MULTIFREQUENCY TYMPANOMETRY IN CHILDREN WITH AND WITHOUT CONGENITAL SENSORINEURAL HEARING LOSS

KIRUBAHARANE S I

Register No: 18AUD016

A dissertation submitted in part fulfillment for the degree of

Master of Science in Audiology

University of Mysore, Mysuru.

ALL INDIA INSTITUTE OF SPEECH AND HEARING,

MANASAGANGOTHRI, MYSURU-570006

JULY 2020

CERTIFICATE

This is to certify that this dissertation entitled **"Multifrequency tympanometry in children with and without congenital sensorineural hearing loss"** is the bonafide work submitted in part fulfillment for the degree of Master of Science (Audiology) of the student with Registration Number: **18AUD016**. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other university for the award of any other Diploma or Degree.

Mysuru,

July, 2020

Dr. M. Pushpavathi

Director

All India Institute of Speech and Hearing

Manasagangothri, Mysuru-570006

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Mysuru,
July, 2020

Dr. Ajith Kumar U
Guide
Professor in Audiology,
Department of Audiology,
All India Institute of Speech and Hearing,
Manasagangothri, Mysuru-570006.

DECLARATION

This is to certify that this Master's dissertation entitled **"Multifrequency tympanometry in children with and without congenital sensorineural hearing loss"** is the result of my own study under the guidance of Dr. Ajith Kumar U, Professor in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysuru, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru **Kirubaharane S I**

July, 2020 **Registration No: 18AUD016**

ACKNOWLEDGEMENT

First and foremost, I would like to thank my parents and my big brother for caring for me since my first cry. I would never be a success without your affection. I am so blessed and lucky that I got a chance to work under your guidance, Ajith sir. He always remains a CAPTIAN COOL for all of us. I try to follow your tread in the future. Dear friends, your attachment makes me happy all the time. I am so thankful to be with my clans in clinical postings, cultural, of course in class.

I would like to thank HOD Prawin sir, and all the clinical staff of audiology for their support and guidance throughout my research, and also I like to thank my kids who participated in my data collection. I hope that I made you all smile in the end by a surpise gift. Without your support this cannot be achieved.

My special thanks to Sandeep sir, Saravanan sir, Sreeraj sir, Sumanth somu, Chayashree, Rashmi, Chhandhasi, Ram Prakash, Shyam Sundar, Yasin, Vianaya sir, Sharath Kumar sir, Mahesh sir, Anuprasad sir, Sivaramakrishnan, Kavitha, Merin Mathew, Rajasudhakar sir, Jayakumar sir, Ajith, Basih, Ashique, Manju for your timely help and care and love to me…..

ABSTRACT

The standard low-frequency tympanometry often fails to admit noticeable patterns for various middle ear disorders, which affects the middle ear properties, exceptionally low impedance pathologies like otosclerosis. This is because the tympanic membrane dominates its patterns, which overshadows the conditions affecting more medial structures of the middle ear. Multifrequency tympanometry (MFT) uses two or more frequencies to measure the tympanogram, and also it measures various admittance aspects of the ear over the wide frequency range. The main aim was to study the multifrequency parameters (susceptance, conductance, admittance, and phase angle) across the broad frequency range of 260Hz to 2000Hz in children with sensorineural hearing loss to know the effect the cochlear abnormalities on MFT parameters. Fifty children were volunteered in this study, among which 20 were normal hearing, and 30 were children with sensorineural hearing loss. Pure tone audiometry with ABR was administered in all the children to know the degree of hearing loss, and conventional tympanometry was tested to find their middle ear functions. Multifrequency and multicomponent tympanometry using the sweep frequency method was evaluated using a calibrated GSI-Tympstar meter. The frequency was swept twice from 200 to 2000 Hz at two different pressures, i.e., +200 daPa and the peak pressure of susceptance, conductance, and admittance. The differences between the two vectors (Y_{+200}, B_{+200}, G_{+200} and Y_{peak}, B_{peak}, G_{peak}) i.e. ΔY, ΔB, ΔG was calculated by the device as a function of frequency

Results revealed that overall multifrequency parameters show similar functions in normal and children with sensorineural hearing loss except the comparable change in susceptance magnitude at high frequency, which was a statistically significant and apparent increase in conductance magnitude at the low and resonant frequency which was not statistically significant from normal hearing individuals. This suggests that multifrequency parameters play a role in understanding middle ear function while influenced by cochlear dysfunction.

Keywords: Susceptance, conductance, admittance, phase angle, inner ear disorder

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CHAPTER 1

INTRODUCTION

The easiest and non-invasive way of assessing the middle ear system is tympanometry. It is the measuring of the middle ear acoustic admittance as a function of the ear canal pressure. Terkildsen & Thomsen (1959) introduced this test of checking the middle ear pressure and is most commonly used as routine audiological evaluation across the world. Admittance measurements are more useful to test middle ear function as the change in the admittance is always linear to the change in pressure applied to the external canal, where a change in impedance is always nonlinear with pressure change. Generally, single component tympanometry at 226Hz, which is most commonly performed as a low probe tone frequency, has a valid clinical value of identifying various middle ear disorders. Low probe tone frequency is away from the resonant frequency of the middle ear that results in a bell-shaped tympanograms for susceptance (B), admittance (Y) and conductance (G) respectively. So it often fails to admit noticeable patterns for various middle ear disorders, which affects the middle ear properties, exceptionally low impedance pathologies like otosclerosis. This is because the tympanic membrane dominates its patterns, which overshadows the conditions affecting more medial structures of the middle ear. Due to advancements in instrumentation, tympanometry can also be measured at various probe frequencies. Shanks (1984) found that for a smaller amount of fluid in the middle ear, 226Hz tympanograms are single-peaked, but 678Hz of probe frequency tympanograms showed dramatic changes even when a small amount of fluid is present. Vande Heyning et al. (1982) reported that tympanometry with high frequency probe tones enables a better distinction to be made between typical middle ear system and middle ear function affected by luxations, necrosis, or disruption. Multifrequency tympanometry (MFT) uses two or more frequencies to measure the tympanogram, and also it measures various admittance aspects of the ear over the broad frequency range. It gives knowledge on how components of admittance change concerning probe frequencies. The admittance is a two-dimensional portion and is a combination of susceptance (B) and conductance (G).

Susceptance is maximum, while conductance is minimum at lower probe frequency. Therefore, the admittance vector lies at angles near to 90^0 and carefully follows the susceptance tympanograms. On the other hand, both susceptance and conductance contribute, or conductance may be higher than the susceptance at higher frequency probe tones, which leads to admittance vector shifting nearer to the conductance. By this, we can expect utterly different in information between MFT and conventional single frequency tympanometry (Margolis & Goycoolea, 1993).

Conductance G, which implies the resistive forces that are affected by the cochlea and are higher at the resonance frequency (RF) of the middle ear when susceptance remains zero. Susceptance denotes the reactive forces of the middle ear system. It is the total mass susceptance of the ossicles, and the susceptance of compliance (or stiffness) of the annular ligament (AL) and inner ear are canceled at the RF (Colletti, 1976).

Across the broad range of frequencies, multifrequency components cause variation between normal and abnormal middle ear functions. Middle ear pathology affects the typical transmission characteristics, which evidently cause changes in resonant frequency. Colletti demonstrated the clinical usability of several probe tone signal between 200Hz to 2000 Hz in multifrequency tympanometry for differentiation of mass- and stiffness-predominant pathology. Studies have reported by using admittance component of multifrequency tympanometry helps in improving the detection of the otosclerosis and other middle ear diseases

Even the minute changes in middle ear sound transmission can be easily detected and also sensitive in multifrequency tympanometry when compare to standard low-frequency tympanometry. Inner ear defects also been detected recently using MFT, and literature reported that cochlear mechanical impendence might affect the resonance frequency of the middle ear transaction.

Sugasawa et al. (2013) reviewed that middle ear and inner ear contribution in acoustic admittance. This helps in finding not only ossicular and middle ear lesions but also cochlear abnormalities. They reported a correlation between MFT data and various inner ear pathologies like inner ear fistula, acoustic trauma, perfusion of scala tympani and round window blockage, and complete cochlear atrophy. The change in inner ear pressure will modify the interactions of B and G or their derived values and which interns modify the plots.

These findings clearly state that the acoustic immittance of the ear not only dependent on middle ear variables but also changes in pressure and endolymph fluid within the cochlea also lead to very slight but essential changes parameters of in multifrequency tympanometry. This was seen in meniere's disease. Conventional tympanometry is not able to reveal such differences (Franco-Vidal, Bonnard, Bellec, Thomeer, & Darrouzet, 2015; Sugasawa et al., 2013). The cochlear structure can be added to the stapes footplate to simulate the actual mass, damping, and spring effects, so the part of the cochlear mechanical transfer is contributed when cochlea portion loading the stapes which directly cause the decrease in umbo displacements. Thus, the input impedance of the whole ear should become higher than that individual measurement of the middle ear only. They also observed noticeable changes in admittance magnitude and also in resonance frequency resulted when the removal of a cochlear portion

1.1 Need for the study

The review of the existing literature reveals that there is a significant difference in the middle ear admittance parameter present between individuals with cochlear dysfunctions and healthy middle ear individuals, which was seen in adult populations. Interpretation of middle ear pathology in co-existing sensorineural hearing loss does not only depend on the status of middle ear function but also the involvement of physiology behind the cochlear lesions. Understanding these interactions in children is essential, especially while deciding on cochlear implant surgery.

