Application of the Online Hearing Screening Test “Earcheck”: Speech Intelligibility in Noise in Teenagers and Young Adults

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Abstract

Objective: The objective was to describe the speech intelligibility in noise test results among Dutch teenagers and young adults aged 12–24 years, using a national online speech reception threshold (SRT) test, the Earcheck. A secondary objective was to assess the effect of age and gender on speech intelligibility in noise. Design: Cross-sectional SRT data were collected over a 5-year period (2010–2014), from participants of Earcheck. Regression analyses were performed, with SRT as the dependent variable, and age and gender as explaining variables. To cross-validate the model, data from 12- to 24-year olds from the same test distributed by a hearing aid dispenser (Hoorscan) were used. Results: In total, 96,803 valid test results were analyzed. The mean SRT score was −18.3 dB signal-to-noise ratio (SNR) (standard deviation (SD) = 3.7). Twenty-five percent of the scores was rated as insufficient or poor. SRT performance significantly improved with increasing age for teenagers aged 12–18 years by 0.49 dB SNR per age-year. A smaller age-effect (0.09 dB SNR per age-year) was found for young adults aged 19–24 years. Small differences between male and female users were found. Conclusion: Earcheck generated large quantities of national SRT data. The data implied that a substantial number of users of Earcheck may have some difficulty in understanding speech in noise. Furthermore, the results of this study showed an effect of gender and age on SRT performance, suggesting an ongoing maturation of speech-in-noise performance into late adolescence. This suggests the use of age-dependent reference values, but for this purpose, more research is required.

Keywords: Noise-induced hearing loss, online hearing screening test, recreational noise, speech-in-noise test, speech reception threshold (srt) performance, teenagers and young adults

Background

Prolonged exposure to high levels of noise is known to result in noise-induced hearing loss (NIHL). This results not only in decreased detection of sounds, as reflected by poorer pure-tone thresholds, but also in deterioration in supra-threshold processing affecting speech processing abilities and speech discrimination. Tinnitus is also often reported as an additional consequence of noise-induced hearing damage. Dose–response relationships are predominantly based on the effects of occupational noise exposure. However, in recent years, recreational noise exposure has received increasing attention. Technological advances, such as the proliferation of personal music players (PMPs), are believed to have dramatically increased recreational noise exposure. This had led to an increase in the risk of NIHL, especially among young people, who are not only exposed to noise during the use of PMPs, but also when visiting clubs, music festivals, or concerts.

Literature regarding the relationship between recreational noise exposure and hearing loss has revealed inconsistent results. Some studies reported an increase in the prevalence of NIHL as a result of exposure to recreational noise,[5-7] whereas others failed to prove a dose–response relationship.[1-8,10] A recent systematic review of the literature on this subject by Carter et al.,[11] based on 265 articles, concluded that there is insufficient evidence to determine the extent of the risk of recreational noise. Nevertheless, the review also concluded that a significant proportion of young people are exposed to noise levels that are high enough to cause hearing damage. In most of the studies summarized by Carter et al.,[11] NIHL was measured by pure-tone audiometry.

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screening, and differences in testing conditions and definitions of NIHL used resulted in inconsistent results. The authors suggest using other methods of detecting or quantifying NIHL, for example, supra-threshold tests like speech-in-noise assessments.

Difficulty in understanding speech in noisy situations is often one of the first signs of NIHL. This specific hearing disability can be tested more accurately by means of a speech-in-noise test than by traditional pure-tone audiometry. As such, speech-in-noise tests have more relevance than pure tone audiometry, and a poor result on such a test is more convincing to the listener. Speech-in-noise tests have been shown to be suitable for use as self-administered Internet-based hearing screening tests.\(^\text{[12-15]}\) They are less burdening compared to pure-tone audiometry tests. Moreover, the online application of these tests provides the opportunity to reach a large population of individuals at risk for NIHL and to collect large quantities of national data. Results of online speech-in-noise tests performed at home or at a remote setting have been previously studied, however not specifically in teenagers and young adults. To enhance targeted hearing education and prevention, it is essential to have a good understanding of potential threat of NIHL in this age group.

