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A comparison of test–retest variability and time efficiency of auditory thresholds measured with pure tone audiometry and new early warning test

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ABSTRACT

Objective: The present study measured test–retest variability and time efficiency of an automated hearing assessment method called 'new early warning test (NEWT)' incorporated inside a quietpro® hearing protection device (HPD).
Study design: Test–retest thresholds were obtained with manual pure tone audiometry (PTA) and automated NEWT method. Also, test duration was recorded for PTA and NEWT method. Thirty-two participants having normal hearing in one or both ears were tested with PTA and NEWT at 1, 3, 4 and 6 kHz. Each measurement was repeated to determine test–retest variability and measurement time was recorded.
Results: Test–retest variability for NEWT method was not significantly different from PTA except at 3 kHz ($p < 0.05$). Recording time for NEWT method was significantly lower ($p < 0.001$) compared to PTA. Test–retest difference for PTA trials was ⩽5 dB in 82% at 1 and 6 kHz; 85% at 3 kHz and 80% at 4 kHz. For NEWT trials, test–retest difference was ⩽5 dB in 95% at 1 kHz; 72% at 3 and 6 kHz and 77% at 4 kHz.
Conclusions: The NEWT automated method could serve as a reliable and an efficient method to measure auditory thresholds especially in the presence of high background noise.

1. Introduction

Pure tone audiometry (PTA) has been one of the standardized methods to measure auditory thresholds and it assumes a significant role in diagnosis and interpretation of auditory conditions. The traditional method to estimate hearing thresholds is based on the modified Hughson-Westlake method [1]. Presentation of stimuli in this method involves an increase in fixed steps of 5 dB until the person responds and followed by a decrease in intensity of 10 dB until the person stops responding. This procedure is repeated until the person responds two out of three stimuli presentations.

On the other hand, the use of automated methods in healthcare services has increased in recent years, due to the availability of inexpensive computers. The use of automated method particularly applies to hearing healthcare due to high prevalence of hearing loss worldwide. Recently, measurement of auditory threshold using automated methods is becoming increasingly important due to shortage of specialized personnel [2,3]. The advantage of using automated audiometry is that these methods utilize a software interface to administer the test, thereby controlling for tester variability. Automated methods do not require the skill of an audiologist to administer the hearing test and measure the auditory thresholds.

Previous literature has reported good correspondence in the thresholds obtained between the manual and automated methods [4,5]. It was reported that the thresholds obtained with manual audiometry and automated computer-controlled audiometry resulted in a high correlation and the mean threshold difference between the two measurement techniques was less than 1 dB [4]. Studies have reported the reliability of an automated method to measure auditory thresholds [3,5]. Automated auditory thresholds were measured using an audiometer equipped with insert 3A earphones and additional circumaural earphone attenuation [5]. Results indicated that thresholds obtained for automated

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audiometry did not differ significantly from thresholds obtained from the manual method.

Hearing loss due to excessive noise exposure is a serious occupational hazard with many adverse effects, including sleeping difficulties, elevated blood pressure, annoyance and stress. Such exposure can lead to irreversible loss of cochlear hair cells [6,7] and may also lead to neural damage, even when absolute thresholds return to normal after the sound exposure [8]. To perceive auditory stimuli, sounds must exert a shearing force on the stereocilia of the hair cells lining the basilar membrane of the cochlea. When the sound levels are excessive such as due to excessive noise exposure, this force can lead to cellular metabolic overload, cell damage and cell death. Noise-induced hearing loss (NIHL) therefore represents excessive "wear and tear" on the delicate inner ear structures. Sustained exposure to high sound levels may also cause symptoms such as perceived distortion of sounds, tinnitus, and hyperacusis [9]. In the study of European Union, 28% of workers surveyed reported that at least one-forth of the time, they are occupationally exposed to noise loud enough to raise their voices during a conversation [10]. NIHL typically involves the frequency range of human voices, and thus interferes with spoken communications. The first signs of NIHL can be observed in the typical 4 kHz 'notch' seen in the audiogram, indicating a loss of hearing ability in the speech frequency range. The notch grows with further exposure to loud and long duration noise causing increased interference with the other frequencies in the speech communications. Noise-induced hearing loss is a sensorineural hearing deficit that begins at the higher frequencies (typically 3–6 kHz) and develops gradually as a result of chronic exposure to excessive sound levels. Although the loss is typically symmetric, noise from such sources as firearms or sirens may produce an asymmetric loss [7].