Kumar K.S & Basavaraj (2009) measured MFT in children whose age range of 3 to 6 years with normal middle ear functioning. They found multifrequency admittance components with a phase angle at resonance frequency did not show any change across the age groups, which indicated that the middle ear functioning might be stabilized by 3-6 years of age. Also, they found no changes between the ears and also among genders.

Hanks and Rose (1993) studied multifrequency tympanometry using a sweep frequency method in children whose ages between 6 to 15 years with typical hearing abilities and with sensorineural hearing loss. Results found that there similar interactions for age, group, gender, and no noticeable changes in the resonance frequency of the middle ear. Also, no significant effect of advancing age on multifrequency tympanometry and resonant frequency, even at an age beyond 79 years, has been reported in the earlier studies (Holte, 1996; Lechuga et al., 2000).

One view of the probing was to measure the inner ear effects on the admittance magnitude curve, including susceptance and conductance across wide frequency. Grason-Stadler adapted the sweep frequency procedure of administering multifrequency tympanometry described by Funasaka, Funai, and Kumakawa (1984). the GSI-TS plots each admittance magnitude as a function of frequency that includes peak to tail difference values for acoustic conductance (AG), acoustic susceptance (AB), or admittance magnitude (AY) and also phase angle.

However, there is a lack of information regarding multifrequency parameters of each admittance magnitude across the frequency. So the present study focus on understanding which admittance measures are the most valuable that includes its both subcomponents (i.e., susceptance and conductance) and phase angle should be observed individually.

1.2. Aim of the study

To evaluate the middle ear admittance parameters by using multi frequency tympanometry in children with and without congenital sensorineural hearing loss.

1.3. Objectives of the study

1. To estimate the multifrequency parameters in children with congenital sensorineural hearing loss across the frequencies from 260Hz to 2000Hz.
2. To estimate the multifrequency parameters in children with normal hearing across frequencies from 260Hz to 2000Hz.and normal children.
3. To compare the multifrequency parameters across the frequencies from 260Hz to 2000Hz between normal and congenital sensorineural hearing loss.

CHAPTER 2

REVIEW OF LITERATURE

The middle ear functions as an "impedance matching" system, allowing sounds from the larger portion of the tympanic membrane to the smaller area of the round window to the inner ear effectively through ossicles. While transmitting, the filtering of sounds by the middle ear, which transmits most energy in the frequency range of 1000 to 4000Hz that largely determines our hearing sensitivity for different frequencies.

Membranes, ligaments, muscles, bones, and cavity air help in the middle ear transmission system. Each of these components has susceptance and conductance characteristics, and the overall combination of these will make the input acoustic admittance that is measured with tympanometry (Lilly, 1972).

2.1. Tympanometry

Tympanometry measures the aural acoustic immittance as a function of ear canal volume. It gives information about how sounds pass from the outer ear to the middle ear. So it is beneficial in assessing the movement of the tympanic membrane and functioning of the middle ear structure.

The most common tympanometry tested at a low probe tone frequency of 226 Hz has the valid clinical value of identifying various middle ear disorders like tympanic membrane abnormalities, abnormal middle ear air pressure, and Eustachian tube dysfunction. For the low frequency, primarily, the stiffness characteristic of the middle ear transmission system is assessed. Ear canal admittance, static admittance, tympanometric width, and peak pressure are commonly used in interpreting standard low-frequency tympanograms.

The resonant frequency is affected by mass or stiffness characteristics of the middle ear system. When administering immittance at standard low probe tone frequency, it is less acute to detect the changes in middle ear resonance, which causes various middle ear pathologies like ossicular dysfunction, otosclerosis, etc. because the low frequency probe tone and middle ear resonant frequency are not similar. It is comparably lower and is less consistent (Shanks, 1984).

Due to the more sensitivity of detecting ossicular abnormalities like otosclerosis, ossicular disruption, ossicular chain dysfunction by using higher probe frequency tympanometry. It is gaining clinical benefits than using low probe tone tympanometry. (Iacovou, Vlastarakos, Ferekidis, & Nikolopoulos, 2013)

Typical middle ear systems, as well as pathological ears, mostly generate bell-shaped tympanograms at 226Hz. However, with a high frequency probe tone, discrimination is found between a sharp W shaped tympanogram from normal. While irregular multi extrema or broad W shaped tympanograms from the pathological ears. The most valuable diagnostic information from high probe tone tympanometry resides in the shapes of curves and not in the absolute values of the immittance component.

2.2. High frequency tympanometry

In high frequency tympanometry, 660Hz, 678Hz, 800Hz, or 1000Hz are being used as probe frequency. While administering in children, the 1000Hz probe tone was highly recommended than standard low probe tone tympanometry to understand their typical middle ear functioning and also to detect even subtle changes in middle ear transmission. (Hoffmann et al., 2013; Kei & Mazlan, 2012). In another study, authors compared between low-frequency probe tone of 226Hz and high frequency probe tone of 1000 Hz tympanometry in children with typical middle ear functioning and suggested a 1000Hz probe tone frequency delivered 91%, 226Hz probe tone frequency delivered 35% pass results in neonates and young children. They conclude that the usability of high frequency tympanometry in this age group is highly recommended and also more sensitive (Alaerts, Luts, & Wouters, 2007)

To distinguish and to identify low impedance pathologies like ossicular discontinuity and for high impedance pathology like otosclerosis, higher probe tone tympanometry is more sensitive over standard low probe tone tympanometry. Total admittance measured using a 630Hz probe tone is more prominent for interpreting typical middle ear from otosclerosis. But the role of conductance(G) is unclear between both the groups (Shahnaz & Polka, 2002)

2.3. Multifrequency and multicomponent tympanometry

Multifrequency tympanometry is measuring the middle ear functions by sweeps by an array of multiple frequencies, i.e. 250 to 2000 Hz. In this middle ear resonance frequency can be able to measure directly. And it also gives better knowledge on subcomponents of admittance (conductance and susceptance which includes mass and stiffness reactance) over the wide probe tone frequencies (Iacovou et al., 2013)

Middle ear resonance frequency has diagnostic implications in understanding the changes of mass and stiffness characteristics of the pathological middle ear, which cause a shift in the static immittance with accompanying changes in middle ear resonance.

Middle ear resonance is higher, i.e., above 800-1200 Hz in otosclerosis. Because in this middle ear, stiffness is high. On the contrary, if the mass of the middle ear more and if stiffness is less, then resonance of the middle ear is comparably lower than normal frequency, which is seen in ossicular discontinuity.

With increasing age, mean admittance magnitude at 226Hz remains substantially constant. At higher frequencies, admittance magnitude increases with age during the first four months of age, and it is lower than adult values. By four months of age, the mean admittance phase angle reaches adult values at low frequency. However, it is larger at high frequencies suggesting higher resonant frequency. The phase angle generally decreases with age. Input admittance of an infant's ear is more dominated by mass or resistive elements than in children and adults. Admittance magnitude increase with age is due to some possible reason for the growth of the middle ear cavity. Input admittance increase with the size of the volume in air. Recording in the direction of negative pressure to positive pressure results in an uninterpretable tympanogram. So positive to negative direction is more useful and standardized (Holte, Margolish, & Cavanaugh, 1991)

The overall clinical benefit of multifrequency or multicomponent tympanometry is to detect more sensitively specific middle ear dysfunctions like low impedance abnormalities (ossicular chain dysfunction) and specific high impedance abnormalities (ossicle fixations). These conditions are less sensitive to interpret using Single frequency tympanometry.

Most often, MFT is interpreted based on the derived resonant frequency. The resonant frequency is defined as the frequency at which the ΔB is equal to or close to 0 (zero). RF in healthy adult ears is reported to range between 630 Hz and 2000 Hz

(Margolis & Goycoolea, 1993). There are two methods used to estimate the resonant frequency of the middle ear during multifrequency tympanometry; sweep pressure method and the sweep frequency method.

In the sweep pressure method, by keeping the probe tone frequency fixed, decreasing the air pressure of the external ear canal continuously in a direction of positive to negative pressure at a given pressure rate, for example, 50dapa per second. Margolis and Goycoolea (1993) suggested that the SP method is a more appropriate method for measuring RF than the SF method. Vanhuyse, Creten, and Van Camp (1975) observed several patterns of tympanogram at various probe tone frequencies and developed a model that predicts the shape of susceptance (B) and conductance (G) tympanograms at 678 Hz in healthy ears and various pathologies. The Vanhuyse model categorizes the tympanograms based on the number of peaks or extrema on the susceptance (B) tympanogram and the conductance (G) tympanogram and predicts four tympanometric patterns at 678 Hz.

