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ORIGINAL RESEARCH

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A 4-year follow-up study of hearing acuity in a large population-based cohort of children and adolescents

Danique E. Paping MD[1,2] | Jantien L. Vroegop PhD[2] | Carlijn M. P. le Clercq MD[1,2] | Robert J. Baatenburg de Jong MD, PhD[1] | Marc P. van der Schroeff MD, PhD[1]

[1]Department of Otorhinolaryngology, Head and Neck Surgery, Erasmus University Medical Center, Rotterdam, Netherlands

[2]The Generation R Study Group, Erasmus University Medical Center, Rotterdam, Netherlands

Correspondence
Danique E. Paping, MD, Department of Otorhinolaryngology, Speech and Hearing Centre, Erasmus Medical Centre, PO Box 2040, 3000 CA Rotterdam, Netherlands.
Email: d.paping@erasmusmc.nl

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Abstract

Objectives: To describe the prevalence of hearing loss among 13 year old adolescents, and to examine the change in prevalence between ages 9 and 13 years.

Methods: This study was embedded within Generation R, a population-based prospective cohort study from fetal life onwards in the Netherlands. Pure-tone thresholds were obtained at 0.5 to 8 kHz, and tympanometry was performed. Sensorineural hearing loss (SNHL) was defined as a low-frequency and/or high-frequency pure-tone average of more than 15 dB HL in one of both ears. Audiometric signs suggestive of noise-induced hearing loss (NIHL) included the presence of a notch and/or high-frequency hearing loss. The study was conducted from April 2012 to October 2015, and April 2016 to September 2019.

Results: A total of 4572 adolescents with a mean age of 13 years and 7 months (SD, 5 months) were included, of whom 2334 (51.0%) were girls. Within the cohort, 6.4% (95% CI, 5.7%-7.2%) were estimated to have SNHL, and 12.4% (95% CI, 11.5%-13.4%) met the criteria of NIHL. In total, 3675 participants were included in the longitudinal analysis. The prevalence of SNHL decreased from 8.0% to 5.3% between ages 9 and 13 years ($P < .001$). The prevalence of NIHL increased from 9.8% to 11.7% ($P = .004$), due to an increase in number of participants with a notch.

Conclusions: The prevalence of SNHL significantly decreased by 2.7% (95% CI, 1.6%-3.9%) between ages 9 and 13 years, probably due to a change in alertness during assessment at the age of 13 years. Other possible explanations include the presence of selection bias or a decline in prevalence of conductive hearing loss. The number of participants with audiometric signs suggestive of NIHL increased by 1.9% (95% CI, 0.5%-3.3%).

Level of Evidence: Level 3.

KEYWORDS
audiometry, children, hearing loss, noise, prevalence

1 | INTRODUCTION

Hearing is essential in today's high demanding communication-based society. Untreated hearing loss can have a profound impact on interpersonal communication, psychosocial well-being, employment opportunities, and quality of life.[1-4] The prevalence of hearing loss increases across the life span.[5] Damage to the cochlea may not be immediately manifest, but can become apparent later in life. As early life exposures contribute to hearing ability later on,[6,7] it is important to study hearing loss from a young age onwards. Especially, since an increase in recreational noise exposure has been reported in youths,[8,9] putting them at risk of irreversible hearing loss. By identifying hearing deficits in an early stage, progression can possibly be prevented and adverse effects minimized.

To date, there are relatively few longitudinal studies of hearing in childhood. The available studies with a cross-sectional design are informative, but cannot address the path of change over time. To better understand the trajectories of hearing loss, longitudinal studies are warranted.

In this article, we report on repeated measurements of hearing thresholds observed in a large population-based cohort of children in the Netherlands. Hearing acuity was examined at the age of 9 years, which represents the baseline, and at the age of 13 years. At baseline, 7.8% of the children were estimated to have low- or high-frequency sensorineural hearing loss (SNHL) of at least 16 dB HL in one or both ears.[10] The data of the repeated measurements have now become available, offering unique longitudinal data. The first aim of the present study was to describe the prevalence of SNHL at the age of 13 years. Second, we examined whether the prevalence of SNHL changed over time by using the data of both time points.

