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STATIC COMPLIANCE AND WIDEBAND ABSORBANCE IN ADULT AND CHILDREN

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ABSTRACT

Introduction - Immittance audiometry is the traditional measure to evaluate the status of middle ear. In recent years a new measure of middle ear called Wideband absorbance is gaining interest amongst the audiologist and ENTs. Wideband Absorbance (MEA) is a wideband measurement of the middle ear function that provide information about how much sound energy is absorbed by the middle ear over a wide range of frequency. **Aim -** This study is to compare Traditional Immittance Measure that is Static Compliance with Modern Middle Ear measure that is Wideband Absorbance. **Method -** In this study the comparison was done between static compliance and wideband absorbance and also the comparison of static compliance and wideband absorbance in children and adults. A total number of 30 participants were included in this study. Fifteen participants were normal hearing adults with the age range between 10 to 30 years. Other fifteen were normal hearing children who were of age between 7 and 12 years. **Results -** Static compliance and wideband absorbance were measured in the entire participants at 226, 678, 800 and 1000 Hz. The same values were used for statistical analysis. This study showed a positive correlation between static compliance and wideband absorbance in both normal hearing children and normal hearing adults at all the frequencies (226, 678, 800 and 1000 Hz) expect at 226 Hz in normal hearing children at which the correlation was absent. **Conclusion -** Wideband Absorbance is a valuable clinical tool for assessing the conductive pathway. Wideband Absorbance had higher test performance against composite test batteries compared to single test reference standards in identifying disorders of the conductive system. Wideband Absorbance could be used as a single clinical tool with test performance which is as good as the test battery reference standards.

KEYWORDS: Static compliance, Wideband absorbance, Impedance, Admittance, Reflectance.

INTRODUCTION

Human auditory system is divided into outer ear, middle ear and inner ear. Middle ear is an air-filled cavity which lies between tympanic membrane and oval window that help in transmitting sound from outer ear to inner ear. Middle ear consists of three bones: Malleus, incus and stapes. Sound pressure from the coming acoustic wave vibrates the tympanic membrane.

Middle ear components modify the transmission of acoustic energy from the air of external ear canal into the fluid with in inner ear. If sound reaches oval window directly most of it will be reflected back due to the resistance of oval window and also fluids impedance is greater than impedance of air it results in impedance miss match. The middle ear acts as an impedance matching device that improves the sound transmission and reduces the amount of reflected sound. The middle ear system thus, makes it possible for the sound energy to be efficiently transmitted from the air to the cochlea.

Two mechanisms with in the middle ear are responsible for doing so. Middle ear mechanism is designed to increase the pressure advancing to the cochlea, thereby overcoming the resistance to flow of energy, termed impedance. The pressure of the sound waves on the oval window is some 20 times higher than on the tympanic membrane. The pressure is increased due to the difference in size between the relatively large surface of the tympanic membrane and the smaller surface of the oval window. Transfer of force from tympanic membrane to stapes foot plate depends on action of ossicles which work as a lever system. The lever action of this system is 1.3:1; therefore, force at tympanic membrane is increased by 1.3 at the stapes. This is how the middle ear makes the most significant contribution for amplifying and modifying the spectrum of the sound wave.

Immittance audiometry is the traditional measure to evaluate the status of middle ear. Acoustic immittance is the term used to collectively refer acoustic impedance (Z) and acoustic admittance.[1] Acoustic impedance refers to the resistance to the flow of sound energy through an acoustic medium. The acoustic admittance describes the ease with which the sound energy is transmitted through an acoustic medium. It is important to know that acoustic impedance or acoustic admittance does not tell about how much sound energy is actually absorbed by the middle ear.[2] C.G.S units of impedance and admittance ohm and mho respectively.[1,2] Admittance or impedance can also be expressed in terms of volume (ml/cc^3) under standard atmospheric condition or if corrected for change in these condition.[2] Most of the currently available instrument uses the term static compliance (in ml or cc^3) in place of admittance or impedance.[1,2] Static compliance is also the most widely used measure of estimating middle ear function where a low static compliance value indicates increased middle ear stiffness (which commonly occur in most middle ear disorder) and vice versa. Though it is one of the most successful and reliable measure but it fails to provide frequency specific information as only one frequency particularly 226 Hz is used to obtain static compliance. It is 226 Hz probe tone which is mostly used in measuring static compliance especially in adults. In children it is suggested to use higher probe tone such as 678, 800 or 1000 Hz.[3] This is because of the difference in the middle ear properties of adults and children. Middle ear of adults is stiffness dominated while that of children is mass dominated.