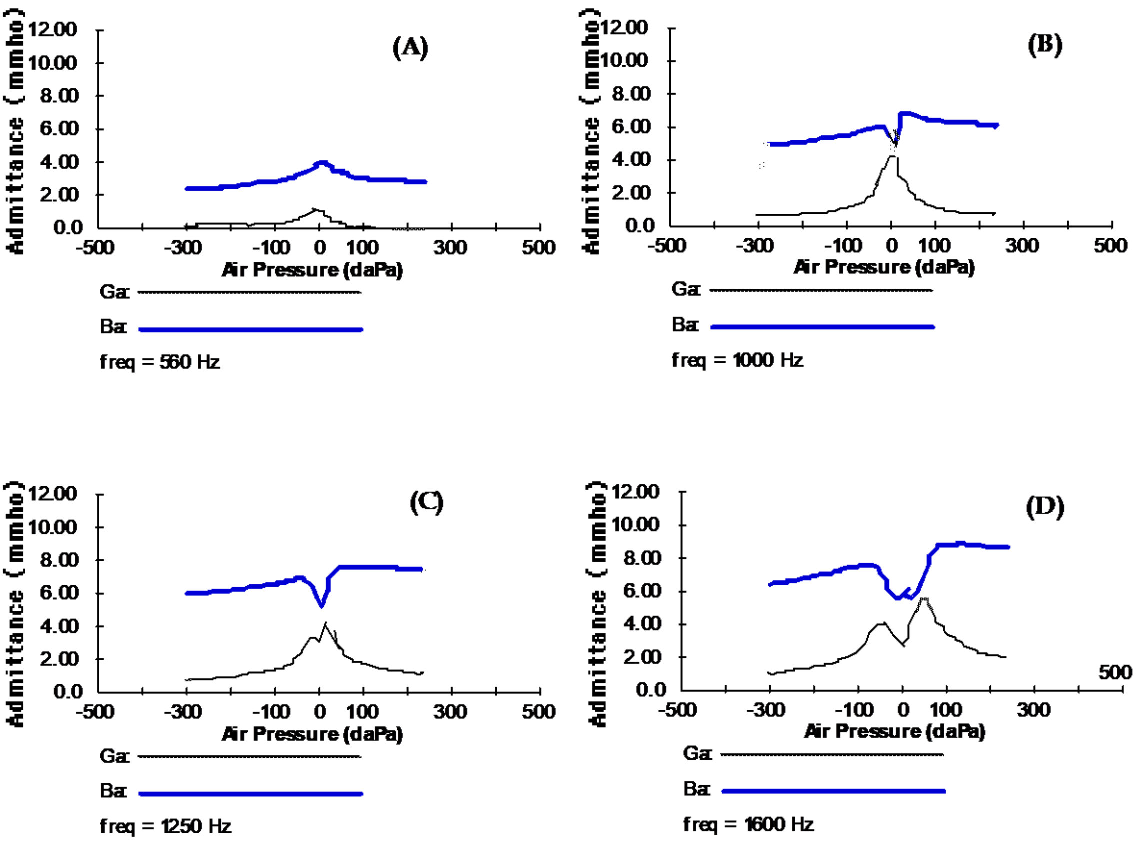

Figure 2.1. The Vanhuyse et al. (1975) model showing four patterns for susceptance (B_a) and conductance (G_a) tympanograms, 1B1G (A); 3B1G (B); 3B3G (C); and 5B3G (D)

Colletti (1975) studied tympanograms for probe tones ranging from 200 to 2000 Hz with 200 Hz increments and concluded that early or late appearance of W shape patterns of tympanograms was a diagnostic criterion for differentiating pathology of the middle ear using sweep pressure method. In this, RF is defined as the frequency at which admittance tympanogram notches and touches the compensated zero.

The second method to estimate resonant frequency in MFT is the Sweep frequency method. In this, frequency is swept between 250 to 2000Hz in the interval size of 50Hz. Funsaka, Funai, and Kumakawa (1984) recorded sweep frequency tympanometry in sixty normal-hearing adults and defined resonant frequency as the one where ΔB is closest to 0. Similarly, the frequency at which ΔB is nearest to ΔG resembles the admittance phase angle of 45° (F45). One can also measure ΔY, ΔB, ΔG, and Δθ at any of the frequencies (as allowed by the equipment) in the sweep frequency method. The present study focuses on this approach to understanding admittance magnitude across the frequency range.

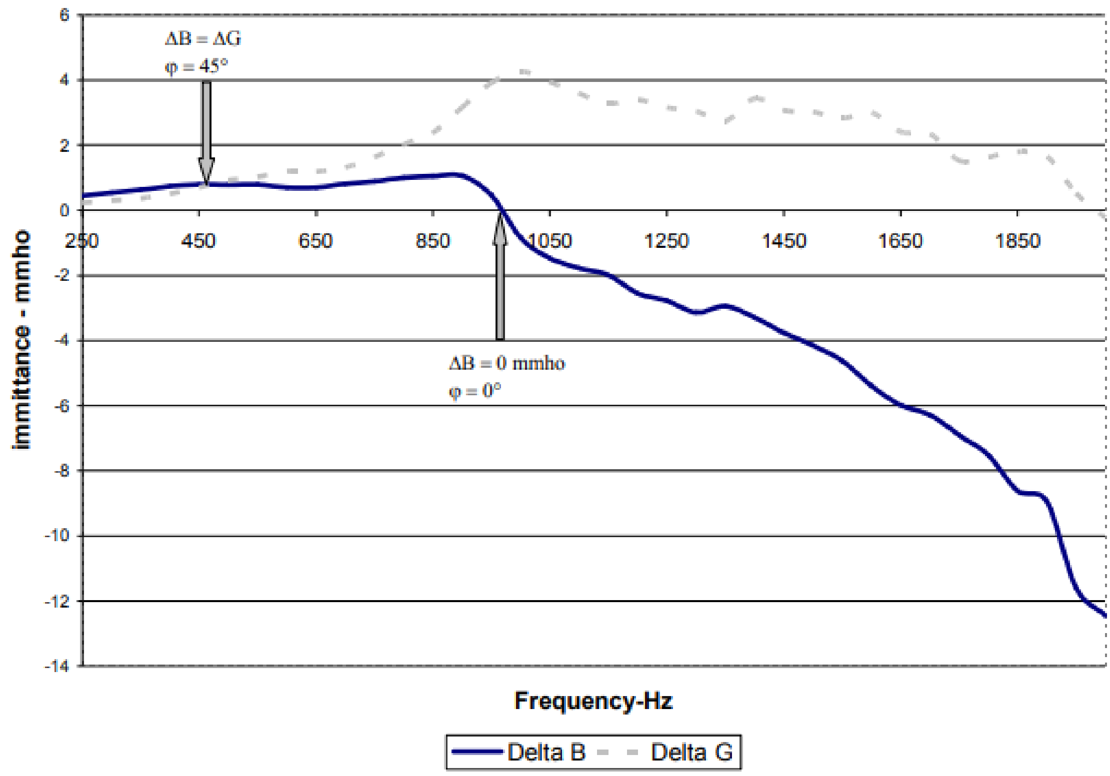

Figure 2.2. A plot of delta B and G as a function of probe tone frequency obtained using GSI-Tympstar.

2.4. Multi Frequency and Multi Component Tympanometry in normal middle ear functioning

.By using sweep pressure method, Margolis, VanCamp, Wilson, and Creten (1985) recorded susceptance and conductance tympanograms in 10 healthy individuals with ranging the probe signal from 220 to 910 Hz (220Hz, 510-910 in 50 Hz intervals). For each probe frequency, both pressure directions were used (ascending and descending). In the results, they found more complicated tympanometric shapes in ascending direction compared to the descending direction. In the ascending direction, the transition from 1B1G to 3B1G occurs at a lower probe frequency (510Hz), and 3B3G was obtained by 610 Hz. At probe frequencies above 810-910 Hz, a 5B3G pattern was observed.

Hanks and Rose (1993) found that the mean value of Resonance frequency as 1003 Hz with standard deviation of 216 in children age ranges of 6 years to 15 years. Sabitha (1994) reported that the mean conductance value was 3.67mmho for children in age groups of 8-12 years. Kumar, Adithya (2007), and Miani et al. (2000) found mean conductance of 3.58 mmho in adults. Megha and Kumar (2008) found that the mean value of resonance frequency, conductance, and phase angle in neonates from birth to 1 month was 261.85 Hz, 0.38 mmho, and -35.73°, respectively. Manuel (2004) found that mean compensated admittance values in neonates were 0.74 mmho with standard deviation of 0.26, and there is a trend of successive increase of compensated admittance from birth to childhood. This could be due to the anatomical changes in structure and the stiffness properties of the middle ear.