2 | METHODS

2.1 | Study design and subjects

This study was embedded in the Generation R study, a population-based prospective cohort study from fetal life onwards in Rotterdam, the Netherlands. The design and population have been described previously.[11] Briefly, pregnant women with an expected delivery date between April 2002 and January 2006 were enrolled in the study (n = 9778). The children born from these pregnancies are intended to be followed at least until young adulthood. Data collection in children and their parents includes questionnaires, interviews, and routine visits to the research center in the Erasmus Medical Center. Hearing assessment was performed at the age of approximately 9 years, and repeated around the age of 13 years. Only participants who completed pure-tone audiometry at all frequencies were eligible for inclusion. Incomplete measurements were due to a lack of time, technical issues, or personal circumstances. The first part of the study included all 13 year old participants meeting the eligibility criteria, and the second part only those participants with repeated measurements, that is, participants who completed pure-tone audiometry both at the age of 9 and 13 years. Data at the age of 9 years were collected from April 2012 to October 2015, and at the age of 13 years from April 2016 to September 2019. Approval for the study was obtained from the Medical Ethical Committee of the Erasmus Medical Center Rotterdam, The Netherlands. Written consent was obtained from both the participants and their parents. Participants received a small present for participation, but there was no financial compensation.

2.2 | Pure-tone audiometry

Pure-tone audiometry was performed in a sound-treated booth meeting the maximum permissible ambient sound pressure levels of ISO standard 8253-1. Hearing thresholds were assessed using a clinical audiometer (Decos audiology workstation; version 210.2.6 with AudioNigma interface) and TDH-39P headphones with MX-41/AR ear cushions, calibrated every 12 months. Participants with known hearing loss were asked to remove hearing aids. Pure-tone thresholds were obtained at the frequencies 0.5, 1, 2, 3, 4, 6, and 8 kilohertz (kHz). All thresholds were measured according to the shortened ascending method based on ISO standard 8253-1, which means that thresholds were defined by the intensity level at which the tone was heard in 2 out of 3 ascents. The right and left ear were alternately tested first. Due to time constraints no bone conduction thresholds were measured.

2.3 | Tympanometry

All participants had middle ear function assessed for both ears, unless there was a contraindication such as excessive wax, otorrhea, acute otitis media or recent ear surgery. Tympanometry was conducted using an Interacoustics AT235h tympanometer with a 226-Hz probe tone. During a pressure sweep, the ear canal volume, middle ear pressure and compliance were automatically calculated. Ears with an ear canal volume smaller than 0.3 mL were excluded to avoid ear canal collapse or occlusive cerumen influencing the results. Tympanograms were categorized according to the classification system of Jerger et al.[12] A compliance of at least 0.25 mL and middle ear pressure between −100 and 100 daPa was considered as normal, presented by a type A tympanogram. A type B or type C tympanogram was suggestive of external or middle ear pathology.

2.4 | Outcome measures

The outcome measure of main interest was the prevalence of SNHL. In addition, we were interested in the prevalence of SNHL suggestive of excessive noise, noise-induced hearing loss (NIHL).

2.4.1 | Definition of sensorineural hearing loss

Consistent with previous studies, the low-frequency pure-tone average (LPTA) was obtained by averaging pure-tone thresholds at 0.5, 1,

and 2 kHz, and the high-frequency pure-tone average (HPTA) by averaging thresholds at 3, 4, and 6 kHz.[10,13,14] Normal hearing was defined as both a LPTA and HPTA of 15 dB HL or less in both ears, regardless of tympanometry results. Any hearing loss in combination with a type A tympanogram was considered as SNHL, since it is unlikely, although possible, that conductive hearing impairment would be present in ears with a normal tympanogram. Hearing loss in combination with a type B or type C tympanogram was categorized as probable conductive hearing loss (CHL), although mixed or underlying SNHL could not be excluded. When tympanometry was missing, hearing loss was of unknown origin. All participants with CHL of hearing loss or unknown origin were excluded from the analyses.

