

Original articles

Sensitivity and specificity of three hearing screening protocols in the school setting

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ABSTRACT

Objective: to evaluate the sensitivity and specificity of three hearing screening protocols: audiometry, tympanometry, and transient evoked otoacoustic emissions (TEOAE).

Methods: a cross-sectional study comprising 70 schoolchildren aged 6-14 years old (9.9 ± 2). All participants underwent a complete audiological evaluation and screening procedures. Procedures were compared regarding sensitivity, specificity, and positive and negative predictive values.

Results: sensitivity and specificity were, respectively, 64.71% and 66.04% for audiometry, 64.71% and 73.58% for tympanometry, and 66.67% and 78.85% for TEOAE. The positive and negative predictive values were 37.93% and 14.63% for audiometry, 44% and 13.33% for tympanometry, and 52.17% and 12.77% for TEOAE.

Conclusions: in the school setting, TEOAE stands out from the two other screening protocols, in all measures regarding sensitivity, accuracy, and predictive values.

Keywords: Hearing; Mass Screening; Child; School; Hearing Loss

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INTRODUCTION

Hearing enables a child's contact with the world of sound and language, in particular¹. The acquisition of hearing skills drives both oral and written language development^{1,2}. Hearing loss has a deleterious effect on speech and language development, as well as on academic performance^{1,3}, also hindering social, emotional, and cognitive developing skills. The larger the degree of hearing impairment, the more difficult it is to perceive and discriminate speech, hence, the larger the language handicaps².

The World Health Organization (WHO) estimates 466.46 million people have hearing loss worldwide, of which 34 million are children⁴. Latin America and the Caribbean has 40.19 million people⁴, and in Brazil about 9.8 million are hearing-impaired⁵. There is a close relationship between the prevalence of hearing loss, family income, and parents' education level⁴. A recent study⁶ showed a prevalence of 16.49% of children with hearing loss, mostly unilateral, mild, and in rural areas. Another study⁷ noted the great variability in the prevalence of hearing loss in children, from 1.4% (regarding 29 countries) to 17.5% (Netherlands). The same was found in Africa⁸ and evidenced in a systematic review⁹. Although there is variability, it is evident that hearing loss in children is common⁷ and has important impacts on their development.

Children with hearing loss may face many challenges in the school setting due to attention deficits, difficulty memorizing and understanding what is said, impaired working memory, and lack of interest and concentration¹⁰. It is also common in the school context for children with mild hearing loss to suffer from hearing discomfort, tinnitus, and worse quality of life¹¹. Mild hearing loss can also affect school performance¹².

Thus, it is essential to invest in early detection, diagnosis, and rehabilitation of hearing impairment by creating a hearing health promotion programs for schoolchildren^{6,12}. For children under 15 years of age, 60% of hearing impairment cases result from preventable causes, 31% of which are related to infections such as mumps, measles, rubella, meningitis, cytomegalovirus infections, and chronic otitis media⁴.

Conductive hearing losses are the most common cause of hearing impairment in school-age children^{13,14} and are simple to correct. Tympanograms without peak compliance or a negative one were the most common among younger children (4 to 10 years old), while tympanograms suggesting normal middle ear function were the most common for children over 10 years old¹³.

The gold standard for hearing screening of schoolchildren is pure tone audiometry¹⁵. Either acoustic immittance or otoscopy performed by otorhinolaryngologist is usually recommended to detect middle ear alterations in schoolchildren¹⁵. However, other methods with objective response capture such as transient evoked otoacoustic emissions (TEOAE) and distortion product otoacoustic emissions (DPOAE), both of which are widely used in neonatal hearing screening¹⁶, may prove useful with preschoolers and schoolchildren^{17,18} when it is not possible to perform pure tone hearing screening. Tympanometric screening is recommended for younger children such as preschoolers or as an alternative option after failure in pure tone audiometry or otoacoustic emission screenings¹⁵.