2.5. Multi Frequency and Multi Component Tympanometry in individuals with middle ear pathology

Binu (1997) recorded MFT in 20 ears of adults and children (seventeen adults, three children) with conductive or mixed hearing loss. They measured admittance (Y) susceptance (B) and Conductance (G) tympanograms at three different probe tone frequencies (226, 678 & 1000 Hz). Subjects were divided into three groups based on their symptoms. Group 1 consisted of ears with a complaint of pain. Group II consisted of ears with a complaint of the previous history of ear discharge. Group III consisted of ears with pain along with the previous history of ear discharge. All the three groups showed abnormal width in 3B1G, 3B3G, and 5B3G tympanograms along with abnormal shape or morphology of the tympanograms. The author found that group with a complaint of ear pain some of the ears had abnormal tympanometric patterns in the MFT despite normal findings, indicating that even subtle changes in the middle ear system could be detected by MFT. Similar findings are reported in chinchillas (Margolis, Schachern, & Fulton, 1998) and other studies in human beings (Hanks & Robinette, 1993; Margolis et al., 1994; Vlachou, Kobayashi, Suetake & Tachizaki, 1999; Vlachou, Tsakanikos, Douniadakis, & Apostolopoulos, 2001).

Vlachou et al. (2001) evaluated the change in phase angle ($\Delta\theta$) provided by automated tympanometry using the sweep frequency technique. Seventy children (45 males and 25 females), suffering from AOM (Acute otitis media), participated in the study. Results showed lower $\Delta\theta$ in ears with AOM compared to healthy middle ears. Abnormal $\Delta\theta$ was associated with abnormal resonance frequency.

Abou-Elhamd, Abd-Ellatif, and Sultan (2006) performed multifrequency tympanometry in otitis media with effusion and adhesive otitis media cases. Fifty participants with long-standing or recurrent otitis media with effusions and a group of 25 normal subjects participated in the study. The Sweep pressure method with ascending pressure sweep was used to derive RF. Results showed a resonant frequency of 428 ± 159 Hz in cases with otitis media with effusion and 1336 ± 230 in adhesive otitis media.

Karel, Camp, and Vogeleer (1986) performed MFT on 29 individuals with otosclerosis and a group of 30 normal subjects. Acoustic resistance, reactance, and phase angle were assessed using 220 Hz and 660 Hz probe tone frequency. They found that at 220 Hz probe tone frequency, both groups have identical phase angle values of about 66º, but the high phase-angle value at 660 Hz (above 60º) has diagnostic value.

Wada, Kobayashi, Suetake, and Tachizaki (1999) performed MFT using sweep-frequency from 220 to 2000 Hz. Fifty normal subjects and cases of discontinuity or fixation of the ossicular chain were taken for the study. Resonance frequency was higher in cases of otosclerosis and lowered ossicular chain discontinuity. They concluded that MFT would provide adequate information in the differential diagnosis of normal and ossicular problems. In a subsequent study, Wada, Koike, and Kobayashi (1998) found a hit rate of 84% for ossicular chain discontinuity and 74% for ossicular fixation.

Similarly Ogut, Serbetcioglu, Kirazli, Kirkim, & Gode (2008) found mean RF for the otosclerotic group to be 1190 Hz, which was higher than that in the control group (934Hz). With a cut off value of 1025 Hz (based on 95% confidence interval), sensitivity was 80%, and specificity was 82%. Shahnaz and Polka (2002) reported the hit rate of otosclerosis to be better with the higher probe tone frequency.

Russolo, Bianchi, and Miani (1991) measured RF in 54 normal ears, 31 otosclerotic ears, and ten ears that had undergone stapedotomy. They found that RF values were higher in otosclerotic cases compared to normal ears (normal subjects 834Hz ± 153; otosclerotic patient's 1282 ±188; postoperative patients 800 ±180). They found MFT to be more specific in the differential diagnosis of otosclerotic ears and normal ears. Similar findings in otosclerosis were found in studies done in the Indian population (Siddhartha, 2001; Nagarajan, Ramkumar, Kapooria & Supraba, 2011).

2.6. Multi Frequency and Multi Component Tympanometry in individuals with inner ear pathology

Hanks and Rose (1993) studied multifrequency tympanometry using a sweep frequency method in normal hearing children and with severe to profound hearing impairment in the age range of 6 to 15 years. Results showed that the mean Resonance Frequency value for all children was 1003 Hz (650 to l400 Hz range) and phase angle, $\Delta\theta$ had a mean of 31° (14° to 54° range). It was concluded from this study that if the parameters of MFT are used appropriately, they aid as a better tool in identifying middle ear disorders in children. No statistically significant difference was found between the two groups which suggest that both the groups have similar middle ear characteristics

(Sato et al., 2002) Studied MFT in 13 individuals with an enlarged vestibular aqueduct, 17 normal-hearing individuals and 17 subjects with sensorineural hearing loss in the adult population. Results showed that the resonance frequency of the vestibular aqueduct is lesser than that of the other two groups. The mean was 777.3 Hz in individuals with an enlarged vestibular aqueduct, 956.2 Hz in normal-hearing individual, and 944 Hz for the person with sensorineural hearing loss.

Authors have suggested the reason could be that the mechanical impedance at the stapes footplate is inversely proportional to the cochlear fluids volume, an increase of the volume of cochlear fluid may be resulted in the reduction in fundamental frequency which was measured using multifrequency tympanometry.

The multifrequency tympanometry can also be used to detect the inner ear defects which was evidently seen in Meniere’s disease that is changes in pressure and endolymph fluid within the cochlea also lead to very slight but essential changes parameters of in multifrequency tympanometry.

The middle ear resonance seems to be determined not only by the mass and stiffness of the middle ear system but also by the cochlear mechanical impedance. The proposed mechanisms include the effect of the increased amount of endolymph on the mechanical impedance at the stapes footplate or a "third window" effect, which can reduce the RF of the entire system.

CHAPTER 3

METHODS

The study aimed at examining the middle ear admittance parameters by using multi frequency tympanometry in children with and without congenital sensorineural hearing loss. The specific objectives of the study were: (a) to estimate the multifrequency parameters in children with congenital sensorineural hearing loss across the frequencies from 260Hz to 2000Hz (b) to estimate the multifrequency parameters in children with normal hearing across frequencies from 260Hz to 2000Hz.and normal children and (c) to compare the multifrequency parameters across the frequencies from 260Hz to 2000Hz between normal and congenital sensorineural hearing loss. The method followed in the study is discussed in the following sections.

3.1. Participants

A total of 50 children participated in the study, and they were divided into two groups. The first group consisted of 30 children with congenital sensorineural hearing loss in the age range of 3-7 years. The second group consists of 20 children with normal hearing in the age range of 3-7 years.

3.1.1. Inclusion criteria

The participants of the study in group 1 had a pure tone threshold of more than 70dBHL, i.e., a degree of severe sensorineural or profound hearing loss with congenital in nature and also in nonsyndromic condition and they had normal findings in conventional tympanometric results, i.e., more than 0.2 mmhos of compliance, tympanometric width of less than 200 daPa and middle ear pressure of less than

-200daPa and absence of acoustic reflex threshold at 500Hz, 1KHz, 2KHz, and 4KHz. Their otoacoustic emissions in all the conventional frequencies were absent and no peak present at 90dBnHL in auditory brainstem response. The participants of the study in group 2 had a pure tone threshold of less than or equal to 15dBHL. They had Normal findings in tympanometry(i.e., more than 0.2 mmhos of compliance, tympanometric width of less than 200 daPa and middle ear pressure of less than -200daPa) and presence of acoustic reflex threshold at 500Hz, 1KHz, 2KHz, and 4KHz and they had no other medical complaints.

3.2. Ethical consideration

The testing procedure was explained to the parents of the participants, and written informed consent was taken before the commencement of the experiment. The study adhered to ethical guidelines as per the "ethical guidelines for Bio-behavioural research at All India Institute of Speech and Hearing, Mysore" (Basavaraj & Venkatesan, 2009)

3.3. Procedure

Testing was administered in a double sound-treated room with appropriate acoustic isolation and with criteria for maximum permissible ambient noise recommended by ANSI/ASA S3.1-1999 (R2018). Subjects who full fill the inclusion criteria were taken for the study. The study involves the following tests.

3.3.1. Otoscopic evaluations

Followed by the detailed case history for probing any compliant or history of middle ear functioning and hearing status, Otoscopic assessment was performed by an ENT specialist or clinical audiologist for interpreting the middle ear status.

3.3.2 Measurement of hearing thresholds

3.3.2.1. *Pure tone audiometry:*

Using calibrated clinical diagnostic audiometer satisfying ANSI S3.6-2004. Conventional audiometry was used for the study, i.e., the response is made similar to which is done for adults such as conditioning the child to raise their hands in response to the sound. Conditioned play audiometry was done in the case of children who perform difficulty in understanding the conventional audiometry. The modified Hughson and Westlake procedure(Carhart & Jerger, 1959) was used to determine thresholds at a conventional frequency(250Hz, 500Hz, 1KHz, 2KHz, 4KHz, and 8KHz) with the help of TDH-39 earphones for air conduction mode and only up to 4 kHz by using B-71 bone transducer in the bone conduction mode were determined using a calibrated audiometer.

