International Journal of Pediatric Otorhinolaryngology 75 (2011) 483–488

Contents lists available at ScienceDirect

International Journal of Pediatric Otorhinolaryngology

journal homepage: www.elsevier.com/locate/ijporl

Full length article

A comparison of audiometric and objective methods in hearing screening of school children. A preliminary study

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ARTICLE INFO

Article history:
Received 29 October 2010
Received in revised form 27 December 2010
Accepted 30 December 2010
Available online 3 February 2011

Keywords:
Hearing screening
Audiometry
Automated audiometry
Tympanometry
Otoacoustic emissions

ABSTRACT

Objective: In newborn hearing screening, one exclusively applies objective hearing testing methods – based on evoked potentials and/or on otoacoustic emissions. However, when testing school children, one can consider both audiometric and electrophysiological methods. The choice of methods is determined by the aims of the program. If one wants to detect conductive hearing losses, impedance audiometry seems to be the method of choice.

Methods: The aim of this study was to compare test performance measures from audiometric and objective methods (OAEs and impedance audiometry), in the hearing screening of school children. Screening protocols were applied on a group of 190 children of about 12 years of age (6th grade of primary school).

Results: For a single application of a screening procedure, the best performance was observed in the automated four-tone audiometry, followed by the tympanometry and the TEOAE-based procedures. Screening performance was enhanced using a combination of automated and impedance audiometry. A four-tone audiometry test combined with tympanometry gives a sensitivity of 65%, and the PPV of 46%, which are reasonable values, acceptable for practical use. The use of a TEOAE protocol degrades the overall performance of screening.

Conclusions: Screening of school children is feasible with a combination of automated audiometry and tympanometry with time requirements equal to 3 min per subject.

1. Introduction

The organization of a mass-scale hearing screening program, requires that numerous problems are solved appropriately, in order to make hearing screening useful, reliable, and cost-effective. The proper choice of the screening method and the selection of testing protocols, for the reliable assessment of hearing, are considered the cornerstones of a successful screening program [1]. Other important factors to consider include the timing, the duration of the hearing test and the type of hearing impairment which is to be identified by the screening program. Time requirements should be possibly short not only to avoid the disturbance of the child but also to allow testing of a possibly great number of children in one session, contributing to the cost effectiveness of the program. In this context, simple automated screening tests are preferable [1,2]. On the other hand, protocols consisting of multiple tests based on more sophisticated procedures, generally have higher sensitivity and specificity, and allow a more precise evaluation of hearing. If the aim of the program is to detect a wider range of hearing impairment, a complex battery of tests must be employed. In such a case, the duration of the hearing assessment and the overall cost of the program are affected.

Data published in the literature [3–8] and the personal experience of the authors [1,9,10] indicate that among the methods for child hearing screening, the multi-tone audiometric test (or sweep test), the speech-in-noise test, the impedance audiometry (tympanometry), and the otoacoustic emissions are good candidates. Other procedures, which could also be considered, are some older simplified hearing tests (whisper test, watch-tick test, etc.) audiologic questionnaires (child's or parental), and otoscopic examination. Applicability of these tests depends on the child's age, purpose of the program, and technical means available. It must be kept in mind, however, that each of them has a different usefulness (reliability, effectiveness, predictive value, etc.), so that the choice must be carefully measured.

The most critical issue within the screening program is the one related to future rehabilitation and intervention strategies. If the expected outcome consists of detecting peripheral impairment

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doi:10.1016/j.ijporl.2010.12.024

(conductive and sensorineural), pure-tone audiometric tests (single- or multi-tone, or sweep tests) and objective tests such as impedance audiometry (tympanometry, SRT) or otoacoustic emissions (transient-TEOAE and/or distortion product-DPOAE) can be employed. However, when central processing disorders are the point of interest, the test battery must include appropriate tests such as, the digital digit test (DDT), the gap detection test (GDT), or other dedicated types of speech tests. Recently, a growing prevalence of tinnitus cases in the pediatric population has been reported [11,12] and this problem must also be taken in to account. For the time being, audiologic/tinnitus questionnaires are the only means to reveal these cases.