Studies have shown a diversity of methods used for hearing screening in schools^{7,9,19,20}, which vary from the combination of clinical procedures with different pass-fail criteria^{7,9,19,20} to the development of new tools^{21,22} and use screening methods varying within the same country²³ as evidenced by the next examples. A study with schoolchildren between 6 and 9 years old combined TEOAE, DPOAE, and tympanometry procedures²⁰. Researchers screened children from 6 to 8 years old using audiometric screening at 1, 2, and 4 kHz at 20dB with type A tympanometric curve and presence of ipsilateral acoustic reflexes at 0.5, 1, 2, and 4 kHz¹⁹. The proposition of a new hearing screening strategy in schoolchildren based on evidence highlights the use of DPOAE as the first technique, and of tympanometry, audiometric screening at 20 dBNA, acoustic reflex, and otoscopy to those who fail²⁴.

In Brazil studies indicate that the most frequent type of hearing loss is conductive^{17,19,20}. The country recommends evaluating the hearing acuity of school-age children and adolescents²⁵. It is essential to use methods that are sensitive and specific to this age group, as well as safe diagnostic techniques.

Hence, the purpose of this study is to investigate the sensitivity and specificity of audiometric, tympanometric, and TEOAE screenings when applied to the hearing screening of school-age children and adolescents.

METHODS

This cross-sectional study was approved by Federal University of Rio Grande do Norte (UFRN) Research Ethics Committee (030/11-P-CEP/UFRN), Brazil. The subjects were 182 1st-5th grade students enrolled in a public school in Natal, RN, Brazil. The sample was

calculated with an estimated proportion of hearing loss of 16.8%²⁶, margin of error and non-response rate of 5%, resulting in 104 students. The entire population was invited to the research. We obtained the informed consent from the subjects' parents or guardians. The inclusion criteria were performing all proposed procedures on the same day, being healthy enough to perform the procedures and having no blockage of the ear canal. The study was performed on consecutive Saturdays from March to September 2012, due to the low noise level required by the procedures. Eighty students came up for the study, of which three special needs students were unable to complete the evaluation, and seven dropped out of the study. The sample thus consisted of 70 students with ages between 6 and 14 years old (9.9 ± 2.0), with 36 males and 34 females.

We submitted all subjects to meatoscopy, audiometric screening, tympanometric screening, transient evoked otoacoustic emissions test (TEOAE) screening, and a complete audiological evaluation, which is the gold standard procedure in this type of research. We measured the intensity of environmental noise using an ICEL Manaus DL-4020 decibel meter. We performed meatoscopy with a Heidji otoscope to identify conditions for performing the procedures. The purpose of pure tone audiometry is to detect hearing alterations. It is the gold standard for hearing screening in schoolchildren¹⁵.

We performed pure tone detection using an Interacoustic® AD229 audiometer with descending method to establish the threshold, considering as the pass criterion the threshold for at least 20 dB NA at three tested frequencies (at 1000, 2000, and 4000 Hz) for both ears¹⁵. The tympanometric screening aimed at verifying middle ear integrity and the mobility of the tympano-ossicular system. We used the Interacoustic® AT 235 immittance meter with a base tone of 226 Hz set to the automatic mode. We considered the tympanometric gradient of at least 0.2 ml in both ears as the pass criterion. We performed the TEOAE test with the Otoportanmic® Otoport with frequencies from 1000

to 4000 Hz, and tests were interrupted whenever the equipment emitted a detection alert. The adopted pass criterion was the presence of TEOAE in at least three consecutive frequency bands at a signal-to-noise ratio of at least 3 dB and over 50% reproducibility in both ears²⁷.

To establish complete audiologic evaluation results we performed pure tone audiometry in an acoustic booth with an Interacoustic AD229 audiometer and TDH-39 earphones to obtain the speech recognition threshold (SRT) and the speech recognition index (SRI). Normal hearing was defined when the threshold was 15 dB or less²⁸, SRI at least 92%, and SRT consistent with 0.5, 1, and 2 KHz means. We performed the tympanometry using the Interacoustic AT235 impedance meter set to the automatic mode, with a pressure of +200 to -400 daPa and a probe tone of 226 Hz. By using these procedures – pure tone audiometry, SRT, SRI and tympanometry, we were able to identify the presence or absence of hearing loss. In order to avoid ear laterality effect, we began the procedures alternately for every child and we blinded evaluators to the results of the other procedures. In case of screening failure, the subject was retested immediately after removing the earphones or olives¹⁵. Subjects who presented altered results were referred to otorhinolaryngological evaluation. To perform the accuracy analysis, the procedures were analyzed and compared relating the gold standard (pure tone audiometry) with the pass-fail results of each screening procedure to establish the values for sensitivity, specificity, and positive and negative predictive values.

