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Original Article

Test–Retest Reliability of the Components of Multi–Frequency Tympanometry

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OBJECTIVE: Multi-frequency tympanometry and its components are extensively used to identify middle ear disorders. However, there are a limited number of studies that have attempted to determine its test–retest reliability. Thus, the present study attempted to determine the test–retest reliability of the different components of multi-frequency tympanometry.

MATERIALS and METHODS: The resonant frequency (RF), F45, and ΔG were determined three times in 40adults with normal hearing. The results obtained across the three trials were compared to determine the test–retest reliability.

RESULTS: F45 and ΔG had excellent intra- and inter-session reliabilities. The reliability of the RF was also good, but it was relatively less compared to that of the other two measures. The study also showed that there was no effect of gender on the reliability measures.

CONCLUSION: Thus, F45 and ΔG can be clinically used considering theirhigh reliability, and the RF should be interpreted with caution. However, further studies on a larger group of patientsincluding a clinical group are essential for determining the further applicability of these results.

KEYWORDS: Reproducibility of results, acoustic impedance tests, middle ear

INTRODUCTION

Multi-frequency tympanometry provides valuable information on the multiple components of admittance (conductance, mass reactance, and stiffness reactance) across different probe tone frequencies [1]. The admittance of the middle ear is a two-dimensional quantity and is a vector sum of conductance (G) and total susceptance (B).There can be differences in these components in different middle ear disorders [2]. Changes in multi-frequency components across frequencies are different between normal and pathological middle ears. The resonant frequency (RF) reportedly varies as there are changes in the transmission characteristics of the middle ear because of the pathology [2]. Colletti [3, 4] elucidated the clinical usefulness of multiple probe tone frequencies from 200Hz to 2000 Hz in tympanometry for distinguishing between mass- and stiffness-dominated disorders. Studies have reported that the identification of otosclerosis and other middle ear disorders can be substantially improved using the different components of multi-frequency tympanometry [5-7].

The different components of multi-frequency tympanometry such as RF, F45, and ΔG at the RF are extensively used in the differential diagnosis of different middle ear disorders [7, 8]. The procedure for recording different components of multi-frequency tympanometry is well described [8]. According to the procedure, frequencies are swept from 200Hz to 2000 Hz twice at +200 daPa and at peak pressure. ΔG, ΔB, and ΔY values are calculated by the subtraction of corresponding values at each frequency between the two sweeps. The RF is calculated as the frequency at which ΔB was equal to 0 mmho. The compensated conductance (ΔG) is recorded at the calculated RF. F45 is calculated as the lowest frequency at which ΔG first becomes equal to or greater than the peak compensated susceptance (ΔB), i.e., ΔB≤ΔG. F45. It is computed by comparing the delta plot values of susceptance and conductance at each frequency from 200 Hz to 2000 Hz in 50-Hz steps. Thus, if these components of multi-frequency tympanometry have to be clinically used, the measured components should be reliable. There are a very limited number of studies that have attempted to determine the test–retest reliability of the components of multi-frequency tympanometry. Margolis and Goycoolea [9] reported that sweep-frequency tympanometry is more reliable than sweep-pressure tympanometry for identifying abnormally low RFs. However, there have been no systematic studies that have attempted to determine the test–retest reliability of F45 and ΔG at the RF. Thus, for efficient clinical usage of multi-frequency and multi-component tympanometry, it is important to determine its test–retest reliability. Hence, the present study attempts to determine the intra-session and inter-session test–retest reliability of RF, F45, and ΔG at the RF in individuals with normal hearing. An attempt was also made to determine if there is any effect of gender on the test–retest reliability of RF, F45, and ΔG at the RF.

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MATERIALS and METHODS

Participants

Forty adults with normal hearing (20 males and 20 females) between the ages of 18 and 25 years (mean age: 19.2 years) participated in the study; they had no significant otological history, noise exposure, and ototoxic drug intake. All participants had audiometric thresholds less than 15 dB HL from 250 Hz to 8 kHz. They all had normal middle ear functioning with an A-type tympanogram and presence of acoustic reflexes (ipsilateral and contralateral) at 500, 1000, 2000, and 4000 Hz.

