

# Sensitivity and Specificity of Portable Hearing Screening in Middle-Aged and Older Adults

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## Abstract

**Introduction** Hearing screening allows the identification of individuals with hearing loss.

**Aim** To determine the sensitivity and specificity of a portable hearing screening device in middle-aged and older adults using the manufacturer scoring and a scoring system proposed by the researchers.

**Methods** In this transversal study, participants underwent anamnesis, otoscopy, and hearing screening using portable equipment. After this, a pure tone audiometry was performed, with participants classified into two groups: with and without hearing loss. The sensitivity and specificity of the hearing screening were calculated for the right and left ears using two methods of interpretation: the original method recommended by the manufacturer (criteria 1) and the method proposed by researchers (criteria 2).

**Results** The sample consisted of 55 individuals, 83.6% ( $n = 46$ ) of whom were women. Per criteria 1, the sensitivities were 26.3 (right ear) and 21.4% (left ear). The specificity was 100% for both ears. Using criteria 2, the sensitivity was 94.7 (right ear) and 100% (left ear). The specificity was 74.3 (right ear) and 65.9% (left ear).

**Conclusion** This study showed that the criteria proposed by the manufacturer presented low sensitivity in the hearing screening. The criteria proposed by the researchers to achieve a more efficient performance reached high and balanced values for sensitivity and specificity.

## Keywords

- ▶ hearing
- ▶ mass screening
- ▶ audiology
- ▶ older adult
- ▶ gerontology

## Introduction

Aging causes a series of changes in the body. As in other organs, the first changes in the functioning of the auditory system can be observed around 30 to 40 years, and these

changes intensify over time. Hearing loss due to aging is called *presbycusis*<sup>2–4</sup>; it has a high prevalence among the older adult population and can cause several social difficulties due to the communication disturbances it entails.<sup>5–8</sup>

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The consequences of hearing loss may vary according to the type, degree, and age of onset. Adults and older adult persons generally present with mild to moderate sensorineural hearing loss,<sup>2,4,6,9,10</sup> which can lead to isolation and restrict participation in social and family life, often as an effort to avoid becoming the subject of ridicule or contempt.<sup>11</sup> Hearing loss can also be associated with cognitive impairment, depression, and reduced functional status and quality of life.<sup>5,7,8,12–16</sup>

The diagnosis and early intervention, as well as the implementation of a hearing reeducation program specific to the population of adults and older adults, are key issues to improve quality of life for this population and, consequently, enable them to enjoy a better family life and social integration.<sup>3,4,8,17–19</sup> In presbycusis, however, as the hearing loss occurs gradually and progresses slowly,<sup>4,20,21</sup> and it often goes unnoticed or is denied by individuals during its early stage.<sup>3,11</sup> Therefore, hearing screening should be a standard procedure in hospitals, health centers, and clinics, with the aim of quickly, easily, and inexpensively testing a large number of individuals, thus enabling early diagnosis and treatment and decreasing the consequences of hearing deprivation.<sup>5,10,17,18,20,22</sup> This procedure, however, is still not commonly used by professionals working with adults and older adults.<sup>23</sup> In Brazil, the most commonly used method to detect hearing loss is the complete audiometric evaluation, which requires a soundproof booth, and thus it is not accessible as a screening tool.

Currently, screening can be performed by means of standardized questionnaires<sup>10</sup> or by undertaking simplified hearing tests, not intended to determine hearing thresholds but rather to identify the possibility of an individual presenting hearing loss.<sup>24</sup> Recently, a piece of portable equipment for hearing screening that can be used on individuals of different age groups has been launched in Brazil. It is designed for use in quiet environments and does not require an audiometric booth. The operation of the device is extremely simple and does not cause any discomfort to the patient. Subjects are instructed to pay attention and signal every sound they hear by raising their hand. A positive test indicates that the subject should undergo a complete audiological evaluation, according to the device's user manual.<sup>25</sup>

Given the nonexistence of similar devices in the Brazilian market and the lack of a theoretical framework on the subject, this study aims to verify the device's ability to discriminate between middle-aged and older adults with or without mild or moderate hearing loss, using two interpretation criteria: the one recommended by the manufacturer's manual (criteria 1) and the one proposed by the authors of this study (criteria 2).

## Materials and Methods

This cross-sectional, observational, comparative study had a sample consisting of both men and women participating in university outreach projects, aged 45 years or older. The study was initiated after participants had signed the informed consent form.