RESULTS

The sample loss was 32.7%. Among the participants (N=70), 53 (75.72%) had normal hearing and 17 (24.28%) presented hearing loss, of which 11 (15.71%) were conductive and 6 (8.57%) were sensorineural losses (Figure 1). Amid the students with hearing loss, 7 (41.17%) were bilateral and 10 (58.83%) were unilateral, varying from mild to moderate impairments.

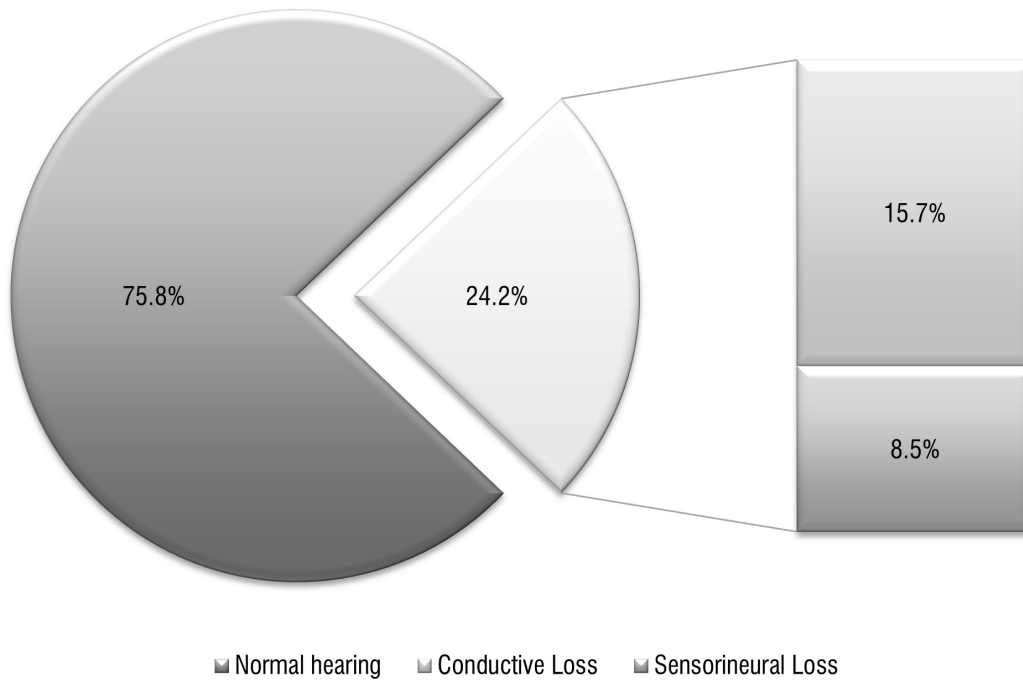
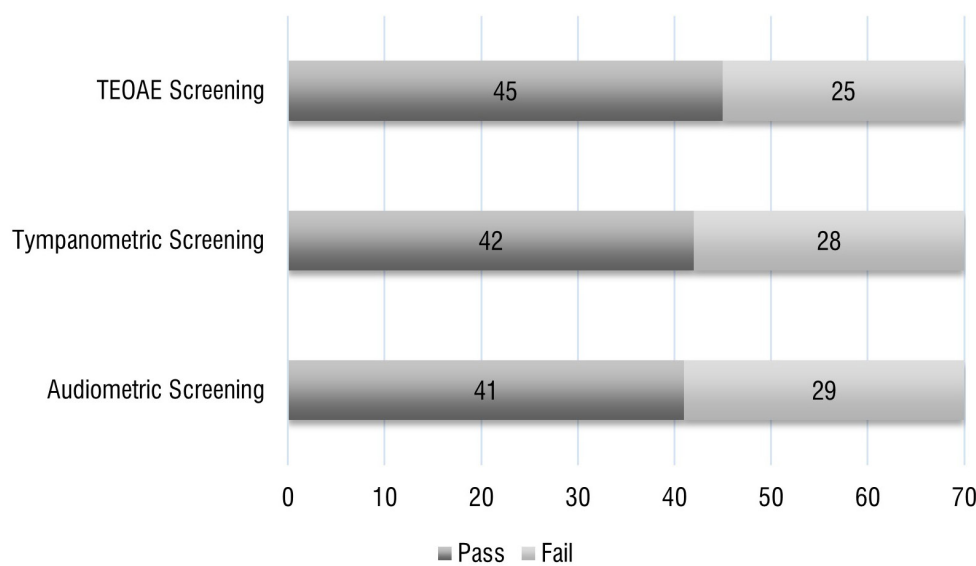