Procedure

A two-channel diagnostic audiometer was used to obtain air and bone conduction pure tone thresholds and speech identification scores. A Grason-Stadler Inc. Tympstar (GSI-TS) middle ear analyzer was used for immittance testing. The tympanogram and acoustic reflexes were obtained for a probe tone frequency of 226 Hz. Acoustic reflexes were measured using 500, 1000, 2000, and 4000 Hz pure tones, which were presented to the ipsilateral and contralateral ears. Multi-frequency tympanometry was performed using the sweep frequency method described by Funasaka and Funai [8] using a GSI-TS middle ear analyzer. The RF, F45, and ΔG at the RF were recorded in the participants. These components of multi-frequency tympanometry were recorded thrice: baseline, immediately after a 10-mi break (intra-session), and after three days (inter-session). The values obtained were compared across all the three trials, and the test–retest reliability was determined.

Statistical Analysis

Appropriate statistical analyses were performed using IBM Statistical Package for Social Sciences Statistics for Windows, Version 20.0 (Armonk, New York: IBM Corp). Cronbach's alpha was obtained to determine the inter-class correlation coefficient (ICC) between the three trials for the RF, F45, and ΔG. Shapiro–Wilks test of normality was administered to determine if the data were normally distributed. Parametric tests were then administered to determine the test–retest reliability. Repeated measures analysis of variance was performed to determine if there was any significant difference across the trials. The independent t-test was performed to determine if there was any significant effect of gender.

Ethical Considerations

In the present study, all testing procedures were performed using non-invasive techniques adhering to the conditions of Ethical Approval Committee of All India Institute of Speech and Hearing. All test procedures were explained to the participants before testing, and informed consent was taken from all participants for participating in the study.

RESULTS

The RF, F45, and ΔG were similar across all three trials. The mean data for the RF across trials 1, 2, and 3 was 839 Hz [Standard deviation (SD) =153 Hz] 823 Hz (SD=146Hz), and 895 Hz (SD=188 Hz), respectively. The mean F45 values recorded across trials 1, 2, and 3 were498 Hz (SD=173 Hz), 492 Hz (SD=169 Hz), and 512 Hz (SD=185 Hz), respectively. The RF and F45 values across the trials are shown in figure 1. The mean ΔG values recorded across trials 1, 2, and 3 were2.8 mmho (SD=2.7), 2.9 mmho (SD=3.02), and 3.1 mmho (SD=3.2), respectively, as shown in Figure 2.

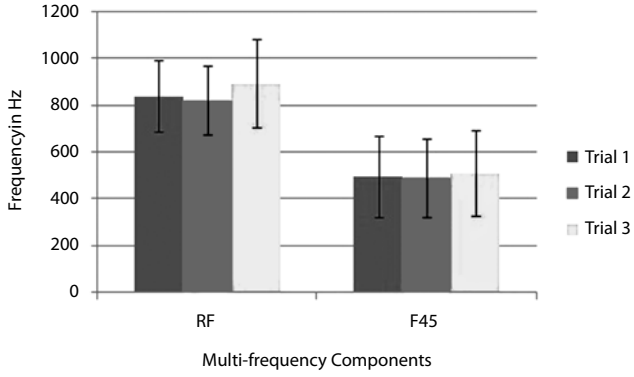

Figure 1. Mean and SD of the RF and F45 across the three trials.
SD: standard deviation; RF: resonant frequency