Earcheck (Dutch: Oorcheck, www.oorcheck.nl), a Dutch online speech-in-noise test, was developed to detect NIHL. The test was developed, validated, and improved by audiological scientists of the Leiden University Medical Center (LUMC) and the Academic Medical Center Amsterdam (AMC), and a new version was launched nationwide in 2010.\(^\text{[16,17]}\) The test targets teenagers and young adults aged 12–24 years, to raise their awareness of NIHL and to screen for NIHL in an easily accessible and relevant way. The test discriminates quickly between normal hearing individuals and individuals with hearing difficulties by means of a pass/fail outcome.

This study aims to describe the intelligibility of speech in noise among teenagers and young Dutch adults aged 12–24 years using Earcheck responses, collected nationally. As about 20,000 youngsters perform the online Earcheck each year, test results will give an insight into the intelligibility of speech in noise among teenagers and young adults. It will also reveal what proportion of users have poor scores, whom potentially have an incipient hearing loss. A secondary objective is to study the relationship between performance in speech-in-noise testing and the gender and age of the respondents.

**Materials and Methods**

**Test characteristics**

Earcheck is a Dutch speech-in-noise test which consists of nine different monosyllabic words, randomly presented in a low-pass filtered masking noise. Subjects respond via a screen showing nine response buttons and a tenth button saying “not recognized.” This last button was added to prevent respondents from guessing. Words are presented to the subject who is asked to identify the word by clicking on the corresponding button on the computer screen. The level of the noise is fixed and the level of presented words varied using an up–down procedure with a 2 dB step size. This test procedure is based on the method developed by Plomp and Mimpen,\(^\text{[18]}\) with the exception of the fact that the first stimulus of Earcheck is presented only once at a fixed signal-to-noise ratio (SNR) of −10 dB. The SNRs in the test range from −6 dB SNR to −30 dB SNR.

A list of 27 stimulus words is used to estimate SNR at which 50% of the speech material was identified correctly. This is defined as the speech reception threshold (SRT), and is calculated by taking the arithmetic average of the SNRs of the last 20 presentations. The result is shown immediately after completing the test, and is classified into categories “good,” “insufficient,” or “poor.” When a user fails the online test (an insufficient or poor test result), diagnostic audiological evaluation by a general practitioner, hearing aid dispenser, or at an audiological center is recommended. This recommendation may also encourage users to protect their hearing by making behavioral changes or by actively seeking medical help. The Earcheck is also applied in the adult population under the name Hoorscan (www.hoorscan.nl). The Hoorscan is aimed at adults considering using hearing aids and is provided online by the hearing aid dispenser.

**Test validation**

Previous research in our department indicated that a test with a stationary low-pass filtered masking noise, instead of a broadband noise, discriminated better between normal hearing and hearing-impaired subjects with different degrees of NIHL (n = 98). This resulted in a high sensitivity of 95% and a high specificity of 98%, with SRT thresholds of −18.4 dB SNR (cut-off value for the categories good and insufficient) and −12.7 dB SNR (cut-off value for the categories insufficient and poor), and without a reduction in test reliability.\(^\text{[17]}\) The SRT performance was compared to clinical pure-tone audiometry, which was considered the gold standard. This validation took place in an adult population (age range: 18–72 years), and in a laboratory setting, but currently gives the best approximation of the validity of the test. Exact values for test sensitivity and specificity for the teenagers and young adult population in a home-based test situation are yet to be determined.

Home-based application of Earcheck and Hoorscan may result in different test results due to poorer testing conditions resulting from uncontrollable parameters such as ambient background noise and the quality of the sound cards or transducers used. A previous study investigating the influence of test environment on the applicability of Earcheck showed that SRTs measured at home were poorer than those obtained in the laboratory.\(^\text{[19]}\) As a consequence, cut-off values for NIHL should be 1.2 dB.
SNR higher in a home-based setting than the cut-off values that were determined in a well-controlled lab setting.\cite{15} To account for the observed differences in SRT when completing the test at home, we applied a correction factor of 1.2 dB SNR.

**Test procedure**

Earcheck is performed at an individually set presentation level. Prior to starting the test, a word is presented repeatedly without noise. Respondents use their personal computer (PC) volume control or a slider on screen to adjust the volume to a level at which the presented word is clearly intelligible. This user-selected presentation level is used for the presentation of all subsequent test stimuli. All testing is done binaurally (in diotic presentation, i.e., the same signals are presented to both ears) and either headphones or loudspeakers can be used for testing. Headphones are recommended to obtain a more reliable test result and in this study only the headphone data are included. The test can be performed in less than 5 min, including introduction and instruction, presentation of test results, and recommendations.

