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Gender and ear differences in multi-frequency tympanometry

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Abstract
Objective: The aim of the study was to find the effects of gender and ear difference of multi-frequency tympanometry in Indian young adult population.
Method: A total of 30 individuals include 15 males and females with normal hearing were taken for the study. Resonant frequency and F45 were determined in both ears of all individuals and compared.
Result: The test results showed that the mean resonant frequency and mean F45 have no significant difference in left and right ears. Females have slightly better RF and F45 than males.

Keywords: Multi-frequency tympanometry, resonant frequency, F45, middle ear function, ear difference

Introduction

The middle ear is the impedance matching system, which allows the sounds to transmit effectively through. Ossicles and the sound pressure is concentrated on the oval window. All sounds are not transmitted equally by the middle ear. The middle ear system filters sound which determine our hearing sensitivity of different frequencies.

Tympanometry is the dynamic measurement of acoustic immittance in the external ear canal as a function of changes in air pressure in the ear canal. The term acoustic immittance covers various aspects of impedance, admittance and their components. The immittance of the ear is derived from its various sources of mechanical and acoustical springiness, mass and resistance.

Multi-frequency tympanometry provides information on how components of admittance change as a function of probe frequency and it is a useful tool to predict the diagnosis of various middle ear pathologies. The admittance (Y) of the middle ear is a two-dimensional quantity and is a vector sum of conductance (G) and total susceptance (B). Multi-frequency tympanometry record admittance across a wide range of frequencies and measures how its components i.e., stiffness reactance, mass reactance and conductance change as a function of frequency. As changes in mass and stiffness of the middle ear system affects the resonant frequency, multi-frequency tympanometry is very helpful in finding various middle ear pathologies. It analysis tympanograms from frequencies 226Hz to 2,000Hz. Multi-frequency tympanometry record the changes after acute otitis media in the middle ear which were not always measured by 226Hz tympanometry.

The different components of multi-frequency tympanometry such as tympanometric configuration, resonant frequency (RF), frequency corresponding to admittance phase angle of 45 degree (F45), ear canal volume (Vea) and static admittance are extensively used in the differential diagnosis of different middle ear disorders. 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. Resonant frequency is the frequency at which susceptance is equal to zero, ΔB is equal to 0 mmho. It is an important parameter, as many middle-ear pathologies greatly affect tympanometric patterns around the resonant frequency. F45 is the angle at which susceptance is equal to conductance. And calculated as the lowest frequency at which ΔG first becomes equal to or greater than the peak compensated susceptance (ΔB), i.e., $\Delta B \leq \Delta G$. 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.

Tympanogram provides useful information about Vea. Admittance (Y) is an important component that is obtained through tympanometry. It is the ease of flow of energy through a system.
Colletti *et al*. (1993) [2] conducted a research on 73 otosclerotic patients, 138 subjects who had undergone stapes surgery and the results indicated that the surgery abnormally reduces the stiffness of the tympano-ossicular system. Ogut *et al*. (2008) [8] examined multi-frequency tympanometry in 25 years with surgically confirmed otosclerosis and 100 normal and results showed increased resonant frequency in otosclerotic ears (mean RF value of 1,190Hz). Otosclerosis increases the stiffness of the system due to the fixation of the stapes. Therefore, resonant frequency increases. Researches by Shahnaz and Polka (1997) [11] showed that both resonant frequency and F45 were larger in otosclerotic ears in which 14 ears were tested. Wada *et al*. (1998) [13] examined 26 ears with ossicular chain discontinuity and reported that ossicular chain discontinuity (surgically confirmed in 84% of the cases) results in lowering the resonant frequency with mean resonant frequency value of 830Hz, due to decrease in the stiffness in the middle ear. Ferekidis *et al*. (1999) [3.] in his research on 76 ears with acute otitis media reported decreased resonant frequency with mean resonant frequency value of 499Hz. Lai *et al*. (2008) [6] conducted a research on 85 ears with otitis media with effusion and obtained reduced mean resonant frequency value of 400Hz. There have been no systematic studies that have attempted to determine the effects of gender and ear difference of multi-frequency tympanometry. Thus, for efficient clinical usage of multi-frequency and multi-component tympanometry, it is important to determine effects of gender and ear difference. Hence, the present study attempts to determine the effects of fender and ear differences of RF and F45 in individuals with normal hearing.

Method

Aim of the study

The aim of the study was to find the effects of gender and ear differences of multi-frequency tympanometry in Indian young adult population.

Participants

30 individuals with normal middle ear functioning were chosen for the study. This includes 15 Females and 15 Males.

Inclusion criteria

- Subjects within age range of 18-23 years were taken for this study. (mean age 20.5 years)
- Participants had audiometric thresholds less than 15 dB HL from 250 Hz to 8 kHz
- Subjects with normal middle ear functioning g with an A-type tympanogram and presence of acoustic reflexes.