According to the norms established for human research, this study was reviewed and approved by the Research Ethics Committee of the Institute of Psychology of the Universidade Federal do Rio Grande do Sul (under registration number 22229). Subjects included individuals who, at the time of data collection, presented with wax obstructing their ear canal, either unilaterally or bilaterally, identified by visual inspection of the ear canal; outer ear pathologies; cholesteatoma; or chronic suppurative otitis media (identified by a medical report or through information provided by the subject).

After signing the informed consent form, the individuals answered a sociodemographic questionnaire consisting of questions related to hearing, tinnitus, and earache. After this, participants underwent a meatoscopy using a WelchAllyn (New York, USA) brand otoscope. The hearing screening and pure tone audiometry were then conducted.

The hearing screening was performed using the HearChek Screener equipment from Siemens (Munich, Germany) in a quiet environment, with noise levels under 50-dB SPL (sound pressure level) as per the guidelines in the device's user manual.<sup>25</sup> The environmental noise level was checked using the Manaus DL-4020 sound pressure meter (Manaus, Brazil). The subjects were instructed to signal every time they heard a sound. The machine produces a sequence of three sounds at the frequency of 1,000 Hz (55-, 35-, and 20-dB hearing level [dBHL]) and three other sounds in the frequency of 3,000 Hz (75, 55, and 35 dBHL). Results were recorded in a specific form, indicating the number of times and the intensities at which the individual perceived the sound. According to the equipment's user manual, individuals who perceived more than three sounds were considered to have "passed" the screening, whereas individuals who heard less than three sounds in each ear were considered to have "failed" (criteria 1).

Because two of proposed sounds (35 and 20 dBHL at 1,000 Hz) fall in the normal hearing threshold, the authors of this work decided to test also different criteria: the participant was considered to have failed the screening if they did not hear five of six sounds. Therefore, individuals who perceived at least five of the sounds presented in each ear were considered to have "passed" (criteria 2).

The pure tone audiometry was conducted in an acoustically treated booth. Tone thresholds were tested by air conduction from 250 to 8,000 Hz and by bone conduction from 500 to 4,000 Hz. An AD 229e audiometer (Denmark) was used, with TDH-39 (USA) headphones. The degree of hearing loss was classified by finding the mean of the thresholds obtained at the frequencies of 500, 1,000, 2,000, and 4,000 Hz. Mean values equal to or under 25 dBHL indicated normal hearing; mean values between 26 and 40 dBHL indicated mild hearing loss; mean values between 41 and 60 dBHL indicated moderate hearing loss; mean values between 61 and 80 dBHL indicated severe hearing loss; and mean values over 81 dBHL indicated profound hearing loss.<sup>26</sup> After the examinations had been performed, the sensibility (percent of true-positive tests) and specificity (percent of true-negative test) were calculated for both criteria.

We chose to include only subjects with normal hearing thresholds and mild to moderate hearing loss in the study,

because they represent more significantly the effects of aging on hearing. As described earlier, most of the individuals in the age group under study presented with these degrees of hearing loss.<sup>2,4,6,9,10</sup>

**Statistical Analysis**

The data analysis initially approached descriptive statistics, with the distribution of simple and relative frequencies, as well as mean, standard deviation, and range, and the symmetry was investigated using the Kolmogorov–Smirnov test.

For greater statistical robustness in the research, the nonparametric Kruskal–Wallis test was performed to check if the discriminatory accruals were significantly different, because this test does not require observing the assumptions of the previous tests.

To evaluate the accuracy of the screening tests for the diagnosis of hearing loss, calculations of sensitivity, specificity, positive predictive value, and negative predictive value were performed using the result of the pure tone audiometry as the gold standard, through the McNemar test.

Data were treated statistically using the Statistical Package for Social Sciences for Windows 17.0 software (USA) and, for decision criteria, a significance level ( $\alpha$ ) of 5% was adopted.

**Results**

The sample consisted of 55 subjects, with a mean age of  $65.3 \pm 8.4$  years, with ages ranging between 48 and 85 years. Of the total of study participants, 20.0% ( $n = 11$ ) were between 48 and 59 years, 52.7% ( $n = 29$ ) were between 60 and 69 years, and 27.3% ( $n = 15$ ) were between 70 and 85 years. The majority of the group under study were females, accounting for 83.6% ( $n = 46$ ) of the sample.

There was a predominance of normal hearing thresholds ( $p < 0.001$ ) in both the right ear (64.8%) and the left ear (74.5%; **Table 1**).

To analyze the use of the screening equipment regarding sensitivity and specificity in terms of detecting hearing loss, the result of the audiometry was defined as the gold standard.