**Data measures**

Cross-sectional data were derived from all participants of Earcheck over a 5-year period (January 2010 until December 2014). The participants represented an Internet convenience sample, that is, the study sample was not actively recruited for the purpose of this study. The test is embedded in the website of the National Hearing Foundation (www.hoorstichting.nl), alongside with other educational materials, which are all available free online. Users reached the test website in several ways, and all voluntarily performed the online hearing screening test, for example, at home or at school as part of an education program.

Earcheck collected self-reported information on age (in years), gender (male/female), self-rated hearing status (good, less, or poor), and type of transducer used (headphones or speakers). It also collected test results, including SNRs per stimuli, mean SRT scores (in dB SNR), test result category (good, insufficient, or poor), and intra-individual standard deviations (SDs) (in dB).

Only test results of teenagers and young adults with reliable intra-individual SDs and tests performed by headphones were analyzed. Subjects younger than 12 years old or older than 24 years were excluded. In addition, participants with invalid intra-individual SDs of 0 dB or ≥3 dB were excluded. The intra-individual SD describes the variation within a single test measurement, and therefore is a measure for the accuracy of a test performed by an individual.

**Data analysis**

Cross-sectional statistical analyses were performed using International Business Machines Corp. (IBM) Statistical Package for the Social Sciences (SPSS) version 22 (SPSS Inc., Chicago, IL, USA). Descriptive statistics were performed for the variables age, gender, self-rated hearing, and test results. In addition, relationships between the factors were assessed. At first, bivariate relationships between SRT score and gender, and SRT score and age were explored by means of simple linear regression analyses. Then, multivariable regression analyses were performed, with SRT score (in dB SNR) as primary outcome variable, significant explanatory factors, and relevant interactions. The results are presented as beta values, 95% confidence intervals (95% CIs), $P$-values, and explained variance ($R^2$-squared). The multivariable regression model was cross-validated in a data sample of users of Hoorscan between the age of 12 and 24 years, collected over the same period. The same exclusion criteria as for Earcheck data were applied. The same regression model was applied to the Hoorscan data sample, and the beta values were compared.

**RESULTS**

In total, 242,383 completed Earcheck tests were registered for the period January 2010 until December 2014. After excluding data according to the before-mentioned exclusion criteria, 96,803 valid test results remained for analysis. 69,647 results were excluded, as subjects were younger than 12 years or older than 24 years. 26,208 test results were excluded due to invalid intra-individual SDs of 0 dB or ≥3 dB. Finally, 49,725 results were excluded, as these tests were not performed using headphones.

Because there was no great variation in SRT scores between the years, data of all years were pooled for further analyses. Table 1 displays the SRT scores per year (in percentiles). To assess whether there were differences in mean SRT score between the years, a one-way Analysis of Variance (ANOVA) was performed, with SRT score as the dependent variable and year as factor. There was a significant effect for year ($F = 6.715$, $P < 0.001$). When performing a post-hoc test, only the year 2010 differed in mean SRT score from other years. However, this difference was rather small, and not relevant (mean difference of 0.15 dB).

Overall, the proportion of male users was slightly smaller than the proportion female users (48 and 52%, respectively). The mean age of the users was 15.7 years (SD = 2.8). The majority of all users (76%) rated their own hearing as good, 23% as insufficient, and only 1% as poor. The mean SRT score of all users was –18.3 dB SNR (SD = 3.7). The largest proportion of users (74.5%) had a good result, while 18.5% had an insufficient result and 7.0% a poor result.

**Table 1: SRT scores (in dB SNR) in percentiles, per year**

| Year   | 25th percentile | 50th percentile | 75th percentile |
|--------|-----------------|-----------------|-----------------|
| 2010   | –20.8           | –19.4           | –17.4           |
| 2011   | –20.8           | –19.4           | –17.0           |
| 2012   | –20.7           | –19.4           | –17.2           |
| 2013   | –20.7           | –19.3           | –17.2           |
| 2014   | –20.7           | –19.3           | –17.2           |
Results from the simple linear regression analyses for the bivariate relationships are shown in Table 2. The factors age and gender significantly explained variation in SRT outcome. Mean SRT scores decreased with increasing age. Overall, male users had slightly better scores compared to female users. Then, a multivariable regression analysis was performed, including the outcome factor SRT and explanatory factors age and gender. The model included an interaction term for age and gender, resulting in the following formula:

\[
\text{SRT} = \text{intercept} + \text{age} \times b_1 + \text{gender} \times b_2 + \text{age} \times \text{gender} \times b_3
\]