3.3.2.2. *Auditory brainstem response (ABR):*

ABR was done in addition to behavioral audiometry to estimate the hearing. Intelligent Hearing System (IHS) or Biologic EP was used in which the stimulus was presented through an ER-3A insert receiver using the standard test protocol for children.

3.3.3. Physiological measurement

3.3.3.1. *Conventional single-frequency tympanometry:*

The immittance was evaluated using a calibrated GSI-Tympstar meter (version 2) satisfying ANSI S3.6-2004 with the probe tone frequency of 226Hz. Acoustic reflex thresholds were measured in 500Hz, 1 kHz, 2 kHz, and 4 kHz ipsilaterally and contralaterally.

3.3.3.2. *Otoacoustic emissions (OAE):*

A calibrated Otodynamics ILO V6 Echoport system was used to obtain the DPOAE (distortion product otoacoustic emissions) or TEOAE (transient evoked otoacoustic emissions) to check the cochlear integrity of the ear.

3.3.4. Measurement of Multifrequency Tympanometry

Multifrequency and multicomponent tympanometry were evaluated using a calibrated GSI-Tympstar meter (version 2) satisfying ANSI S3.6-2004. For measuring multifrequency parameters, the procedure described by (Funasaka, Funai, & Kumakawa, 1984), i.e., the sweep frequency method of multifrequency tympanometry, was used. In the sweep frequency tympanometry, the frequency was swept twice from 200 to 2000 Hz at two different pressures, i.e., +200 daPa and the peak pressure. Susceptance and phase measurements at each frequency were automatically stored in the memory of the equipment. At +200daPa, the vectors were measured as Y_{+200}, B_{+200}, G_{+200} with respect to the selection of delta plots Y, B, and G, respectively. Whereas at peak pressure, the vectors were measured as Y_{peak}, B_{peak}, and G_{peak} with respect to the selection of delta plots Y, B, and G, respectively. The differences of the two vectors (Y_{+200}, B_{+200}, G_{+200} and Y_{peak}, B_{peak}, G_{peak}), i.e. ΔY, ΔB, ΔG was calculated by the device as a function of frequency in step size of 10Hz.

CHAPTER 4

RESULTS

The objectives of this study were to estimate and compare the multifrequency parameters across the frequencies from 260Hz to 2000Hz between normal and congenital sensorineural hearing loss

A total of 50 individuals participated in the study. Among these 20 participants were children with normal hearing, and 30 participants (16 bilateral and 14 unilateral) were children with sensorineural hearing loss. To verify the normality of the sample, the Shapiro Wilk test was administered. Result revealed non-normal distribution. Hence non-parametric tests were used.

4.1. Effect of cochlear pathology on susceptance parameter of the multifrequency tympanometry:

Figure 4.1.1. represents the line graphical representation of the mean of susceptance magnitude curve across the frequency from 260Hz to 2000Hz in children with normal hearing (control group) and children with profound hearing loss (Clinical group).

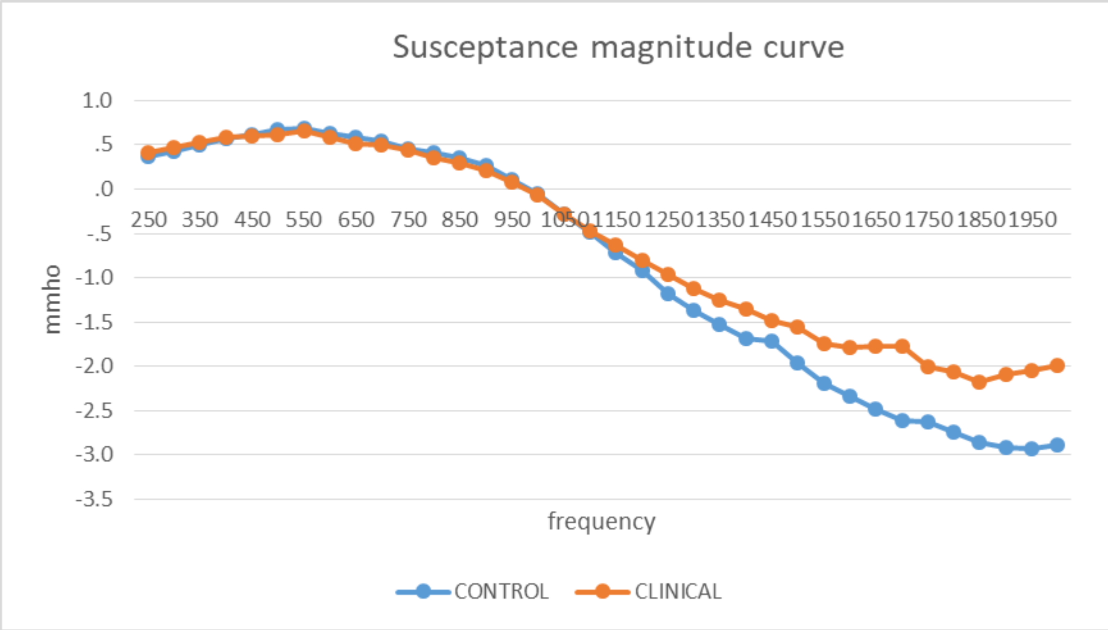

Figure 4.1.1. A plot of delta B (mean) as a function of probe tone frequency in both the groups

Table 4.1.1. *Mean, median and standard deviation of susceptance magnitude across the wide frequency in children with normal hearing and with sensorineural hearing loss*

Frequency (Hz)	**Control Group**			**Clinical Group**		
	Mean	**Median**	**SD**	**Mean**	**Median**	**SD**
250	.37	.36	.11	.41	.43	.15
300	.43	.41	.12	.47	.50	.16
350	.50	.48	.13	.53	.54	.19
400	.57	.55	.16	.59	.60	.20
450	.62	.55	.20	.60	.55	.21
500	.67	.66	.16	.61	.62	.15
550	.69	.71	.18	.66	.64	.14
600	.63	.69	.21	.58	.56	.20

650	.59	.62	.21	.51	.50	.20
700	.55	.55	.21	.49	.50	.21
750	.46	.50	.25	.44	.40	.18
800	.41	.47	.27	.36	.33	.20
850	.35	.45	.36	.30	.22	.24
900	.27	.34	.41	.21	.20	.19
950	.11	.24	.46	.07	.08	.25
1000	-.05	.02	.49	-.07	.01	.36
1050	-.29	-.16	.55	-.29	-.12	.46
1100	-.49	-.49	.53	-.47	-.29	.52
1150	-.72	-.84	.57	-.63	-.52	.66
1200	-.92	-.98	.56	-.81	-.77	.70
1250	-1.18	-1.26	.66	-.96	-.87	.67
1300	-1.36	-1.44	.69	-1.12	-1.12	.65
1350	-1.53	-1.70	.78	-1.25	-1.37	.64
1400	-1.69	-1.81	.89	-1.35	-1.32	.62
1450	-1.71	-1.96	1.14	-1.48	-1.40	.72
1500	-1.96	-2.14	.93	-1.56	-1.48	.68
1550	-2.19	-2.44	.97	-1.75	-1.72	.70
1600	-2.33	-2.63	1.08	-1.78	-1.92	.68
1650	-2.49	-2.81	.90	-1.78	-1.97	.85
1700	-2.60	-2.81	.80	-1.78	-1.88	1.02
1750	-2.62	-2.70	.79	-2.00	-1.94	.66
1800	-2.74	-2.90	.79	-2.05	-2.11	.68
1850	-2.86	-2.96	.87	-2.17	-2.16	.76
1900	-2.92	-3.04	.85	-2.09	-2.00	.71
1950	-2.93	-3.25	.83	-2.04	-1.94	.83
2000	-2.89	-3.19	.84	-1.99	-1.83	.96

Note: 'SD' – Standard deviation

From figure 4.1.1. and table 4.1.1. it can be seen that both the groups have similar susceptance magnitude in the low and mid-frequency range. However, children with profound hearing loss had higher susceptance magnitude, especially at the high frequency and most prominently seen from the probe signal of 1550Hz to 2000Hz.. To evaluate the statistical significance of these observations, the Mann Whitney U test was administered between the groups. Results of Mann-Whitney U Test shown in table 4.1.2. Results reveals that there is a significant difference (p <0.001) between both the groups in a probe frequency of 1550Hz, 1600Hz, 1650Hz, 1700Hz, 1750Hz, 1800Hz, 1850Hz,1900Hz, 1950Hz and 2000Hz

Table 4.1.2.: *Mann-Whitney U Test Group Comparison for delta B*

Frequency (Hz)	**U value**	***p*-value**	**Frequency (Hz)**	**U value**	***p*-value**
260	777.0	.215	1150	768.5	.189
300	773.5	.204	1200	741.0	.121
350	866.0	.640	1250	729.0	.098
400	865.5	.637	1300	737.0	.113
450	905.0	.897	1350	715.0	.076
500	753.5	.149	1400	717.5	.079
550	808.5	.334	1450	766.5	.184
600	802.0	.307	1500	696.5	.053
650	727.0	.095	1550	631.5	.012*
700	766.5	.184	1600	547.0	<0.001**
750	808.0	.332	1650	505.0	<0.001**
800	740.0	.119	1700	429.0	<0.001**
850	757.0	.158	1750	511.0	<0.001**
900	709.0	.068	1800	462.5	<0.001**
950	729.5	.099	1850	507.5	<0.001**
1000	858.0	.591	1900	431.5	<0.001**
1050	836.0	.467	1950	397.5	<0.001**
1100	890.5	.798	2000	406.5	<0.001**

Note: ** indicates a highly significant difference (p<0.001)

: * indicates a significant difference (p<0.05

4.2. Effect of cochlear pathology on conductance parameter of the multifrequency tympanometry

Figure 4.2.1. represents the line graphical representation of the mean of conductance magnitude curve across the frequency from 260Hz to 2000Hz in children with normal hearing (control group) and children with profound hearing loss (Clinical group).