2.4.2 | Definition of noise- induced hearing loss

Audiometric signs suggestive of NIHL include the presence of a notch and/or high-frequency hearing loss (HFHL). A notch was defined according to the criteria described by Niskar et al, which include (1) thresholds at 0.5 and 1 kHz of 15 dB or less HL; (2) the poorest threshold at 3, 4, or 6 kHz must be at least 15 dB poorer than the poorest threshold at 0.5 and 1 kHz; and (3) the threshold at 8 kHz must be at least 10 dB better than the poorest threshold at 3, 4, or 6 kHz.[15] HFHL was defined as (1) a hearing threshold of 15 dB or less HL at 0.5 and 1 kHz, and (2) an average threshold of 3, 4, 6, and 8 kHz greater than 15 dB HL.[16] A notch or HFHL was only considered to be present in combination with a type A tympanogram.

Increased hearing levels were classified according to the American Speech-Language-Hearing Association guidelines, namely slight (16-25 dB HL), mild (26-40 dB HL), moderate (41-55 dB HL), moderately severe (56-70 dB HL), severe (71-90 dB HL), or profound hearing loss (≥91 dB HL).[17]

2.5 | Demographic characteristics and covariates

Demographic characteristics of the participants (age, sex, ethnicity, educational level), information on maternal education, and household income were collected via parental questionnaires at different time points, as part of the general study.

2.6 | Statistical analyses

Statistical analyses were performed using IBM SPSS statistics version 24. Between-group differences were analyzed using the independent samples *t*-test and Pearson Chi-square test. Hearing thresholds between age 9 and 13 years were compared with the paired samples *t*-test. Prevalence estimates with 95% confidence intervals (CI) were calculated for the presence of SNHL. We compared differences in proportions with the McNemar's test. A sensitivity analysis was performed to assess the prevalence of SNHL and NIHL among the excluded participants. A *P*-value of <.05 was considered statistically significant.

3 | RESULTS

3.1 | Part I

A total of 4929 adolescents visited the research center between April 2016 and September 2019 (61.9% of those invited), of whom 4774 (96.9%) completed pure-tone audiometry at all frequencies. Tympanometry was performed in 4696 (98.4%) adolescents. Of the 4774 adolescents that completed pure-tone audiometry, 2.9% had CHL based on tympanometry, and 1.4% hearing loss of unknown origin as there was no tympanogram available. These participants were excluded from further analyses. The mean age of the 4572 participants included was 13 years and 7 months (SD, 5 months), and 2334 (51.0%) were girls. The participants included in the analyses more often attended a higher level of education than the participants who were excluded.

Of the 4572 participants included in the analyses, 293 (6.4%) participants had audiometric signs suggestive of SNHL, and 567 (12.4%) met the criteria of a NIHL. The demographic characteristics of the participants are presented in Table S1. There was no significant difference in demographic characteristics between the participants with normal hearing and those with SNHL and NIHL (Tables S2 and S3).

3.2 | Sensorineural hearing loss

The mean (SDs) LPTA of the total cohort was 5.4 (4.3) dB HL for right ears and 5.3 (4.7) dB HL for left ears, and the mean HPTA 6.4 (4.9) dB HL for right ears and 6.9 (5.2) dB HL for left ears. The mean hearing thresholds of participants with normal hearing, SNHL and NIHL are demonstrated in Figure 1. In total, 6.4% (95% CI, 5.7%-7.2%) had audiometric signs suggestive of SNHL. SNHL was unilateral in most cases; 50.9% in the left ear and 32.8% in the right ear. Low-frequency SNHL loss was present in 2.5% (95% CI, 2.1%-3.0%) of the participants, and 5.4% (95% CI, 4.8%-6.1%) had high-frequency SNHL. Of the 245 participants with unilateral hearing loss, the degree of SNHL was slight (16-25 dB HL) in 91.8%, mild (26-40 dB HL) in 4.9%, moderate (41-55 dB HL) in 1.2%, and moderate severe or severe (>56 dB HL) in 2.0%. Of the 48 participants with bilateral hearing loss, 83.3% had SNHL of slight degree in both ears, 2.1% of slight and mild degree, 6.3% of mild degree in both ears, and 8.3% had hearing loss of moderate to severe degree in at least one of both ears.