Results are presented in Table 3. The main factors age and gender were both significantly related to SRT score. SRT score decreased (improved) with 0.31 dB SNR per age-year. To illustrate, there was a 3.6 dB SNR difference in SRT performance between a 12-year-old and a young adult male user aged 24 years. Female users had a slightly better score as compared to male users. For the reference category of 12-year olds, this difference was 0.13 dB SNR. However, the interaction term between age and gender was significant, indicating a different relation between SRT score and age for male and female users. According to the model, SRT score improved by age for both male and female users. The mean SRT score for male users was more favorable than for female users from the age of 15 years and above.

A graphical presentation of the relationship between age and SRT score, for both male and female users, is given in Figure 1. SRT scores tend to decrease much more sharply for teenagers (12–18 years) compared to young adults (≥18 years), for both male and female users. This consistent decrease in SRT scores with age is displayed in more detail in Figure 2, by means of percentiles. A Mann–Whitney U test showed that the SRTs of teenagers were significantly worse than those of young adults (P < 0.001), with a difference in mean SRT score of 1.4 dB SNR.

For this reason, multiple regression analyses were repeated for teenagers and young adults separately.

Both models included the outcome factor SRT score, explanatory factors age and gender, and an interaction term for age and gender. Results are presented in Table 4. For the teenagers, the main factors age and gender were both significantly related to SRT score. SRT score decreased (improved) with almost half a dB SNR per age-year. Female users had a slightly lower score compared to male users (−0.32 dB SNR). However, the interaction

![Figure 1](image1)

**Figure 1:** Average SRT score as a function of age, for male (black line) and female (interrupted lines)

![Figure 2](image2)

**Figure 2:** SRT score by age, in percentiles

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| Table 2: Bivariate relationships with age and gender |  |
|-----------------------------------------------|---|
| **Outcome:** SRT score (dB SNR)               |  |
| **β-Value** | 95% CI | **P-value** |
| Age (years)\* | −0.28 | −0.29 to −0.27 | <0.001 |
| Gender** | 0.32 | 0.27 to 0.37 | <0.001 |

\*Reference category: 12-year-old, **Reference category: male.

| Table 3: Multivariable regression results |  |
|------------------------------------------|---|
| **Outcome:** SRT score (dB SNR)          |  |
| **β-Value** | 95% CI | **P-value** |
| Intercept\* | −17.21 | −17.26 to −17.15 | <0.001 |
| Age (years) | −0.51 | −0.52 to −0.50 | <0.001 |
| Gender    | −0.13 | −0.21 to −0.05 | 0.001 |
| Age * gender | 0.07 | 0.05 to 0.09 | <0.001 |

\*Reference category: 12-year-old male user, R² = 0.042.
term between age and gender was significant. SRT score improved with age for both male and female users, but the difference between SRT scores of male and female users became greater with age with a more favorable mean SRT score for male users. For the young adults, the age-effect was significant but quite small, with a change of −0.09 dB SNR per age-year. The mean SRT score of female users was about half a dB poorer than those of male users. There was no significant interaction between age and gender for the young adults.

The models for teenagers and young adults were cross-validated in a Hoorscan sample using the same inclusion criteria [Table 5]. These analyses showed models similar to those obtained with Earcheck data, except that the main effect of gender was not significant for the teenagers. For the teenagers in the Hoorscan sample, the main effect of age was significant, and the beta-value was somewhat smaller than for the teenagers in the Earcheck sample. There was a similar interaction effect between age and gender. For the young adults in the Hoorscan sample, there was no significant relationship between age and SRT score. The effect of gender was very similar to the effect of gender in the Earcheck sample. The interaction model was not significant in this sample either.

### Table 4: Multiple regression results for teenagers ($n = 76,070$) and young adults ($n = 20,733$)

| Outcome: SRT score (dB SNR) |  $\beta$-Value | 95% CI | $P$-value |
|----------------------------|----------------|--------|----------|
| Teenagers                  |                |        |          |
| Intercept $^*$              | −16.76         | −16.84 to −16.68 | <0.001   |
| Age (years)                | −0.49          | −0.52 to −0.47   | <0.001   |
| Gender                     | −0.32          | −0.43 to −0.22   | <0.001   |
| Age × gender               | 0.14           | 0.10 to 0.17     | <0.001   |
| Young adults               |                |        |          |
| Intercept $^*$              | −19.45         | −19.53 to −19.38 | <0.001   |
| Age (years)                | −0.09          | −0.12 to −0.07   | <0.001   |
| Gender                     | 0.58           | 0.47 to 0.70     | <0.001   |
| Age × gender               | 0.00           | −0.04 to 0.04    | 0.883    |

$^*$Reference category: 12-year-old male user, $^\ddagger$Reference category: 18-year-old male user; $R^2$ model teenagers $= 0.028$, $R^2$ model young adults $= 0.015$.