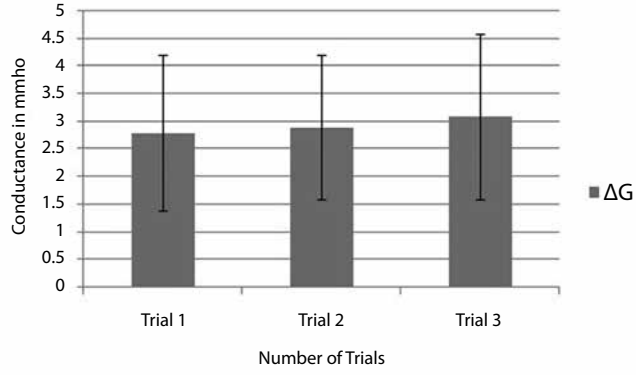

Figure 2. Mean and SD of ΔG across the three trials.
SD: standard deviation

Table 1. Results of repeated measures ANOVA for all three parameters

Parameters	Test statistics and degrees of freedom	Significance
Resonant frequency	F (2, 78)=16.78	p>0.05
F45	F (2, 78)=18.41	p>0.05
ΔG	F (2, 78)=12.6	p>0.05

Cronbach's alpha was used to determine the ICCs across the trials for the RF, F45, and ΔG. The alpha value was equal to 0.825 for the RF, 0.91 for F45, and 0.93 for ΔG. Based on the classification of internal consistency using Cronbach's alpha by Dunn and Baguley [10], ΔG and F45 had excellent reliability. The RF of the middle ear had good reliability [10]. The result shows that ΔG had good intra-subject reliability but varied across individuals. Shapiro–Wilks test of normality showed that the data was normally distributed (p>0.05). Repeated measures of analysis of variance (ANOVA) suggested that there was no significant difference (p>0.05) across the trials for the RF, F45, and ΔG. The results of repeated measures ANOVA are shown in Table 1. The results of the independent t-test also showed that there was no effect of gender (p>0.05) for all three measures across the trials.

DISCUSSION

Multi-frequency tympanometry is efficient for detecting middle ear pathologies that may be missed in single-frequency tympanometry [1, 11-12]. The components of multi-frequency tympanometry are efficient for detecting mass- and stiffness-dominated pathologies [7, 8].

They are also more sensitive for detecting small changes in the transmission of sound in the middle ear than single-frequency tympanometry [3]. Multi-frequency tympanometry has also been recently used to detect inner ear disorders. It has been reported in the literature that the RF of the middle ear is influenced by the mechanical impedance of the cochlea [13, 14]. It has been reported that individuals with large vestibular aqueduct syndrome have a reduced RF as the endolymphatic space increases the impedance of the compartments of the cochlea [13]. It has been proposed that increased endolymph space alters the mechanical impedance of the stapes footplate, leading to the "third-window" effect, which may reduce the RF of the middle ear [14]. Multi-frequency tympanometry is also used as a simple, noninvasive, complementary test in the diagnosis of endolymphatic hydrops [15]. Considering these wide applications of the components of multi-frequency tympanometry, its test–retest reliability was assessed for determining efficient clinical application of these measures.

The results of the present study showed that F45 and ΔG had excellent test–retest reliability. The test–retest reliability of the RF was relatively lesser than that of the other two measures. Thus, F45 and ΔG are more clinically reliable in identifying middle ear disorders than the RF. It has also been reported in the literature that components of multi-frequency tympanometry does not vary across gender on performing sweep-frequency tympanometry [16, 17]. The results of the present study confirm that there was no effect of gender on the reliability of multi-frequency and multi-component tympanometry. Thus, all components of multi-frequency tympanometry used in the present study had good reliability, with a higher internal consistency noted for F45 and ΔG. However, further studies on a larger clinical group are essential for generalizing the results.

CONCLUSION

The present study attempted to determine the test–retest reliability of the components of multi-frequency tympanometry. The results show that F45 and ΔG had excellent intra-session and inter-session reliabilities. The reliability of RF was also good, but it was relatively less compared to that of the other two measures. The study also showed that there was no effect of gender on the reliability measures. Thus, F45 and ΔG can be clinically used considering their high reliability, and the RF should be interpreted with caution. However, further studies on a larger group of patients including a clinical group are essential for determining the further applicability of the results.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of All India Institute of Speech and Hearing.