3.3 | Noise-induced hearing loss

Of the 4572 participants included in the analyses, 6.5% (95% CI, 5.8%-7.3%) met the criteria of a notch, 4.4% (95% CI, 3.8%-5.0%) of HFHL, and 1.5% (95% CI, 1.2%-1.9%) of both a notch and HFHL. Among the adolescents with a notch (n = 367), the notch was unilateral in 92.4% of the participants (35.7% in the right ear and 56.7% in the left ear). The hearing threshold for 17.4% of the notches was within the range of normal hearing (≤15 dB HL), 59.9% were slight

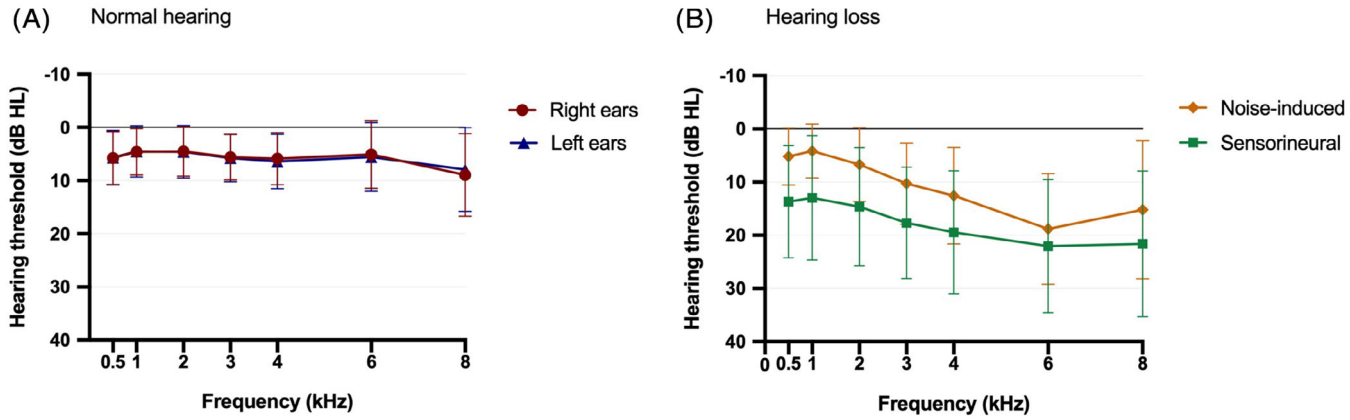

FIGURE 1 A, Mean hearing thresholds of participants with bilateral normal hearing at the age of 13 years. B, Mean hearing thresholds of participants with sensorineural hearing loss and noise-induced hearing loss. In case of bilateral hearing loss, the hearing thresholds of the ear with the poorest thresholds are presented. The error bars represent ±1 SD

TABLE 1 The low-frequency pure-tone averages (LPTAs) and high-frequency pure-tone averages (HPTAs) of right ears and left ears at baseline (9 years) and during follow-up (13 years). Results are presented for the total cohort, ears with normal hearing, and ears with sensorineural hearing loss

	Baseline		Follow-up	
	Right	Left	Right	Left
Total cohort				
LPTA[a] (dB HL), mean (SD)	7.2 (4.3)	7.0 (4.6)	5.1 (4.1)	5.0 (4.3)
HPTA[b] (dB HL), mean (SD)	7.3 (4.8)	7.6 (4.9)	6.2 (4.8)	6.6 (4.9)
Normal hearing				
LPTA (dB HL), mean (SD)	6.9 (3.7)	6.6 (4.0)	4.9 (3.6)	4.8 (3.8)
HPTA (dB HL), mean (SD)	6.8 (3.8)	7.0 (4.0)	5.8 (3.8)	6.2 (4.0)
Sensorineural hearing loss				
LPTA[a] (dB HL), mean (SD)	20.4 (5.7)	20.0 (5.6)	21.9 (8.8)	21.0 (7.1)
HPTA (dB HL), mean (SD)	21.1 (6.9)	20.7 (7.4)	22.2 (8.2)	21.3 (8.4)

[a]Low-frequency pure-tone average (0.5, 1, and 2 kHz).
[b]High-frequency pure-tone average (3, 4, and 6 kHz).

(16 to 25 dB HL), 20.2% were mild (26 to 40 dB H) and 2.5% of the notches were moderate to profound (≥41 dB HL). The notches involved most often a single frequency (94.0%). In 5.4% of the participants two frequencies were involved, and in 0.5% three frequencies were involved. HFHL, which was present in 269 participants, was most often unilateral. In total, 42.0% of the participants had HFHL in the right ear, 45.0% HFHL in the left ear. Most participants had HFHL of slight degree (90.7%), 8.2% of mild degree, and 1.1% of moderate to profound degree.