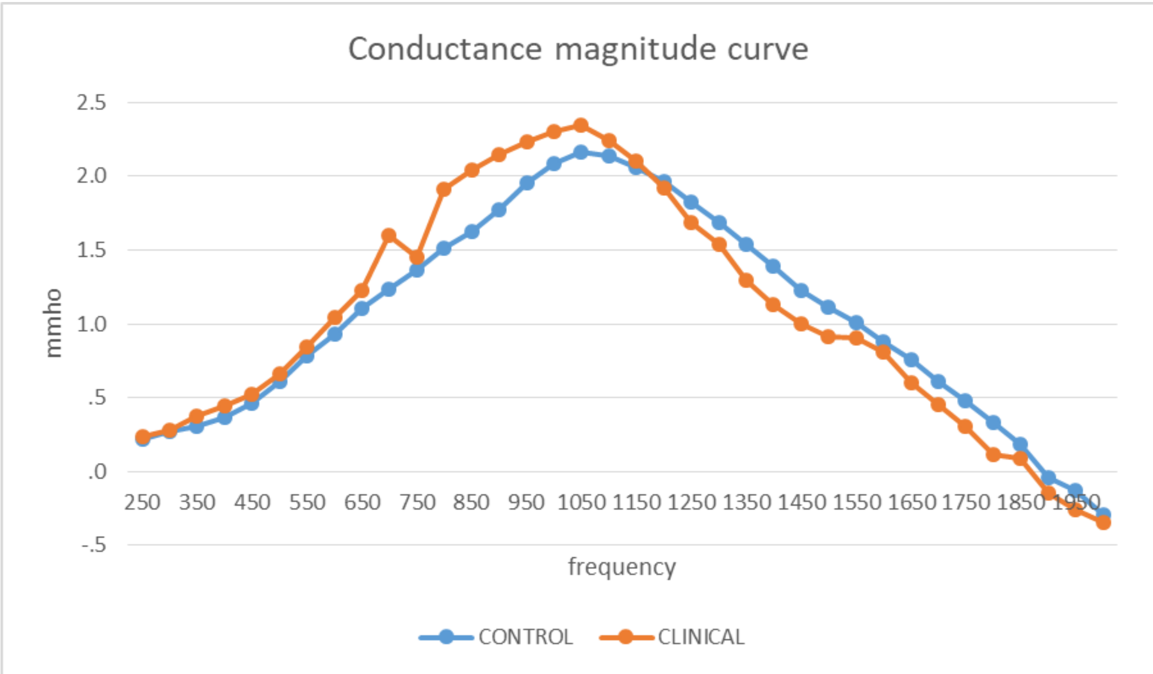

Figure 4.2.1. A plot of delta G (mean) as a function of probe tone frequency obtained using GSI-Tympstar

Table 4.2.1. *Mean, median and standard deviation of conductance magnitude across the wide frequency in children with normal hearing and sensorineural hearing loss*

Frequency (Hz)	**Control Group**			**Clinical Group**		
	Mean	**Median**	**SD**	**Mean**	**Median**	**SD**
250	.22	.21	.10	.24	.24	.08
300	.27	.26	.12	.28	.29	.09
350	.31	.31	.11	.38	.36	.19
400	.37	.37	.14	.45	.43	.22
450	.46	.47	.17	.52	.51	.22
500	.61	.56	.26	.66	.59	.29
550	.78	.79	.37	.85	.89	.35
600	.93	.91	.43	1.04	.99	.44
650	1.10	.99	.61	1.22	1.02	.71
700	1.23	1.10	.73	1.60	1.32	1.01
750	1.36	1.23	.75	1.45	1.21	.88
800	1.52	1.33	.87	1.91	1.57	1.20
850	1.62	1.29	.89	2.04	1.76	1.21
900	1.78	1.54	.88	2.15	1.91	1.17
950	1.96	1.80	.84	2.23	2.08	1.09
1000	2.09	1.88	.91	2.30	2.25	1.09
1050	2.17	1.89	.88	2.34	2.42	1.08
1100	2.13	1.89	.81	2.24	2.35	1.07
1150	2.06	2.00	.80	2.11	2.21	1.01
1200	1.96	1.83	.79	1.92	2.02	.99
1250	1.83	1.76	.77	1.69	1.70	.93
1300	1.69	1.67	.79	1.54	1.60	.99
1350	1.54	1.68	.73	1.29	1.50	.84
1400	1.39	1.64	.77	1.13	1.37	.85

1450	1.22	1.51	.82	1.00	1.11	.87
1500	1.11	1.24	.92	.91	1.05	.92
1550	1.01	1.18	1.02	.90	.97	.94
1600	.87	1.01	1.10	.81	.88	1.02
1650	.76	.95	1.15	.60	.66	1.14
1700	.61	.71	1.17	.46	.45	1.14
1750	.48	.63	1.12	.31	.25	1.11
1800	.33	.31	1.05	.12	-.01	1.11
1850	.18	.17	1.01	.09	.14	1.18
1900	-.04	-.07	.91	-.15	-.10	1.20
1950	-.13	-.14	.90	-.26	-.24	1.18
2000	-.29	-.20	.91	-.35	-.32	1.18

Note: 'SD' – Standard deviation

From figure 4.2.1. and the table 4.2.1 it can be seen that both the groups have similar conductance magnitude in all the frequency range. To evaluate the statistical significance of these observations, the Mann Whitney U test was administered between the groups. Results of the Mann-Whitney U Test shown in table 4.2.2. Results reveal that there is no significant difference ($p > 0.05$) between both the groups across the frequency range.

Table 4.2.2. *Mann-Whitney U Test Group Comparison for delta G*

Frequency (Hz)	**U value**	***p*-value**	**Frequency (Hz)**	**U value**	***p*-value**
260	803.5	.313	1150	865.0	.634
300	808.5	.334	1200	914.0	.959
350	735.0	.109	1250	855.0	.574
400	752.0	.145	1300	850.5	.547
450	778.0	.219	1350	735.5	.110
500	816.5	.370	1400	735.0	.109
550	804.0	.315	1450	752.5	.147
600	783.0	.235	1500	768.0	.188
650	825.0	.411	1550	825.0	.411
700	705.5	.063	1600	884.0	.755
750	865.5	.637	1650	861.0	.609
800	742.0	.123	1700	859.5	.600
850	718.0	.080	1750	843.5	.508
900	728.0	.096	1800	814.0	.359
950	754.5	.152	1850	874.5	.694
1000	777.0	.216	1900	865.0	.634
1050	813.5	.356	1950	866.5	.643
1100	835.5	.464	2000	888.0	.782

4.3. Effect of cochlear pathology on admittance(Y) parameter of the multifrequency tympanometry

Figure 4.3.1. represents the line graphical representation of the mean of admittance magnitude curve across the frequency from 260Hz to 2000Hz in children with normal hearing (control group) and children with profound hearing loss (Clinical group).