Informed Consent: Written informed consent was obtained from individuals who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - P.P., S.M., B.N.A.; Design - P.P., S.M., B.N.A.; Supervision - P.P.; Resources - P.P., S.M., B.N.A.; Materials - P.P., S.M., B.N.A.; Data Collection and/or Processing - S.M., B.N.A.; Analysis and/or Interpretation - P.P., S.M., B.N.A.; Literature Search - P.P., S.M., B.N.A.; Writing Manuscript - P.P., S.M., B.N.A.; Critical Review - P.P., S.M., B.N.A.

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REFERENCES

1. Iacovou E, Vlastarakos P V, Ferekidis E, Nikolopoulos TP. Multi-frequency tympanometry: clinical applications for the assessment of the middle ear status. Indian J Otolaryngol Head Neck Surg 2013; 65: 283-7. [CrossRef]
2. Lilly DJ. Multiple frequency, multiple component tympanometry: new approaches to an old diagnostic problem. Ear Hear 1984; 5: 300-8. [CrossRef]
3. Colletti V. Tympanometry from 200 to 2000 Hz probe tone. Audiology 1976; 15: 106-19. [CrossRef]
4. Colletti V. Multifrequency tympanometry. Audiology 1977; 16: 278-87. [CrossRef]
5. Margolis RH, Shanks JE. Tympanometry : basic principles and clinical applications. In: Rintelmann W, editor. Hearing Assessment. Austin, TX: Pro-Ed; 1981. p. 179-245.
6. Shanks J, Shelton C. Basic principles and clinical applications of tympanometry. Otolaryngol Clin North Am 1991; 24: 299-328.
7. Shahnaz N, Polka L. Standard and multifrequency tympanometry in normal and otosclerotic ears. Ear Hear 1997; 18: 326-41. [CrossRef]
8. Funasaka S, Funai H, Kumakawa K. Sweep-frequency tympanometry: its development and diagnostic value. Audiology 1984; 23: 366-79. [CrossRef]
9. Margolis RH, Goycoolea HG. Multifrequency tympanometry in normal adults. Ear Hear 1993; 14: 408-13. [CrossRef]
10. Dunn TJ, Baguley T, Brunsden V. From alpha to omega: A practical solution to the pervasive problem of internal consistency estimation. Br J Psychol 2014; 105: 399-412. [CrossRef]
11. Hunter LL, Margolis RH. Multifrequency Tympanometry: Current Clinical Application. Am J Audiol 1992; 1: 33-43. [CrossRef]
12. Alaerts J, Luts H, Wouters J. Evaluation of middle ear function in young children: clinical guidelines for the use of 226- and 1,000-Hz tympanometry. Otol Neurotol 2007; 28: 727-32. [CrossRef]
13. Darrouzet V, Dulon D, Franco-Vidal V. Multifrequency Immittancemetry in Experimentally Induced Stapes, Round Window and Cochlear Lesions. Audiol Neurotol 2007; 12: 85-100. [CrossRef]
14. Sato E, Nakashima T, Lilly DJ, Fausti SA, Ueda H, Misawa H, et al. Tympanometric Findings in Patients With Enlarged Vestibular Aqueducts. Laryngoscope 2002; 112: 1642-6. [CrossRef]
15. Sugasawa K, Iwasaki S, Fujimoto C, Kinoshita M, Inoue A, Egami N, et al. Diagnostic Usefulness of Multifrequency Tympanometry for Ménière's Disease. Audiol Neurotol 2013; 18: 152-60. [CrossRef]
16. Hanks WD, Rose KJ. Middle ear resonance and acoustic immittance measures in children. J Speech Hear Res 1993; 36: 218-22. [CrossRef]
17. Li X, Bu X, Driscoll C. Tympanometric norms for Chinese schoolchildren. Int J Audiol 2006; 45: 55-9. [CrossRef]