3.4 | Part II

A total of 4139 participants completed pure-tone audiometry both at the age of 9 and 13 years, of whom 464 were excluded due to the presence of conductive or unclassified hearing loss at one or both visits. This resulted in the inclusion of 3675 participants with repeated measurements. A total of 51.3% were girls. The mean (SD) time interval between baseline and follow-up was 3 years and 10 months (5 months).

TABLE 2 Distribution of degree of sensorineural hearing loss at baseline (9 years) and during follow-up (13 years). Increased hearing levels were classified according to the American Speech-Language-Hearing Association guidelines. In case of bilateral hearing loss, the degree of the ear with poorest thresholds is presented

	SNHL[a] at baseline (n = 295)	SNHL during follow-up (n = 193)
Slight (16-25 dB HL), n (%)	261 (88.5)	164 (85.0)
Mild (26-40 dB HL), n (%)	26 (8.8)	22 (11.4)
Moderate (41-55 dB HL), n (%)	4 (1.4)	3 (1.6)
Moderately severe (56-70 dB HL), n (%)	4 (1.4)	4 (2.1)
Severe (71-90 dB HL), n (%)	0	0
Profound hearing loss (≥91 dB HL), n (%)	0	0

[a]Sensorineural hearing loss.

The cohort's mean LPTAs and HPTAs of the right and left ears showed significant improvement during follow-up, as shown in Table 1. Meanwhile, the mean LPTAs and HTAs of the ears with

SNHL demonstrated deterioration. The prevalence of SNHL was 8.0% (95% CI, 7.2%-9.0%) at baseline, and 5.3% (95% CI, 4.6%-6.0%) during follow-up ($P < .001$) (decrease of 2.7%; 95% CI, 1.6%-3.9%). In Table 2 the distribution of the degree of SNHL at baseline and during follow-up is demonstrated. Within the group of participants with SNHL, the proportion of participants with SNHL of mild degree or worse (≥26 dB HL) increased from 11.5% to 15.0%, and the proportion of participants with bilateral SNHL increased from 16.9% to 20.2% during follow-up. Among the participants who had SNHL at baseline but normal hearing during follow-up, SNHL at baseline was of slight degree in 93.5%, and unilateral in 88.3% of the participants.

The prevalence of probable NIHL increased from 9.8% (95% CI, 8.8%-10.8%) to 11.7% (95% CI, 10.7%-12.8%) ($P = .004$) (increase of 1.9%; 95% CI, 0.5%-3.3%), due to the increase in number of participants with a notch. The prevalence estimates with 95% confidence intervals at baseline and during follow-up are presented in Figure 2. Table 3 shows the distribution of the degree of NIHL at baseline and during follow-up. Within the group of participants with a notch, 29.3% had a notch of mild degree or worse (≥26 dB HL) at baseline, in comparison to 20.6% during follow up. The proportion of participants with a bilateral notch increased from 5.1% to 7.7% during follow-up. Within the group of participants with HFHL, 8.7% had HFHL of mild degree or worse (≥26 dB HL) at baseline, in comparison to 10.3% during follow-up. Bilateral HFHL was present in 15.9% of the participants with HFHL at baseline, and in 8.7% during follow-up. Among participants who had HFHL at baseline but normal hearing during follow up, HFHL at baseline was of slight degree in 90.4%, and unilateral in 83.1%.

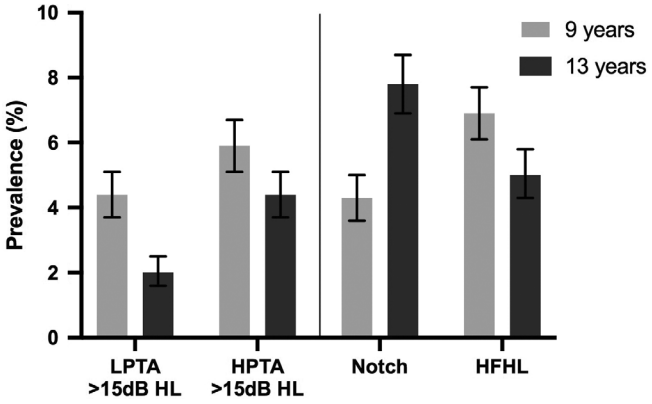

FIGURE 2 Prevalence of sensorineural hearing loss, and specifically noise- induced hearing loss, at baseline (9 years) and during follow-up (13 years) (n = 3675). The error bars represent the 95% confidence interval