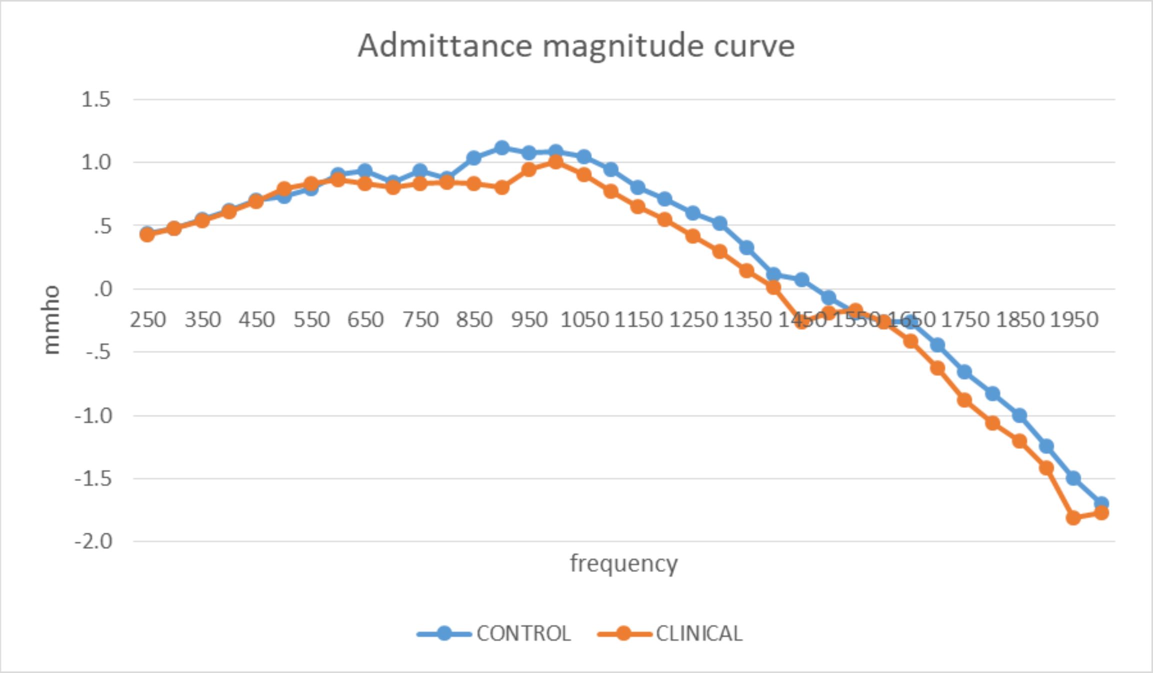

Figure 4.3.1. A plot of delta Y (mean) as a function of probe tone frequency obtained using GSI-Tympstar

Table 4.3.1. *Mean, median and standard deviation of admittance magnitude across the wide frequency in children with normal hearing and sensorineural hearing loss*

Frequency (Hz)	**Control Group**			**Clinical Group**		
	Mean	**Median**	**SD**	**Mean**	**Median**	**SD**
250	.44	.43	.15	.43	.42	.16
300	.48	.46	.16	.48	.47	.18
350	.55	.50	.18	.54	.53	.20
400	.63	.57	.22	.61	.60	.26
450	.71	.66	.26	.69	.65	.29
500	.73	.69	.50	.79	.73	.34
550	.80	.82	.55	.83	.76	.42
600	.91	.89	.40	.86	.82	.47
650	.94	.88	.40	.84	.82	.56

700	.84	.91	.57	.81	.81	.69
750	.94	.89	.41	.84	.77	.74
800	.88	.80	.56	.84	.78	.79
850	1.04	.94	.53	.83	.71	.80
900	1.12	1.00	.63	.80	.75	.81
950	1.08	1.14	.61	.95	.87	.77
1000	1.08	1.11	.73	1.00	.79	.81
1050	1.04	.92	.77	.91	.83	.79
1100	.94	.96	.80	.78	.66	.78
1150	.80	.74	.84	.65	.65	.77
1200	.71	.71	.87	.55	.62	.84
1250	.60	.61	.91	.42	.52	.84
1300	.52	.61	.94	.30	.37	.89
1350	.33	.42	.93	.14	.17	.87
1400	.12	.38	.98	.01	.06	.95
1450	.07	.31	1.07	-.26	-.32	1.05
1500	-.06	.34	1.07	-.19	.26	1.18
1550	-.19	-.07	1.21	-.17	.22	1.31
1600	-.26	-.19	1.25	-.26	-.03	1.32
1650	-.27	-.32	1.16	-.41	-.34	1.35
1700	-.44	-.45	1.00	-.63	-.60	1.24
1750	-.65	-.63	.89	-.88	-.76	1.19
1800	-.83	-.70	.85	-1.06	-.90	1.15
1850	-1.00	-.78	.82	-1.20	-1.01	1.11
1900	-1.24	-.93	.84	-1.41	-1.06	1.01
1950	-1.50	-1.27	.80	-1.81	-1.31	1.24
2000	-1.70	-1.32	.88	-1.77	-1.54	1.19

Note: 'SD' – Standard deviation

From figure 4.3.1. and table 4.3.1. it can be seen that both the groups have similar admittance magnitude in all the frequency range except at mid-frequency range. To evaluate the statistical significance of these observations, the Mann Whitney U test was administered between the groups. Results of the Mann-Whitney U Test shown in table 4.3.2. Results reveal that there is no significant difference ($p > 0.05$) between both the groups across the frequency range.

Table 4.3.2. *Mann-Whitney U Test Group Comparison for delta Y*

Frequency (Hz)	**U value**	***p*-value**	**Frequency (Hz)**	**U value**	***p*-value**
260	888.5	.785	1150	792.0	.268
300	903.0	.883	1200	788.0	.253
350	913.5	.955	1250	803.5	.313
400	908.5	.921	1300	773.0	.203
450	840.5	.491	1350	792.5	.269
500	885.0	.762	1400	868.5	.655
550	901.5	.873	1450	735.5	.110
600	887.5	.778	1500	891.5	.805
650	821.5	.394	1550	889.0	.788
700	857.0	.585	1600	906.5	.907
750	854.0	.568	1650	889.5	.792
800	866.0	.640	1700	841.5	.496
850	785.5	.244	1750	837.0	.472
900	718.0	.080	1800	810.0	.340
950	829.5	.433	1850	816.0	.368
1000	893.5	.818	1900	770.0	.194
1050	841.5	.497	1950	832.0	.446
1100	799.5	.297	2000	905	.897

4.4. Effect of cochlear pathology on phase angle parameter of the multifrequency tympanometry:

Figure 4.4.1 represents the line graphical representation of the mean of phase angle measurement curve across the frequency from 260Hz to 2000Hz in children with normal hearing (control group) and children with profound hearing loss (Clinical group).

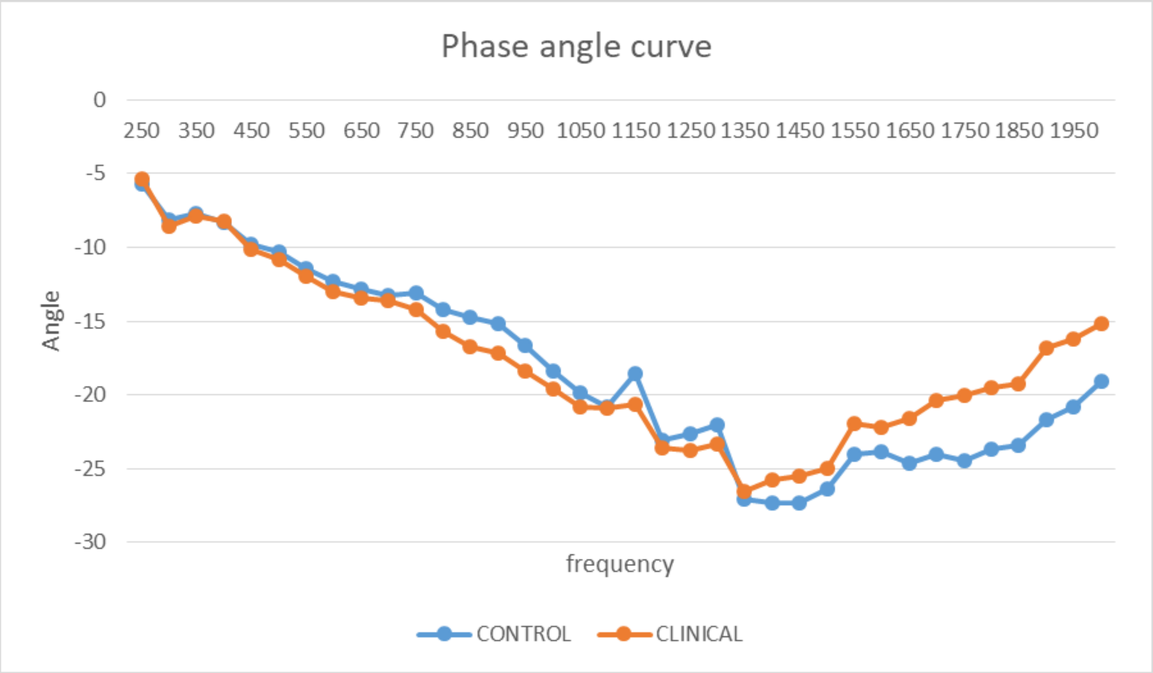

Figure 4.4.1. A plot of delta θ (mean) as a function of probe tone frequency obtained using GSI-Tympstar

Table 4.4.1. *Mean, median and standard deviation of phase angle across the wide frequency in children with normal hearing and sensorineural hearing loss*