Exclusion criteria

- Subjects below 18 and above 23 years of age.
- Subjects with excessive ear wax.
- Subjects with ear discharge.
- Subjects with history of conductive, sensorineural and mixed hearing loss.
- Subjects with congenital or other neurological conditions.

Test room

In order to attain reliable result in the test the ambient sound levels must be sufficiently low. The test was conducted in a sound attenuating enclosure or room with thick heavy walls with no air gaps between walls, floor and ceiling, around the door. The room conditions were considered with regard to the patient's comfort.

Materials

Otoscope
Pure Tone Audiometer (GSI)
Immittance Device (GSI Tympstar Pro)
Probes of different sizes

Procedure

A total of 30 subjects (15 males and 15 females) with normal middle ear functioning were taken for the study. The participants were counseled regarding the aim and the procedure of the study. Prior to audiometry testing, otoscopic examination was done.
Air and bone conduction pure tone thresholds were obtained by a Grason-Stadler Inc. two- channel diagnostic audiometer. The subject was asked to sit straight in front of the immittance device. A Grason-Stadler Inc. Tympstar pro was used for immittance testing. The patient was instructed not to have any movements and was not allowed to talk throughout the procedure. The probe tip is inserted into the ear canal after the selection of an appropriate size probe. A probe tone was presented through the probe tip. 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. Multi-frequency tympanometry was performed using the sweep frequency method using GSI Tympstar Pro instrument. The resonant frequency, f45, peak pressure and admittance were measured in both ears of all individuals by the immittance device and were displayed on the screen. The values obtained were compared between ear differences and gender and the differences were determined.

Ethical considerations

In the present study, all testing procedures were performed using non-invasive techniques adhering to the conditions of the Ethical Approval Committee of Dr. M. V. Shetty College of speech and Hearing. All test procedures were explained to the participants before testing, and written informed consent was obtained from individuals who participated in this study.

Results

The study aimed to find the effects of gender and ear differences of multi-frequency tympanometry in Indian young adult population.

a) Comparison of resonant frequency of both ears in males and females.
b) Comparison of F45 of both ears in males and females.

Results

Comparison of resonant frequency in males and females

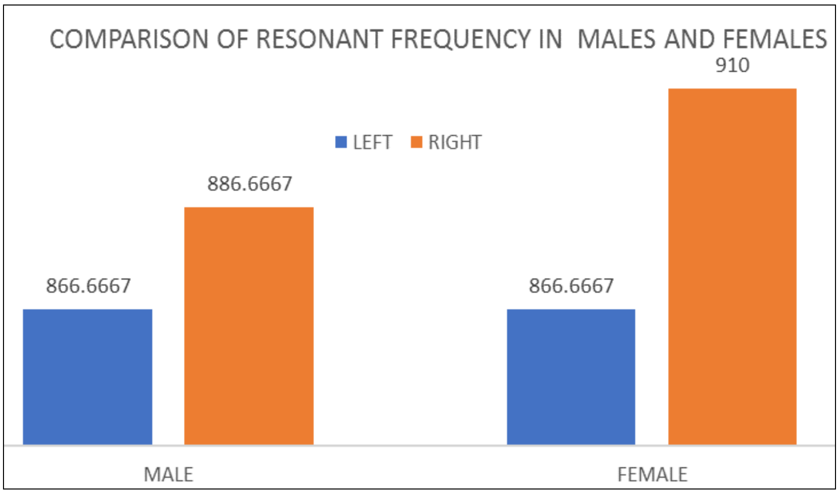

Fig 1: Shows the difference in mean resonance frequency in normal males and females in both ears.

From Fig 1, it is observed that the mean resonant frequency in males are 866.67 and 886.67 and in females 866.67 and 910 in the left and right ear respectively.

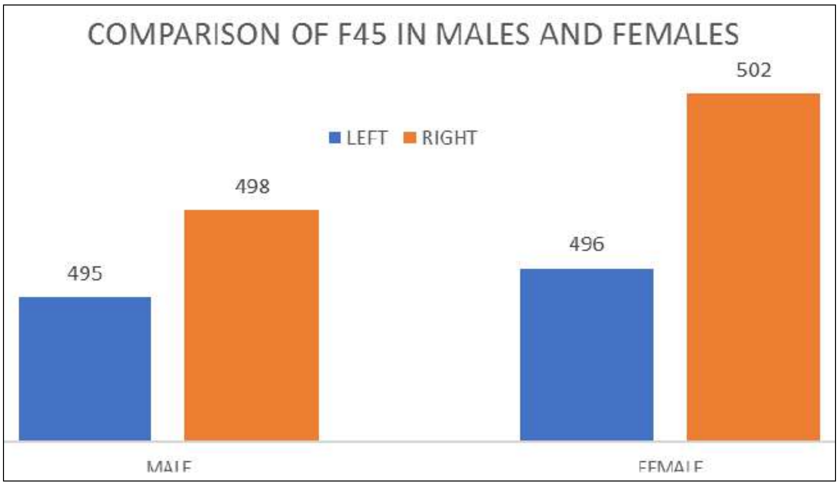

Fig 2: Shows the comparison of mean F45 in normal males and females in both ears.