Another limitation of static compliance is that it doesn't give information on the amount of energy absorbed by the middle ear and how much is reflected back. This information is audiologically necessary as it would give an elaborative idea about the frequencies at which hearing might get affected in presence of a particular disorder.

In recent years a new measure of middle ear called Wideband absorbance is gaining interest amongst the audiologist and ENTs. Wideband Absorbance (MEA) is a wideband measurement of the middle ear function that provide information about how much sound energy is absorbed by the middle ear over a wide range of frequency. It is defined as the ratio of sound absorbed by the middle ear to the sound incident to into the external auditory canal.[4] Previously it was also called "transmittance" by Keefe and Simmons (2003).[4] Wideband Absorbance is a simple modification of another wideband measurement of the middle ear functioning known as middle ear reflectance [MER],[5] which is defined as the ratio of sound energy reflected at the tympanic membrane to sound energy incident to the middle ear.[6] Considering the energy conservation law and that no sound energy is absorbed by the ear canal walls the two measurements are related as; Wideband Absorbance = 1 – MER. Liu et al. (2008)[5] suggested that clinically the interpretation of the middle ear function based on the Wideband absorbance estimation would be rather easy than MER.

In contrast to traditional immittance measurements, wideband absorbance measurements can be measured from 226 Hz to 8 kHz. According to Keefe et al. (2000),[7] wideband absorbance has several advantages over Tympanometry : Wideband immittance is a very fast test, requiring only several seconds to acquire a response; unlike tympanometry, it can measure energy transmission under ambient pressure conditions; it measures a wide range of frequencies from 250 to 8000 Hz and provides more detailed information on the status of the outer and middle ear; it provides clinical information on the range of frequencies crucial for speech perception, and it is less susceptible to environmental and subject noise.

Need of the study

Since the wideband absorbance measurement became available several studies have been conducted to develop its age related normative,[8][9] how the measure looks like in various middle ear disorders,[10] and the usage of wideband absorbance in estimating acoustic reflexes.[11] Most of these studies are done in the western countries as the measure is only lately introduced elsewhere. As a first step to understand the wideband absorbance in details it is important to find out that how this measurement is related to the traditional immittance measure of static compliance. Presently no such study has been reported in literature especially in Indian context. There is also a need to see if there are adult-child differences present in the measure of wideband absorbance as some differences are mentioned in literature taking static compliance into consideration mainly when it is measured with different probe tone i.e., 226, 678, 800 and 1000 Hz.

Aim of the study

Aim of the study is to compare Traditional Immittance Measure that is Static Compliance with Modern Middle Ear measure that is Wideband Absorbance.

Objectives of the study

- To study and compare the static compliance and wideband absorbance
- To compare the static compliance and wideband absorbance in children and adults

METHODOLOGY

Participants - A total number of 30 participants were included in this study. Fifteen participants were normal hearing adults with the age range between 10 to 30 years. Other fifteen were normal hearing children who were of age between 7 and 12 years. Details subject inclusion criteria for all the participants are mentioned below:

1. Normal air conduction thresholds at 250, 500, 1000, 2000 and 4000 Hz.
2. Normal bone conduction thresholds at 250, 500, 1000, 2000 and 4000 Hz.
3. Positive Rinne test.
4. Static compliance more than 0.2 ml.
5. Acoustic reflex present at 500, 1000 and 2000 Hz.
6. Normal otoscopic examination.
7. Details of instruments used for including participants in the study
a. A calibrated two channel diagnostic audiometer (MAICO MA 53).
b. 500 Hz Tuning fork.
c. A GSI Tympstar immittance audiometer
d. Welch Allyn otoscope
8. Test environment: All the audiological evaluation was carried out in air-conditioned sound treated room. The ambient noise level was within the permissible limits. The test room were with adequate illumination and seating situation.