Figure 1. Occurrence of each type of hearing loss found in the study

The screening procedures showed close numerical values (Figure 2). We compared the results obtained to the gold standard to calculate validity. Regarding sensitivity, all three tested screening procedures showed close values, with greater variation in specificity values. When comparing values of sensitivity, specificity, predictive values, and accuracy, we obtained better results overall for the TEOAE (Table 1).

The noise level during the procedures ranged from 39.70 to 61.70 dB (49.16 ± 5.37 dB) for liminal tone audiometry, SRT and SRI, and from 44.8 to 57.4 dB (48.50 ± 6.00 dB) for transient evoked otoacoustic emissions (TEOAE).



Labels: transient evoked otoacoustic emissions – TEOAE

Figure 2. Results of the different hearing screening protocols

Table 1. Sensitivity, specificity, and predictive values for each procedure

	Sensitivity	Specificity	PPV	NPV	Accuracy
Audiometric screening	64.71%	66.04%	37.93%	14.63%	65.71%
Tympanometric screening	64.71%	73.58%	44.00%	13.33%	71.43%
TEOAE	66.67%	69.23%	42.86%	14.29%	68.57%

Labels: PPV – positive predictive value; NPV – negative predictive value; transient evoked otoacoustic emissions – TEOAE

DISCUSSION

In our study, TEOAE was the screening procedure with the best validity and accuracy. This method has been used before for the auditory screening of preschoolers and schoolchildren^{17,18}. TEOAE had better accuracy when compared to other procedures, similar to another study¹⁶ that found 93.5% accuracy for conductive impairment with high specificity (94.6%) and regular sensitivity (77.3%). Studies in different parts of the world have been using TEOAE as a procedure for screening schoolchildren. They were applied to students from 3 to 18 years old in the Mozambican Audiology Program²⁸, for instance. When assessing the viability of the TEOAE screening program in the age group of 6 to 12 years in Greece, researchers found 100% sensitivity in detecting impairments worse than 30 dB along with a 90% sensitivity and a 64% specificity in detecting impairments worse than 25 dB. The PPV in that study was of 25%, with a 98% NPV²⁹ which are different from the values found in this study but indicate good TEOAE results.

Tympanometric screening has been included either as part of the screening protocol^{10,19} or as a single procedure³⁰ in Brazil. In a systematic review⁹ on the prevalence of hearing loss, the authors found less than 10% of studies including tympanometric procedures. High levels of tympanometric alterations have been previously reported in the literature and corroborate our finding regarding the high prevalence of conductive alterations. However, the tympanometric curve is used as the pass criterion rather than the tympanometric gradient^{10,19,30,31}, although this measure may be useful in detecting otitis media with effusion (OME). A study comparing children and adolescents with and without OME found, in the former group, gradient values between 0.01 and 0.93 ml³², thus agreeing with the 0.2 ml criterion we adopted in this study as a signal of hearing screening failure.

Audiometric screening is also indicated for the school setting^{15,18}. A study with schoolchildren using averages of 0.5, 1, and 4 kHz, as well as a 15

dB normality criterion, found a 24.6% prevalence of hearing loss in the sample³¹. Despite differences in criteria, this value is similar to that found in the present study. According to Prieve et al. (2015)¹⁸, audiometric screening may be less susceptible to transient middle ear conditions and may, therefore, be more reliable in detecting permanent hearing loss. Such results agree with the relationship between conductive alterations and TEOAE accuracy we found in the present study.

These economic and social conditions have important effects on health and diseases. Some factors contribute to illnesses, such as stress, living conditions during the early years, social exclusion, unemployment, and others²⁹. There are also different types and degrees of hearing loss that could be influenced by these social determinants of health³³. These conditions and inequalities are common in Brazil and could probably contribute with the frequent conductive problems in school age as we saw in our results and others^{17,19,20,26,34}. Sensorineural hearing loss is also important but in this context, when TEOEA is used, it is possible to find fail result in both types of hearing loss, so this one could be a promising procedure in such environment. Also, it is crucial to structure the hearing health program for a school population³⁵ by studying more about prevalence and associated factors of hearing loss³⁶. In addition, it is key to study different hearing screening protocols to support that kind of program.