### Table 5: Multiple regression results for teenagers ($n = 10,555$) and young adults ($n = 6557$): Hoorscan data

| Outcome: SRT score (dB SNR) |  $\beta$-Value | 95% CI | $P$-value |
|----------------------------|----------------|--------|----------|
| Teenagers                  |                |        |          |
| Intercept $^*$              | −17.92         | −18.11 to −17.74 | <0.001   |
| Age (years)                | −0.30          | −0.36 to −0.24   | <0.001   |
| Gender                     | −0.01          | −0.27 to 0.25    | 0.963    |
| Age × gender               | 0.16           | 0.08 to 0.24     | <0.001   |
| Young adults               |                |        |          |
| Intercept $^\ddagger$       | −19.85         | −19.99 to −19.71 | <0.001   |
| Age (years)                | −0.04          | −0.08 to 0.00    | 0.060    |
| Gender                     | 0.59           | 0.36 to 0.81     | <0.001   |
| Age × gender               | 0.05           | −0.02 to 0.12    | 0.165    |

$^*$Reference category: 12-year-old male user, $^\ddagger$Reference category: 18-year-old male user; $R^2$ model teenagers $= 0.015$, $R^2$ model young adults $= 0.016$.

### DISCUSSION

The improved and validated online speech-in-noise screening test Earcheck generated large quantities of national data. In total, 242,383 completed tests were registered for the period January 2010 until December 2014. We analyzed 96,803 valid test results for teenagers and young adults (between 12 and 24 years) with reliable intra-individual SDs ($≤$3 dB) and usage of headphones. The proportion of users with a good result was 74.5%, while 18.5% had an insufficient result and 7.0% a poor result. This implies that a substantial number of users of Earcheck may have some difficulty in understanding speech in noise. The cause of these difficulties is not known, but NIHL is one of the potential causes. According to the final multiple regression models that were fitted for teenagers and young adults separately, SRT score tends to improve with age, especially among teenagers between the age of 12 and 18 years. Furthermore, the effect of age appears to be somewhat different for male and female users. Similar effects of age and gender for teenagers and young adults were found in an independent sample of online users of the same test (Hoorscan), which means that the fitted Earcheck model can be generalized to a different Internet convenience sample. An important note, however, is that both samples do not accurately represent the real population, so it is not possible to draw conclusions for all Dutch teenagers and young adults based on this research.

Results of online-speech-in-noise tests performed at home or at a remote setting have not been studied earlier in this specific age group. Studies mainly concern online SRT performance of (older) adults, and focus on whether ageing reduces speech intelligibility. Other studies mainly focus on age-specific normative data of school-aged children. According to these studies, there are age-related improvements in speech in noise recognition among young children (5–12 years); however, no unambiguous age-effect was found. Differences in findings may depend on the type of task, the speech and background noise material used in the task, the study sample (the size of the sample and the number and range of age groups), and the age of the adult reference group. The majority of the studies support the statement that auditory maturation is more or less completed by the time children reach adolescence, with a speech-in-noise performance equal to adults’ performance. Our study shows that the SRT performance improves even after the age of 12 years. It suggests that the maturation process of speech-in-noise performance in this type of speech-in-noise test is not complete until the age of 18 years.

In this sample, 25.5% of respondents failed the test, of which 18.5% of test results were categorized as insufficient and
7.0% as poor. This percentage is higher than previously reported results from population-based surveys. A national cross-sectional survey found prevalence rates of hearing loss in the young U.S. population ranging from 12.5 to 19.5%.\[6,7\] According to another survey, 16% of the young U.S. adults entering an industrial workforce showed high frequency hearing loss.\[30\] It is important to note that these studies used screening audiometry to assess hearing loss, and maintained a very strict criterion of NIHL, defined as hearing thresholds greater than 15 dB hearing level (HL) in either ear at 3, 4, or 6 kHz. Moreover, there were important issues in these audiomeric surveys that question the accuracy of the prevalence estimates, for example, the imprecision of screening audiometry and the unknown influence of other otological problems, such as conductive hearing losses.\[31\]

Although pure-tone audiometry is the reference standard for assessing hearing threshold levels, it is subject to variability due to calibration issues, test–retest reliability, and test environment. These factors, which are particularly present in screening settings, are critical when determining minimal deteriorations in the lowest signal level a person can hear.