Exposure to excessive levels of sound is a major preventable cause of acquired sensorineural hearing loss. For early detection of hearing loss, individuals working in noisy environments need regular assessment of their audiometric thresholds. Accurate assessment of auditory thresholds might not be possible in the presence of high background noise. In order to provide a quiet environment to measure auditory thresholds, there appears to be a need to incorporate auditory threshold measurement method inside a hearing protection unit. A recent study reported the development and calibration of such an automated auditory threshold measurement method called new early warning test (NEWT) [11]. The NEWT method is incorporated inside an active communication earplug called – Quietpro®, which has high attenuation characteristics for background noise. Such a system allows for regular daily testing of hearing thresholds, which might detect the presence of hearing loss at an early stage. The NEWT method incorporates a two-peep stimulus using the adaptive maximum likelihood estimation (MLE) psychophysical procedure [12]. The MLE procedure has been adapted for estimation of auditory thresholds for clinical use [16] and for measurements in a large number of subjects [17]. The MLE procedure has been shown to provide stable threshold estimates with less variability using a limited number of observations [18]. For the purpose of calibration of the NEWT method, thresholds were measured with PTA using Sennheiser HDA200 headphones and the NEWT method was performed using quietpro® insert earphones. A 2 dB step-size was used to measure auditory thresholds with PTA. The amount of threshold deviation obtained in the NEWT method compared to pure tone audiometric thresholds (PTA threshold – NEWT threshold) at 1, 3, 4 and 6 kHz was calculated. The threshold difference values obtained were added to NEWT thresholds in order to get PTA equivalent thresholds for NEWT [11].

The variability of the audiometric test procedure has been measured from the estimate of test–retest threshold variation between two test measurements [4,5,13]. The accuracy of threshold measurement depends upon the step-size used in the method. The normal clinical procedure for manually operated PTA is based on a 5 dB step-size. However, a step-size of 2 dB can be considered based on the degree of accuracy required for measurement of auditory thresholds. It was reported that mean threshold differences between step-sizes of 5 dB and 2 dB measured for frequencies at 0.125, 0.25, 0.5, 1, 2, 3, 4, 6 and 8 kHz was about 1.5 dB lower with a step-size of 2 dB [4]. A measurement method needs to have high sensitivity to detect deterioration in hearing thresholds as early as possible for clinical applications in situations such as hearing conservation programs (HCPs) [4].

Various studies have measured test–retest variability using different transducers in individuals with normal hearing and with hearing impairment. The use of insert earphones has been recommended for measurement of auditory thresholds to overcome the limitations of headphones [14–16]. Previous studies have reported that the use of insert earphones in audiometry offer significant advantages over supra-aural headphones in terms of providing higher attenuation of background noise, increased interaural attenuation and higher efficiency for delivering masking noise [17,18]. A study measured test–retest variability in normal and hearing-impaired (conductive and sensorineural hearing loss) subjects at four frequencies (0.5, 1, 2 and 4 kHz) using 3 different transducers (supra-aural TDH-39 and an insert ER-3A coupled to each of a foam insert and an immittance probe cuff) [17]. Results revealed high test–retest consistency for the three transducers in both group of subjects. Another study reported test–retest data for 30 normal hearing adults using a standard clinical audiometer equipped with Telephonics TDH-50 supra-aural headphone and an Etymotic ER-3A insert earphone [20]. They concluded that insert ER-3A insert earphones produced estimates of auditory threshold similar to the TDH-50 earphone.

Another similar study reported test–retest reliability of audiometric thresholds for normal hearing individuals measured five times in the frequency range from 250 to 8000 Hz [21]. Thirteen subjects were tested for auditory thresholds with insert ER-3A earphones and TDH-49P supra-aural earphones using Békésy audiometry. Test–retest intra-subject variability was within 1.3 dB at all test frequencies measured. It was concluded that the reliability of the ER-3A earphones was comparable to that obtained with the TDH headphone. A close correlation was reported in the test–retest variability between computerized audiometry and manual audiometry. The study used a simple up–down adaptive method in which the level was decreased by 5 dB if a response occurred and was increased by 5 dB for a no response [22]. Test–retest variability for audiometric thresholds with automated and manual audiometry was compared in individuals with normal hearing and hearing-impaired subjects at 0.125, 0.25, 0.5, 1, 2, 4 and 8 kHz [5]. Results indicated no significant difference in test–retest variability across frequencies for manual and automated method for threshold measurement. A recent study evaluated test–retest threshold variability for automated method for testing auditory sensitivity (AMTAS) at 0.25, 0.5, 1, 2, 4 and 8 kHz in individuals having hearing loss [13]. The AMTAS is a prototype computer-based audiometer capable of both air- and bone-conduction testing with masking to the non-tested ear and incorporated quality control features [23]. Results indicated that test–retest variability was within 5 dB for all frequencies except at 1 and 2 kHz.

The purpose of the present study was to measure variability and time efficiency of the NEWT method relative to manual PTA. Test–retest thresholds were obtained in individuals having normal hearing with manual PTA and the automated NEWT methods. Also, test duration was recorded for PTA and NEWT methods. Test duration was defined as the time taken from the presentation of the first stimulus until the response provided by the participant for the last stimulus.