A sensitivity analysis was performed to examine the prevalence of SNHL and NIHL among the participants that were excluded. In the group of participants who completed pure-tone audiometry at the age of 9 years but who were excluded (n = 1680), due to missing pure-tone audiometry, conductive hearing loss or hearing loss of unknown origin at the age of 13 years, the prevalence of SNHL was 7.3%, and 8.8% met the criteria of NIHL. Of the excluded participants at the age of 13 years (n = 1099), due to missing pure-tone audiometry, conductive hearing loss or hearing loss of unknown origin at the age of 9 years, 9.1% were estimated to have SNHL, and 13.6% met the criteria of NIHL.

4 | DISCUSSION

This article presents a 4-year follow-up study of hearing acuity in a large population-based cohort of children in the Netherlands. The baseline situation at the age of 9 years has previously been described by le Clercq et al.[10,16] The objective was to estimate the prevalence of SNHL at the age of 13 years, and to examine the change in prevalence between ages 9 and 13 years.

Understanding the epidemiology of childhood hearing loss is important for the purpose of prevention and design of interventions to avert progression of hearing loss. At the age of 13 years, 6.4% of

TABLE 3 Distribution of the degree of a notch and high-frequency hearing loss at baseline (9 years) and during follow-up (13 years). In case of bilateral hearing loss, the degree of the ear with poorest thresholds is presented

	Notch at baseline (n = 157)	Notch during follow-up (n = 286)		High-frequency hearing loss at baseline (n = 253)	High-frequency hearing loss during follow-up (n = 184)
A notch within the range of normal hearing, n (%)	16 (10.2)	55 (19.2)	Slight (16–25 dB HL), n (%)	231 (91.3)	165 (89.7)
Slight (16–25 dB HL), n (%)	95 (60.5)	172 (60.1)	Mild (26–40 dB HL), n (%)	18 (7.1)	17 (9.2)
Mild (26–40 dB HL), n (%)	38 (24.2)	52 (18.2)	Moderate (41–55 dB HL), n (%)	2 (0.8)	1 (0.5)
Moderate to profound (41–55 dB HL), n (%)	6 (3.8)	6 (2.1)	Moderately severe (56-70 dB HL), n (%)	2 (0.8)	1 (0.5)
Moderately severe (56-70 dB HL), n (%)	2 (1.3)	1 (0.3)	Severe (71–90 dB HL), n (%)	0	0
Severe (71–90 dB HL), n (%)	0	0	Profound hearing loss (≥91 dB HL), n (%)	0	0
Profound hearing loss (≥91 dB HL), n (%)	0	0			

the participants were estimated to have SNHL in at least one ear, and 12.4% fulfilled the criteria of NIHL. Lower estimates were reported in the National Health and Nutrition Examination Survey (NHANES), a population-based study conducted in the United States.[8,13,14,18] In the NHANES study that resembles our study most, excluding participants who failed tympanometry, 6.5% of the US adolescents aged 12 to 19 years were estimated to have low- frequency, and 12.9% high-frequency hearing loss of at least 15 dB HL in one or both ears.[8] In addition, 16.8% had a notch suggestive of NIHL, compared to the 8.0% found in our study. With more than the half of the participants being older than 15 years, it is not surprising that higher prevalence estimates were found in the study of Henderson et al. (2011).[8] It may confirm the held view that hearing acuity declines with age.[5,13] In the present study, most cases of hearing loss were unilateral, more commonly on the left side. As the majority hearing losses were of slight degree, the differences between right and left hearing thresholds were small. The finding of inferiority of the left ear was consistent with previous literature.[13,19,20] It may be attributed to the more prominent efferent auditory system on the right side, which decreases the susceptibility of the right ear to cochlear damage.[20]