**Table 1** Absolute and relative distribution of hearing classification for the right ear and left ear

Variables	Total	
	<i>n</i>	%
Right ear hearing classification <sup>a</sup>		
Normal (0–25 dBHL)	35	64.8
Mild (26–40 dBHL)	15	27.8
Moderate (41–60 dBHL)	4	7.4
Left ear hearing classification <sup>a</sup>		
Normal (0–25 dBHL)	41	74.5
Mild (26–40 dBHL)	7	12.7
Moderate (41–60 dBHL)	7	12.7

Abbreviation: dBHL, decibel hearing level.

<sup>a</sup>There was a loss by nonresponsiveness in the right ear evaluation.

Accordingly, the results of the equipment were tested against the audiometry classification. Data were analyzed for each ear separately, so as to more accurately identify the probability of pass or fail.

According to the results presented in **Table 2**, for the right ear, it was found that the screening had a very low sensitivity using criteria 1, reaching a value of only 26.3%. Of the 19 ears identified as having hearing loss, 14 passed the screening. Specificity, in turn, was 100% (i.e., all ears classified as having normal hearing passed the screening). When using criteria 2, there was an increase in sensitivity (94.7%; i.e., of the 19 ears with hearing loss, 18 failed the screening). Sensitivity, however, decreased from 100 to 74.3%. Of the 35 right ears with normal hearing, 26 passed the screening (**Table 2**).

**Table 3** presents the results of the hearing screening in the left ear. Using criteria 1, sensitivity values were extremely low, at only 21.4%. Thereby, of the 14 ears with hearing loss, only three failed the screening. Specificity was at 100% (i.e., all ears with normal hearing passed the screening). With the use of criteria 2, sensitivity was at 100% (i.e., all the ears diagnosed with hearing loss failed the screening). Specificity, however, decreased to 65.9%. Thus, of 41 ears with normal hearing, only 27 passed the hearing screening (**Table 3**).

**Discussion**

This study aimed to verify the sensitivity and specificity of hearing screening in middle-aged adults and older adults with or without mild to moderate hearing loss, when compared with a pure tone audiometry (gold standard). Studies have underscored the screening as an important hearing care activity, because it enables early diagnosis and intervention in adults and older adults.<sup>7,8,18,22,23,27–31</sup>

This study showed a sample made up mostly of females (83.6%). This factor may be related to the greater number of women in the studied age group,<sup>9,32–34</sup> as well as to a more effective presence of the female gender in group activities and to a more active lifestyle,<sup>33</sup> because the population under study attends university outreach activities.

A significant number of individuals had hearing classified as normal (64.8% for right ear and 74.5% for left ear). Mild (27.8% right ear and 12.7% left ear) to moderate (7.4% right ear and 12.7% left ear) cases of hearing loss were also observed in this work, because one of the characteristics of presbycusis is mild to moderate hearing loss.<sup>2,4,6,9,10</sup>

Mild hearing loss is not regarded as disabling, because it allows individuals to perceive most environmental sounds. Moderate hearing loss, on the other hand, can incapacitate an individual for adequate social life.<sup>26</sup> It should be noted, however, that even mild hearing loss hinders the perception of consonant sounds that are important to proper speech recognition and discrimination, thus causing communication disturbances that can lead to social isolation and alienation from the family. Therefore, even mild hearing loss should be identified, and individuals suffering from it should be referred for rehabilitation.

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**Table 2** Analysis of responses to hearing screening in right ear, considering the interpretation according to criteria 1 and 2

	Total	Right ear hearing classification		p
		Normal hearing	Hearing loss	
Criteria 1				
Passed	49 (90.7%)	35	14	<0.001 <sup>a</sup>
Failed	5 (9.3%)	0	5	
Total	54 (100%)	35 (64.8%)	19 (35.2%)	
Sensitivity/specificity (%)		26.3/100		
Criteria 2				
Passed	27 (50%)	26	1	0.021 <sup>a</sup>
Failed	27 (50%)	9	18	
Total	54 (100%)	35 (64.8%)	19 (35.2%)	
Sensitivity/specificity (%)		94.7/74.3		

<sup>a</sup>McNemar test.