From the above Figure 2, the mean value of F45 in males are 495 Hz, 498 Hz and females are 496 Hz, 502 Hz in left and right respectively.

Discussion

Multi-frequency tympanometry is more sensitive and measures a minute changes in the middle ear mechanism which is difficult to be identified by conventional tympanometry. It is very sensitive to ossicular-chain discontinuity. They are also more sensitive for detecting small changes in the transmission of sound in the middle ear than single-frequency tympanometry. 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. e "third-window" effect, which may reduce the RF of the middle ear. Multi-frequency tympanometry is also used as a simple, non-invasive, complementary test in the diagnosis of endolymphatic hydrops.

Various studies were conducted on the effect of gender and ear difference across different areas and some studies found slight or significant variations. Newmark *et al*. (1997) [7] conducted a research on inter-aural and gender differences in click evoked otoacoustic emissions and tested 120 healthy, full term newborns, 61 females and 59 males using an Otodynamic ILO 92 system. The results showed that the CEOAEs of the females were significantly larger than those of the males. For the frequency bands 2, 3, and 4 kHz and for the overall response, the emissions were larger in the right ear, for both males and females and these inter-aural differences were more pronounced in males than in females. Females tend to have shorter latency and higher amplitude ABRs than males (Allison *et al*., 1980; Beagley & Sheldrake, 1978; Elberling & Parbo, 1987; Jerger & Hall, 1980). Wave V latency averages about 0.2 ms shorter in females, and amplitude is higher in females, particularly for waves IV, V, VI, and VII. Females also show shorter interwave latencies than males. The differences in latency and amplitude in the ABR between males and females may be related to shorter cochlear response times in females than males. (Don, Ponton, Eggermont, & Masuda, 1994). A study on extended high-frequency (9-20KHz) audiometry reference thresholds in 645 healthy subjects aged 5 to 90 years was conducted by Valiente *et al*., (2014) [10]. The aim of the study was to study patterns in the extended spectrum of the human hearing (0.125 to 20 kHz) in order to obtain reference thresholds and then, compare values with existing results at extended high-frequencies (9 to 20 kHz) in an attempt to establish new standards for potential international adoption. Pure-tone thresholds were determined for conventional and extended high-frequencies. For the 20 to 69 years old group, thresholds were lower in females than in males, especially at 12.5 and 16 kHz. Considering these effects of gender in various auditory tests, the components of multi-frequency tympanometry was assessed for determining the influence gender differences.

The present cross-sectional, comparative study has shown that the resonant frequency and F45 has no significant effect on gender. But females have a slight greater RF and F45. Thus, it is important to consider gender of the patient while using multi frequency in clinics.

Vincent G. Wettstein and Rudolf Probst (2018) [14] conducted a study on right ear advantage of speech audiometry in single-sided deafness. In this study, 406 patients with SSD were identified, 182 with right-sided and 224 with left-sided SSD. The two groups had similar pure-tone thresholds without significant differences. All test parameters of speech audiometry had better values for right ears when compared with left ears. A right ear advantage of speech audiometry was found in patients with SSD. T Pirila *et al*., (1992) [9] conducted a study on left-right asymmetries in hearing threshold levels in 3 age groups of a random population and average asymmetry between the hearing threshold levels in the left and right ears was analyzed in a random population (n = 3487) representing a normal population. Males and females of age groups 5-10 years, 15-50 years and over 50 years were analyzed separately. A significant average inferiority of the hearing in the left ear was found at high frequencies, especially at 3-6 kHz, among adult males and females but not among children. A slight but statistically significant average superiority of the left ear at low frequencies was noted in all age groups. At corresponding hearing threshold levels at 4 kHz, the average inferiority of the left ear in the male population was significantly greater among subjects aged 15-50 years than among older subjects. The inferiority of hearing in the left ear at 4 kHz seems to be associated more with noise damage than with presbyacusis.

The present cross-sectional, comparative study has shown that the resonant frequency and F45 has no significant effect on ear difference. In this study, a total of 30 individuals i.e., 15 males and 15 females were tested. A slight but statistically significant average superiority of the right ear was noted in both male and females. The results of the present study confirm that there was no effect of gender on the 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. However, further studies on a larger clinical group are essential for generalizing the results.

Conclusion

The goal of the study was to find the effect of gender and ear difference of multi-frequency tympanometry in Indian young adult population aged 18 to 23 years. The resonant frequency and F45 were the two main components considered and were obtained from both ears.

The test results showed that the mean resonant frequency in males is 866.67 and 886.67 and in females are 866.67 and 910 in left and right ears respectively. No significant difference was observed. The mean F45 values were obtained and the results showed a slight deviation that the females obtained slightly larger values for F45 in both ears, but no significant difference was observed. The mean F45 values in males are 495 and 498 and in females are 496 and 502 in left and right ears respectively. However, further studies on a larger group of patients including a clinical group are essential for determining the further applicability of the result.

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