An important strength of this study is that Earcheck, a functional supra-threshold test that measures speech intelligibility in noise, was used to assess hearing loss. Because of its test characteristics, the main limitations that are linked to pure-tone audiometry could be avoided. By measuring a SNR, the influence of testing conditions is minimized.\[32\] In addition, speech-in-noise tests are insensitive to conductive hearing losses. Therefore, Earcheck results might yield more accurate prevalence estimates than previously reported. Another strength is that the test is convenient and easily accessible. The self-administered online speech-in-noise test made it possible for teenagers to measure SRT performance in the comfort of their own home or school. The test could be performed free of charge, and the online applicability resulted in a large quantity of data, collected nationally and in an interesting age group of 12- to 24-year olds. Finally, the estimated models were cross-validated in a separate sample of similar data. This strengthened the reliability of the relationships among age, gender, and SRT observed in the Earcheck data.

Despite the above-mentioned strengths of Earcheck, the percentage of subjects failing the test is high. The most important explanation for this high percentage of respondents with non-normal performance is the use of a convenience sample of Dutch adolescents and young adults who performed the test voluntarily and on their own initiative. This sort of sampling is usually biased by selection. It most likely does not fit the definition of a random sample, where everyone in the population has an equal chance of being selected for participation. Since it does not truly represent the population, the study is limited when it comes to generalization. Although a large proportion of the study sample performed Earcheck in their school class as part of an educational program (about 40%), a higher response rate for subjects that have doubts about their hearing is expected in this study. This selection bias probably resulted in an overestimation of hearing losses in this population. However, we do not expect that the likely selection bias affected our findings concerning the influence of age and gender on SRTs results. Another explanation for the high percentage of poor results is that the tests were performed in uncontrolled home settings by anonymous users; hence, the results were based on self-testing. Although we tried to limit the influence of inaccurate self-testing by using a criterion for reliable intra-individual SD, and including only tests performed by headphones, unreliable self-tests cannot be completely ruled out. In addition, test characteristics of home-based application using a sample of young adults are unknown, but it is likely that the values for sensitivity and specificity are poorer than in laboratory testing.\[19\] Finally, fixed, age-independent, cut-off values for the result categories were used in this study. Although the influence of home-based testing was accounted for, the effects of age were not. An improvement in speech intelligibility with age was proven, the use of fixed cut-off values may have overestimated the prevalence of poorer test results.

To gain a better insight into speech discrimination abilities of teenagers using the online speech-in-noise test Earcheck, it is important to study normal age-specific SRT performance of this target group in a controlled study. Earcheck was comprehensively validated among adults in earlier studies; however, it is important to study the test in normal-hearing teenagers as well, to set appropriate reference values and to correctly interpret Internet screening outcomes. In addition, further work investigating the maturation effect of speech understanding among normal-hearing teenage students aged 12–18 years is needed.

**Conclusion**

The goal of this study was to investigate intelligibility of speech in noise among teenagers and young adults in the Netherlands, using Earcheck responses. Earcheck is a Dutch online speech-in-noise test, specifically designed to detect high-frequency hearing loss. The majority of the respondents scored “good”; however, an “insufficient” or “poor” test result was obtained by part of the respondents, indicating that hearing loss may be present in this population of teenagers and young adults. The percentage of respondents with a poor result was higher than previously reported results from population-based survey studies. It is important to note that these findings are only applicable to the convenience sample used in this study and cannot be generalized to the general population due to the significant likelihood of selection bias. This research also gave insight into the relationship among SRT score, gender, and age. The results of this study show a significant effect of gender and age on SRT performance. SRT scores tended to improve with age, especially among teenagers between the age of 12 and 18 years, and this effect was greater in male than in female respondents. The results of this study suggest that the maturation process of Earcheck performance is not
complete until adulthood and suggest the use of age-dependent reference values for Earcheck; however, more research is required.

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**Conflicts of interest**

There are no conflicts of interest.

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