Undoubtedly, the easiest and most economical solution for a school child hearing screening program would be application of a simple automated multi-tone audiometric test. The term automated implies that the tested child interacts directly with the testing device without an intervention of a human operator. For such a procedural approach, several questions arise, related to the adequate sensitivity and specificity of the test and to the testing-reliability of the automated procedure performed in school conditions. To answer these questions, one must verify experimentally the test performance in real conditions, and possibly seek additional elements of the test battery that would improve test effectiveness without significantly deteriorating other qualities.

Recently in Poland, a country-wide hearing screening programs for school age children, has been initiated [13]. In the preliminary stage of the program, several hundred of six-grade students from Warsaw schools were examined, and the "refer" cases were re-evaluated at the Institute of Physiology and Pathology of Hearing. The children identified with hearing deficits have undergone adequate treatment and rehabilitation [10]. This screening program provided an opportunity to (i) assess the qualities of the applied testing methods (basically tone audiometry and audiologic questionnaires) and (ii) to evaluate alternative methods of screening (i.e., automated audiometry, otoacoustic emissions, impedance audiometry). The next stage of the program (2009–2011) would be carried out in over a half of country's territory (ten provinces in the western part of Poland), and would involve several hundred of thousands of children. In this context, test performance measures on the effectiveness of hearing assessment, its accuracy, as well as the quality of the instrumentation have been of utmost importance.

The main goals of the study can be summarized in the following: (i) to determine the specificity, sensitivity and predicting value of the automated audiometric screening test, referenced to conventional pure tone audiometry and (ii) to estimate test performance measures of the employed methods.

Assuming that the basic element of the screening test battery would be a multi-tone automated audiometric test, the study investigated whether additional screening procedures based on impedance audiometry and otoacoustic emissions could be integrated in the test battery. Test performance measures were determined by estimating the sensitivity, specificity and positive predictive value (PPV) of each testing procedure. These indices were combined with cost-effectiveness and total examination time. Other questions pertinent to the quality of information were also addressed, such as: (i) the effects of noise on the screening procedures and (ii) the reliability of the data in reference to diagnostic tests performed in clinical conditions.

The outcome of this investigation was to find an optimal test battery, consisting of a minimum number of tests, which would be recommended for the next stages of the mass hearing screening program in Poland.

Fig. 1. The hardware used for the conventional and automated audiometry. The figure shows the Audiometer S PDA unit with a pair of ATH 50 headphones and the response button.

2. Materials and methods

2.1. Subjects

In the study participated 190 students (380 ears), 87 male and 103 female, randomly selected from seven Warsaw primary schools. The age of children, at the moment of examination, ranged from 10.9 to 14.9 years. The subjects (sixth grade juniors) were a sub-group of the population examined during the Warsaw hearing screening program, carried out in 2008 [10]. None of the children reported any otolaryngological problems prior to testing. For each subject, the parents were asked to sign a statement of consent, and to complete a part of an audiologic questionnaire (the remaining part of this questionnaire was filled by the test leader during an interview with the child).

The sample size used for this paper is prone to the well-known issues of the "small sample variability", for which most non-demographic studies suffer. For the more mathematically inclined reader additional information on the variability of the three sample performance measures (sensitivity, specificity and PPV) is presented in Appendix A.

2.2. Instrumentation

2.2.1. Measuring the hearing threshold with conventional and automated protocols

Conventional and automated tone audiometry tests were carried out using the "Audiometer S", a Fujitsu-Siemens PDA-based screening device, model LOOX N560. The software for the device and additional hardware components were developed at the Institute of Physiology and Pathology of Hearing in co-operation with the Institute of Innovation Technology EMAG [10].

The PDA works under the MS Windows Mobile operating system and it is equipped with a pair of ATH M50 audiometric headphones and a response button (Fig. 1). The headphones an around-ear type with muffling pads are comfortable and ensure partial insulation from ambient noise (no data are available from the manufacturer, our measurements indicate that noise attenuation ranges from approx. 5 dB at 500 Hz to >10 dB at 2–8 kHz). Because calibration characteristics for these headphones were not available either, we calibrated them psychoacoustically in a group of normal-hearing subjects using a clinical audiometer (Madsen Itera) equipped with the TDH 39 audiometric headphones. The accuracy of the calibration was verified in a control group of subjects with different hearing losses, in whom we determined hearing thresholds using the Audiometer