One limitation of this study is related to sensitivity, specificity and predictive values. The AAA (2011)¹⁵ guideline shows that the hearing screening protocol should identify at least 90-95% of individuals with hearing loss and fail no more than 5-10%¹⁵. We probably had results influenced from our sample loss, which shows that we need more studies with that kind of methodology in different places. The guideline also indicates that pure tone screening has its limitations¹⁵, as we agree that so do all isolated procedures like the three procedures studied. However, when the sources are limited and there are different social determinants of health among the world population, there is a need

to study different solutions as we see in diagnostic accuracy studies like this one. It is important to do more research with this population to understand the procedures.

In this study, the prevalence of hearing loss was considerably high (24.2%). This hearing problems are similar to previous results obtained in other Brazilian cities, such as São Luís (MA)³⁷ (24.3% of children from 7 to 9 years old) and Goiânia (GO) (24% of children from 7 to 14 years old)³⁴. However, they are larger than those observed in other studies performed in more developed regions of Brazil^{26,36,38} and other countries^{6,7,8,13,14}. The differences in prevalence rates are due, in part, to the great variability in the procedures, methods, and techniques of the auditory screening tests performed and in the adopted pass and fail criteria of these procedures^{7,9}. In addition to the difficulty to identify in each studied location the measures of immunization and prevention adopted that may be related to the prevalence rates⁷, as well as the associated factors⁹, it is also observed that most prevalence studies use pure tone audiometry as a hearing screening procedure. Thus, the results obtained can be different if the next studies use TEOAE as a hearing screening procedure in schoolchildren. It is noteworthy that TEOAE is an electroacoustic and non-psychoacoustic examination, therefore it informs about the functioning of the peripheral auditory system. Yet, it does not contribute, in isolation, to differentiating conductive changes from sensorineural, which can also be a disadvantage in the Hearing Screening Program in Schoolchildren. On the other hand, the inclusion of TOAE in the hearing screening protocol can increase the accuracy and differentiate between conductive and sensorineural hearing loss, but it is difficult to implement it in mass screening performed in schools⁶ due to the increased cost of equipment and qualified professionals, as well as for the longer application time of the procedures.

Most etiologies that cause hearing loss in children are preventable⁴ and, therefore, can be avoided as long as there is a hearing health program at different times in life focused on identifying hearing loss by using protocols with proven accuracy and cost-effectiveness. Thus, it becomes a routine procedure in the health care of schoolchildren, contributing both to the detection of congenital and acquired problems and avoiding the consequences and/or aggravations in child development⁶. This will allow to measure the hearing problem magnitude at school as well as understand and characterize these problems to determine measures of

promotion, prevention, and intervention. School health management will only take place in the field of hearing health care, encompassing stages of identification, monitoring and referral, and intervention. An example of this aspect is related to conductive hearing loss caused by ear infections. By identifying this silent problem in children, notifying parents, and referring them for evaluation and treatment in the healthcare network, action is taken to solve the problem and avoid worsening hearing loss by preventing it from becoming permanent and/or of higher degree. It is also possible to analyze other similar cases in the school and to relate to the places where the children live to identify the source of the conductive problem in hearing, following up on collective health actions⁴.

Thus, it is important to perform clear recommendations and raise awareness about hearing loss to avoid it and reduce any future impact. The implementation of public health strategies to solve this problem will result in improved quality of life for children with hearing loss, as well as it may reduce the financial impact of uncorrected hearing loss⁴.

The results evidenced in this study also point that there is a need for further research comparing these conventional procedures of audiological clinics with technological innovations available in new generation equipment or available in applications for smartphones and tablets.

CONCLUSION

Among the three evaluated procedures, TEOAE had the best validity (sensitivity, specificity, and predictive values) for use in the school setting. Furthermore, it is characterized by shorter application times and greater acceptability among schoolchildren and can detect the most common causes of hearing impairment in the school context, although it has limitations in differentiating between conductive or sensorineural problems. If this is not the objective of the student's hearing health program identification stage, TEOAE may be a method of better validity when compared to pure tone audiometry and tympanometry.

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