The screening is an examination aiming to determine whether or not a person is likely to have the investigated disorder. The usefulness of a screening should be evaluated against an independent standard; in audiology, this standard is the pure tone audiometry.<sup>35</sup>

Hearing screenings in older adults, however, have been the subject of few studies. Previous studies have reported the use of various methods, such as self-assessment questionnaires,<sup>3,5,10,18,21,28</sup> tests using a tuning fork,<sup>5,22</sup> the whispered voice test,<sup>3,5,22</sup> the finger snapping test,<sup>3,35</sup> tests using a single generic question,<sup>3,27</sup> and tests using a portable audioscope (Welch Allyn Inc., Skaneateles Fall, New York, United States) device.<sup>3,5,22,28</sup> Among these methods, the most reliable for screening hearing impairment involve the use of the audioscope,<sup>5,22,29</sup> and the joint application of the Hearing Handicap Inventory for the Elderly instrument—reduced version—and the audioscope.<sup>22,29,30,36</sup>

The audioscope is similar to the equipment used in our study. It is an otoscope that emits pure tones at the frequencies of 500, 1,000, 2,000, and 4,000 Hz, at intensities of 20, 25, and 40 dBHL. Screening using this equipment does not require expertise in audiology and lasts approximately 3 minutes.<sup>36</sup>

The results obtained show that, by analyzing the responses of the hearing screening using criteria 1, there was high specificity but low sensitivity (i.e., the equipment did not allow for the identification of individuals with mild to moderate hearing loss).

Considering this method of analyzing the results, sensitivity and specificity values were lower than with the audioscope. In a previous study,<sup>37</sup> seniors had been screened in medical offices and at an audiological center. Sensitivity was identical in both locations (94%) and specificity was lower in medical offices (72%) when compared with the audiological center (90%).

**Table 3** Analysis of responses to hearing screening in left ear, considering the interpretation according to criteria 1 and 2

	Total	Left ear hearing classification <sup>a</sup>		p
		Normal hearing	Hearing loss	
Criteria 1				
Passed	52 (94.5%)	41	11	0.001 <sup>a</sup>
Failed	3 (5.5%)	0	3	
Total	55 (100%)	41 (72.5%)	14 (25.5%)	
Sensitivity/specificity (%)		21.4/100		
Criteria 2				
Passed	27 (49.1%)	27	0	0.001 <sup>a</sup>
Failed	28 (50.9%)	14	14	
Total	55 (100%)	41 (74.5%)	14 (25.5%)	
Sensitivity/specificity (%)		100/65.9		

<sup>a</sup>McNemar test.

When using the new evaluation method proposed by the researchers (criteria 2), however, there was a significant increase in sensitivity, but a decrease in specificity was observed. With this new way of interpretation, the sensitivity values reached 94.7% in the right ear and 100% in the left ear. The values proved similar to those obtained with the audioscope, thus extending the possibility of identifying individuals with mild and moderate hearing loss, which usually occurs in presbycusis. However, this interpretation decreased specificity values, which was 100% for both ears using the manufacturer's criterion. With the new criterion, the specificity obtained was 74.3% for the right ear and 65.9% for the left ear, which means that the possibility of false-positives increased.

In diseases of high prevalence in the population, such as hearing loss, screening tests must have a high sensitivity to be useful to clinicians, because, otherwise, negative results may be false-negatives.<sup>38</sup> False-negatives should be the main concern for the screening. When hearing loss goes undetected, individuals are not referred for assessment and diagnosis, which consequently prevents treatment from being initiated. Thus, the cutoff or criterion used must prioritize maximum sensitivity,<sup>24,38,39</sup> because prioritizing greater specificity is likely to increase the number of false-negatives.<sup>5,7,8</sup>

Based on this premise, it is believed that the interpretation of results using the criterion set by the investigators is more effective and efficient for detecting hearing loss in adults and older adults. It is suggested, therefore, that professionals begin using this new criterion, thus reducing the possibility of false-negatives and ensuring that individuals with mild to moderate hearing loss are identified during hearing screening using portable equipment. It is important to reinforce that testing was performed considering individuals with normal hearing and with mild to moderate hearing loss. In these individuals, the method developed by the researchers was more appropriate, proving to have enough sensitivity to identify minimal hearing loss.

Therefore, it became clear that, provided the properly established criteria for analysis of the responses, this portable equipment possesses excellent usefulness in daily clinical practice, allowing middle-aged adults and older adult persons with hearing loss to be identified, referred for evaluation, and, if necessary, oriented on the use of hearing aids.

This study showed that, in the hearing screening of middle-aged adults and older adults using portable equipment, the rules for interpreting results suggested by the manufacturer showed low sensitivity and high specificity in identifying mild to moderate hearing loss. However, the adoption of a new criterion developed by researchers increased the sensitivity, thus allowing individuals with such degrees of hearing loss to be identified. We concluded that, when using the proper methodology, hearing screening devices can be effective in screening for hearing loss in adults and older adult persons.

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