this study was not expected. However, the higher prevalence in Uppsala may be related to the fact that the Stockholm cohort consisted of children referred for rehabilitation, whereas this study also included children not offered rehabilitation. Furthermore, the Stockholm study focused on the age at diagnosis, and diagnosis after screening is sometimes delayed; this study considered instead of the age when the child was first identified at the screening.

According to the WHO, the global incidence of BHL (≥35 dB HL) among children aged 5–9 years is 15 per 1000; however, this figure includes patients with THL [2,20]. In this study, the prevalence of permanent BHL (≥35 dB HL) was 1.87 per 1000 among 6-year-olds. Two studies on delayed onset of permanent hearing loss among 3- to 6-year--olds who had passed the newborn screening found a prevalence of unilateral or bilateral PHL (≥25 dB HL) of 0.75 per 1000 and > 25 dB HL of 0.77 per 1,000, respectively [21,22]. In this study, 15 children (excluding those that had not been screened as newborns) had a delayed onset of hearing loss >29 dB HL, leading to a higher prevalence of 1.65 per 1000. The high number of children with delayed onset shows the necessity of repeated screening.

Concerning the outcome of the screening occasions in Uppsala, the prevalence of PHL in this study supports a satisfactory newborn screening, but there are too few comparable studies about the prevalence of PHL loss in 6-year-olds to evaluate. Regardless, a high prevalence of PHL after newborn screening and a high prevalence of later onset PHL compared to the mentioned studies indicates a high estimated prevalence in 6-year-olds in this study, but the actual prevalence of PHL might be even higher, though the coverage of the screenings is not known. The prevalence of PHL in Uppsala is similar or higher compared to that reported in other studies, despite a low prevalence of common risk factors for hearing loss such as consanguineous marriage, chronic otitis, meningitis, use of ototoxic drugs, or intrauterine infections. This finding is likely due to several factors such as the free healthcare system, the newborn healthcare program for newborns encompassing almost all families in the region, the registration of personal security numbers that allows for follow-up contacts even if the family changes location, a program consisting of repeated screenings and extra referrals, simple access to diagnostics, and a general acceptance of hearing rehabilitation. Thus, the actual prevalence of PHL may be underestimated in several countries.

In this study, the prevalence of PHL based on the clinician's definition more than doubled from birth to 6 years of age (from 4.82 to 10.11 per 1000 children), whereas it increased by approximately 30 % (from 4.45 to 6.16 per 1000 children) based on the WHO 2021 definition and by approximately 10 % (from 2.35 to 2.64 per 1000 children) based on the WHO 1991 definition. Most cases (n = 16) of disabling permanent BHL (≥35 dB HL) were identified at the newborn screening, and there were three more at the age of 6 years. Regarding UHL (≥35 dB HL), 14 and nine cases were identified among newborns and 6-year-olds, respectively. Among mild BHL cases (20–34 dB HL), seven cases were identified at the newborn screening, and ten more at the age of 6 years. These findings support that newborn screening is the most important for the early identification of children with disabling PHL; nonetheless, newborn screening alone is insufficient to identify all children with PHL. Children with PHL diagnosed later were mostly identified after a preschool or school screening referral even though families are free to contact the clinic at any time if they become suspicious about their child's hearing ability. This indicates that the hearing loss might have remained undetected or received a delayed diagnosis without repeated screening. Fifty-five of the children with PHL had not been identified at the newborn screening; two had missed the screening for unknown reasons, and one had emigrated from a country that did not offer newborn screening. Eleven of the children diagnosed later had failed their initial otoacoustic-emission screening but passed the automatic ABR 35-dB follow-up and, per definition, had passed the newborn screening. It is uncertain if as newborns they already had a mild progressive PHL or if their hearing loss had a later onset. Currently, the pass criteria for automatic ABR has been lowered to 30 dB, and this may reduce the number of children who pass newborn screening but are later diagnosed with PHL. It is a limitation of the three auditory screenings programme that a register of coverage does not exist.

This study did not attempt to evaluate whether the screening in Uppsala is cost-effective. A common hearing screening program in Sweden as well as a national register for the hearing screening outcome, including the coverage, number of referrals, type of hearing loss, and age at diagnosis, would be preferable to monitor the quality and cost-effectiveness of child healthcare in Sweden.

Presently, Sweden has a national quality register of children with PHL to monitor equal access to hearing diagnostics and rehabilitation. The inclusion criteria consist of permanent PTA4 hearing loss of >29 dB HL in at least one ear, a Swedish personal security number, and age <18 years. Fifty-six of the 95 children diagnosed with PHL fulfilled these criteria. Among the 70 children referred to hearing rehabilitation, 17 did not fulfil the Swedish National Quality Register criteria, of whom seven were fitted with hearing aids. Though a huge proportion of the children receiving hearing rehabilitation are not monitored by the quality register a change of inclusion criteria would enable more accurate monitoring.

This study focused on PHL; however, most children who were diagnosed with hearing loss according to the clinician's definition in this study had THL. THL was identified in 42 % of newborns diagnosed with hearing loss, in 82 % of the children diagnosed with hearing loss at the fourth-year screening, and in 73 % of the children diagnosed at the school screening. When evaluating the outcome and benefit of hearing screening, the number of children requiring treatment with transmyrringeal drainage should be addressed. This is a shortcoming of this study.

This study is also limited by its small sample size. Although the entire population from two age groups (children born in 2011 and 2012) was included, the total number of children affected by PHL was small. In addition, the number of children not attending the screenings is unknown. In contrast, this study is strengthened by its coverage of PHL. Informed consent was not needed because of the retrospective nature of the study; thus, all children whose hearing was examined at the clinic were included. The use of personal security numbers facilitated the screening follow-up, and only a few children were lost at follow-up.

Furthermore, comparing the prevalence of PHL in 6-year-olds to those in the same cohort diagnosed as newborns elucidated the increase of PHL during early childhood.

5. Conclusions

This study contributes to the accuracy of the statistics on the prevalence of PHL in children and demonstrates the necessity of repeated hearing testing during childhood to identify PHL. The prevalence of childhood PHL, especially mild BHL and UHL, is likely to be underestimated worldwide. Furthermore, the definition of hearing loss greatly impacts its estimated prevalence. Future studies using the WHO 2021 definition will help compare the prevalence between countries. However, a clarification from the WHO on how to best report hearing loss in children of different ages is warranted. Finally, defining the type, grade, permanency, and onset of childhood hearing loss is critical when evaluating hearing screening or designing future studies.

Declaration of competing interest

I declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Acknowledgments

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List of Abbreviations

ABR	auditory brainstem responses
BHL	bilateral hearing loss
dB HL	decibel hearing level
PHL	permanent hearing loss
PTA4	pure-tone average from the four frequencies: 500, 1000, 2000, and 4000 Hz
THL	temporary hearing loss
UHL	unilateral hearing loss
WHO	World Health Organization

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