To better understand the trajectories of hearing loss, it is crucial to assess hearing acuity within the same cohort of children over time. In the present study we found that the prevalence of SNHL in one or both ears significantly decreased by 2.7% (95% CI, 1.6%-3.9%) between ages 9 and 13 years. Yet, within the group of participants with SNHL, the proportion of participants with bilateral SNHL and SNHL of mild degree or worse increased. The lower prevalence rate found during follow-up was against expectations, as we assumed the number of participants with SNHL to increase with age. Considering a test-retest reliability of ±5 dB, it is not surprising that some of the participants with SNHL at baseline had normal hearing during follow-up, as 93.5% of the participants had SNHL of slight degree (15 to 25 dB HL) at baseline. In addition, we believe the moment of testing to play an important role. Hearing was just one of the multiple health domains assessed within the Generation R study.[21] Fatigue, motivation, attention, and familiarization have been attributed to affect within-subject variability in audiometric thresholds.[22] Whereas at baseline hearing assessment took place in the last 30 minutes of the 3 hour appointment, it was the first measurement during the follow-up visit. Some other measurements included spirometry, a bicycle stress test, cognitive tests and ultrasonography. The change in sequence of measurements may have resulted in better hearing thresholds during follow-up. In literature, we found only one longitudinal study investigating the prevalence of hearing loss among 2325 school children at the age of 7, 10, and 13 years.[23] Interestingly, the number of children with hearing loss declined between ages 10 and 13 years, consistent with our findings. The authors also believed that it was due to a change in alertness and ability to cooperate during hearing assessment rather than true change in hearing acuity. Another possible explanation for the decrease in prevalence of SNHL is that selection bias might have been present. In a sensitivity analysis we observed that the prevalence of SNHL during follow-up was evidently higher among the excluded adolescents (9.1% vs 5.3%). Last, it could be that the number of participants with CHL decreased, rather than a true change in prevalence of SNHL. Owing to time constraints within the environment, masking was not applied, and bone conduction thresholds were not measured. Middle ear function was judged by tympanometry to distinguish between CHL and SNHL. Although tympanometry is a fairly sensitive and reliable technique in the diagnosis of middle ear dysfunction,[24] it is possible that CHL was not detected by tympanometry and as a consequence of hearing loss was incorrectly classified as SNHL. We expect this error to be more prevalent at baseline, since the prevalence of CHL decreases with age. In contrast to the declining prevalence of SNHL between ages 9 and 13 years, the prevalence of NIHL significantly increased by 1.9% (95% CI, 0.5%-3.3%) due to an increase in the number of participants with a notch. In recent years, there has been a rise in the number of people listening to loud sounds in recreational settings, which puts them at risk of irreversible hearing loss.[8] The majority of participants in this study had a notch within the range of normal hearing or notch of slight degree, involving only a single frequency. Future assessments will provide information on the permanence and course of detected notches. We suspect that continuous exposure to hazardous sounds will lead to progression of the notch, that is, to an increase in the severity and number of frequencies affected. Therefore, we believe it is important to raise awareness and educate adolescents about the harmful effects of excessive noise on hearing. Especially, since the consequences of even mild levels of hearing loss can be far reaching with an adverse effects on language development, academic performance, and social functioning.[25-29]

4.1 | Strengths and limitations of the study

The strengths of this study are the prospective design and large sample size. Hearing acuity was assessed by dedicated research assistants with a small variance, resulting in a relatively homogenous setting. A limitation of the study is that no otoscopic examination and bone-conduction audiometry were performed due to time constraints, as mentioned previously. Since our main interest was permanent hearing loss, we decided to include only participants with a type A tympanogram in case of hearing loss. We considered this to be the best available alternative to exclude middle ear abnormalities associated with hearing thresholds. We did not correct for congenital hearing loss. The cohort selection toward a relatively Dutch and highly educated population over time may affect the generalizability of our findings.[21]

5 | CONCLUSIONS

In this population- based prospective cohort study, 6.4% of the 13 year old adolescents were estimated to have SNHL in one or both ears. A total of 12.4% participants showed a notch and/or high-frequency hearing loss suggestive of NIHL. The findings of the

longitudinal analysis demonstrated a significant decrease in the prevalence of SNHL, and increase in the prevalence of NIHL. Future research is needed to identify potential modifiable risk factors associated with a deterioration of hearing.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

ORCID

Danique E. Paping https://orcid.org/0000-0003-1376-3632

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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