Frequency (Hz)	**Control Group**			**Clinical Group**		
	Mean	**Median**	**SD**	**Mean**	**Median**	**SD**
250	-5.7	-6.0	2.2	-5.3	-4.0	2.0
300	-8.2	-8.0	3.9	-8.6	-9.0	3.7
350	-7.7	-10.0	4.1	-7.9	-8.0	3.5
400	-8.4	-10.0	4.1	-8.2	-10.0	4.4
450	-9.8	-10.0	3.2	-10.2	-10.0	2.3
500	-10.4	-12.0	2.8	-10.8	-11.0	2.0
550	-11.4	-14.0	3.5	-12.0	-13.0	2.6
600	-12.3	-14.0	3.2	-13.0	-14.0	2.6
650	-12.9	-14.0	3.4	-13.5	-14.0	3.2
700	-13.3	-14.0	3.4	-13.7	-15.0	3.5
750	-13.1	-14.0	6.0	-14.3	-14.0	5.7
800	-14.2	-14.0	3.8	-15.7	-16.0	5.6
850	-14.8	-14.0	4.2	-16.7	-14.0	6.3
900	-15.2	-16.0	3.8	-17.2	-17.0	6.9
950	-16.7	-18.0	3.8	-18.3	-18.0	6.7
1000	-18.4	-20.0	4.5	-19.6	-20.0	6.6
1050	-19.9	-20.0	5.4	-20.8	-20.0	6.7
1100	-20.8	-22.0	5.5	-20.9	-22.0	6.7
1150	-18.6	-22.0	14.1	-20.7	-23.0	12.6
1200	-23.1	-24.0	6.1	-23.6	-24.0	7.8
1250	-22.7	-24.0	9.7	-23.7	-24.0	7.5
1300	-22.0	-26.0	13.1	-23.3	-26.0	10.1
1350	-27.1	-28.0	8.3	-26.6	-30.0	8.3
1400	-27.4	-30.0	9.2	-25.8	-24.0	9.3

1450	-27.4	-28.0	9.2	-25.5	-22.0	9.2
1500	-26.4	-24.0	9.4	-25.0	-24.0	9.1
1550	-24.1	-20.0	9.6	-22.0	-20.0	7.6
1600	-23.9	-20.0	9.8	-22.2	-20.0	6.8
1650	-24.6	-21.0	10.7	-21.6	-20.0	6.9
1700	-24.0	-20.0	11.4	-20.4	-20.0	7.3
1750	-24.5	-21.0	12.2	-20.0	-18.0	8.1
1800	-23.7	-20.0	12.0	-19.5	-18.0	8.1
1850	-23.5	-21.0	11.0	-19.3	-16.0	7.9
1900	-21.7	-21.0	11.4	-16.8	-12.0	8.8
1950	-20.9	-19.0	11.1	-16.2	-12.0	8.7
2000	-19.1	-19.0	10.9	-15.2	-12.0	8.8

Note: 'SD' – Standard deviation

From figure 4.4.1 and table 4.4.1, it can be seen that both the groups have similar phase angle measurements in all the frequency range except at high frequency range. To evaluate the statistical significance of these observations, the Mann Whitney U test was administered between the groups. Results of the Mann-Whitney U Test shown in table 4.4.2. Results reveal that there is no significant difference ($p > 0.05$) between both the groups across the frequency range.

Table 4.4.2. *Mann-Whitney U Test Group Comparison for delta θ*

Frequency (Hz)	**U value**	***p*-value**	**Frequency (Hz)**	**U value**	***p*-value**
260	817.0	.340	1150	858.0	.589
300	860.5	.597	1200	876.0	.701
350	907.0	.908	1250	894.5	.823
400	892.0	.802	1300	899.5	.858
450	905.5	.897	1350	908.5	.919
500	874.0	.677	1400	826.5	.412
550	877.0	.692	1450	819.5	.379
600	816.0	.356	1500	853.0	.559
650	812.5	.337	1550	874.5	.687
700	852.5	.545	1600	915.5	.969
750	825.5	.407	1650	850.5	.540
800	813.5	.348	1700	815.5	.355
850	772.0	.193	1750	773.0	.196
900	760.0	.159	1800	765.5	.173
950	825.5	.396	1850	752.0	.136
1000	833.5	.440	1900	708.0	.063
1050	850.5	.542	1950	703.5	.058
1100	880.5	.725	2000	757.5	.152

CHAPTER 5

DISCUSSION

The main objective of the study was to measure and compare the multifrequency parameter of admittance, conductance, and susceptance and phase angle across the probe frequency from 260Hz to 2000Hz in children with normal hearing individuals and with sensorineural hearing loss in the age range between 3 to 7 years.

A novel attempt was made in the present study to calculate the frequency-specific magnitude of admittance component (delta Y) and also its subcomponent that includes susceptance (delta B) and conductance (delta G) then the degree of phase angle (delta Θ) across the multifrequency probe tone from 260Hz to 2000Hz in a step size of 50Hz.

In the results of the susceptance magnitude curve, the mean scores were similar from 260Hz to 1500Hz, and the Mann Whitney U test reveals that there no statistical significance difference between both the groups. However, above 1500Hz, there found a statistical significance ($p<0.001$) till 2000Hz. It suggests that there is an increase in the mass or stiffness reactance at a high-frequency probe tone.

Susceptance (B) is referred to as the "stiffness" of the middle ear system and refers to the relationship between the springy parts and the mass of the middle ear. In other words, this is the way the ligaments, tendons, and muscles work with the bones in the middle ear to transmit sound.

Due to cochlear pathology, mass and stiffness with the other physical properties of the middle ear and the cochlear partition effect on the peculiar characteristics of transmission of the middle ear and the behavior to different frequencies of stimulation in the cochlear partition.

The frequency at which the delta B closest to zero corresponds to the resonant frequency of the middle. In the present study, 1000Hz is considered as the resonant frequency in children with normal hearing and also in sensorineural hearing loss. This supports various studies done on estimating resonant frequency in normal and cochlear pathology. Kumar K.S & Basavaraj (2009) found the resonant frequency of 1087Hz in 3 to 4 years, 1059Hz in 4 to 5 years, and 1049Hz in 5 to 6 years old. (Hanks & Rose, 1993) studied the middle ear characteristic of sensorineural hearing impairment. They found there was no statistical significance between normal and SNHL children and mean (M) resonance frequency of 1003Hz.

The reactive part of the impedance representing the stiffness-mass component is almost the same with and without the cochlea, indicating that its mechanical impedance is virtually a pure resistance. (Møller, 1965)

These results indicated that susceptance related parameters would be clinically useful in the differential diagnosis various middle ear pathologies when tympanometry measuring at higher probe frequency

Results of other subcomponents of admittance, i.e., conductance and admittance and phase angle shown that there is no statistical significance seen in all the probe frequency between both the groups. However, the mean scores of conductance magnitude are comparably higher at low frequency from 260Hz till resonant frequency seen in children with cochlear hearing loss. A possible reason could be due to low resistance when the cochlea gets disconnected, which leads to an increase in conductance. However, it was not statistically significant in the present study. A study done by Maruthy, Megha, Kumar K.S (2012) measures delta G, delta Y, and delta Θ at RF and F45 in a normal individual and sensorineural hearing loss in adult population at an age range of 10 to 40 years. Results showed that there was a significant difference present only at the conductance parameter. It suggests that due to cochlear dysfunction, resistance seems to be lower, which causes an increase in conductance. These findings suggest that if an ear has middle ear pathology along with cochlear hearing loss, one needs to keep in mind the cochlear contribution to conductance while interpreting the middle ear pathology. However, other MFT parameters like phase angle and admittance are not influenced by cochlear dysfunction across the frequency. Even susceptance also not influenced at low frequency to resonance frequency by cochlear dysfunction.

Furthermore, the inferences are drawn, however, shall be restricted to conductance at RF and may not apply to the conductance at other frequencies. That is, conductance may not be affected (higher) at higher probe frequency in ears with cochlear hearing loss.

CHAPTER 6

SUMMARY AND CONCLUSION

Low-frequency tympanometry often fails to admit noticeable tympanometric patterns for various middle ear disorders, which affects the middle ear properties, exceptionally low impedance pathologies like otosclerosis. This is because the tympanic membrane dominates its patterns, which overshadows the conditions affecting more medial structures of the middle ear.

Heyning et al. (1982) reported that tympanometry with high frequency probe tones enables a better distinction of tympanometric patterns from the pathological ear. Multifrequency tympanometry (MFT) uses two or more frequencies to measure the tympanogram, and also it measures various admittance aspects of the ear over the broad frequency range. Even the minute changes in the sound transmission through the middle ear can be easily detected and also sensitive in multifrequency tympanometry when compare to standard low-frequency tympanometry. It has also been recently used to detect inner ear defects, and literature reported that cochlear mechanical impendence might affect the resonance frequency of the middle ear transaction.

The primary objective of this study is to know multifrequency admittance components with a phase angle across the broad frequency range in children with sensorineural hearing loss. Fifty children participated in this study, among which 20 were normal, and 30 were children with sensorineural hearing loss.

Results revealed that overall multifrequency parameters show similar functions in normal and children with sensorineural hearing loss except the comparable change in susceptance magnitude at high frequency, which was a statistically significant and apparent increase in conductance magnitude at the low and resonant frequency which was not statistically significant from normal hearing individuals. This suggests that multifrequency parameters play a role in understanding middle ear function while influenced by cochlear dysfunction.

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