Instrumentation used for experiment

1. A calibrated clinical Immittance audiometer (GSI Tympstar). It was used for measuring static compliance at 226, 678, 800 and 1000 Hz.
2. A calibrated Interacousitc TITAN was used for measuring wideband absorbance.

Experimental procedural steps

1. Participants were asked to sit comfortable in an air-conditioned sound treated room.
2. Participants were instructed to not make any movement while making the measurements.
3. They were also asked not to swallow during the testing.
4. In the first run static compliance was measured at 226, 678, 800 and 1000 Hz in all the participants.
5. Following these measurements, a gap of 15 minutes was given.
6. Absorbance was measured in the second run.

Analysis for absorbance data

Interacoustic TITAN measure and provide absorbance values at frequencies ranging from 226Hz to 8000 Hz. Absorbance values at all the frequencies are also provided at various pressures from +200 dapa to -400 dapa. As the study was indented to compare absorbance and static compliance at peak pressure and also that GSI Tympstar provide static compliance at peak pressure, absorbance value at 226, 678, 800 and 1000 Hz were taken only at peak pressure. The same values were used for the statistical analysis.

RESULTS

This study was conducted to compare the traditional middle ear measures of static compliance with recent middle ear measure of wideband absorbance. Normal hearing adult and normal hearing children were also compared for both the measures. Static compliance and wideband absorbance were measured in the entire participants at 226, 678, 800 and 1000 Hz. The same values were used for statistical analysis.

Mean and standard deviation of static compliance at 226, 678, 800 and 1000 Hz in both normal hearing adults and normal hearing children are mentioned in table 1. Figure 5 shows Mean and standard deviation of static compliance at 226, 678, 800 and 1000 Hz in both normal hearing adults and normal hearing children.

Table 1: Shows mean and standard deviation of static compliance in normal hearing adults and normal hearing children.

Adults – Static Compliance				
Frequency	**226Hz**	**678Hz**	**800Hz**	**1000Hz**
Mean	0.66	1.58	1.56	1.32
Standard deviation	0.34	0.69	0.59	0.54
Children-Static compliance				
Frequency	**226Hz**	**678Hz**	**800z**	**1000Hz**
Mean	0.44	1.10	1.20	0.99
Standard Deviation	0.23	0.51	0.35	0.36

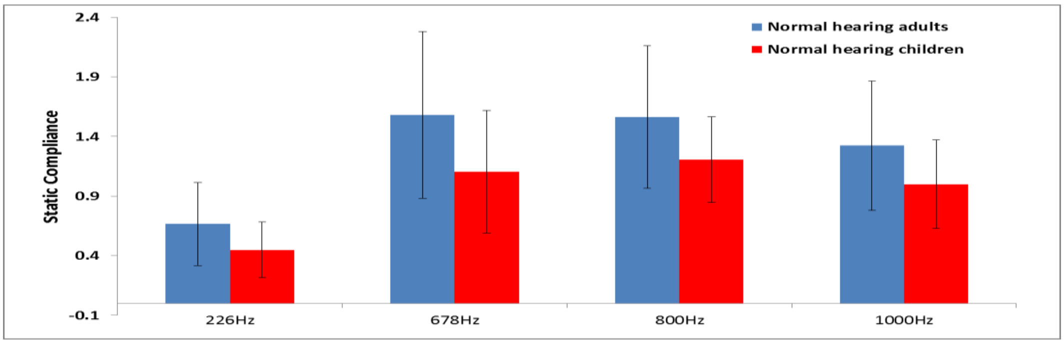

Figure 1: Shows mean and standard deviation of static compliance in normal hearing adults and normal hearing children at 226, 678, 800 &1000Hz.

Mean and standard deviation of wideband absorbance at 226, 678, 800 and 1000 Hz in both normal hearing adults and normal hearing children are mentioned in table 2.

Figure shows Mean and standard deviation of wideband absorbance at 226, 678, 800 and 1000 Hz in both normal hearing adults and normal hearing children.

Table 2: Shows mean and standard deviation of wideband absorbance in normal hearing children and adults.

Adults – Wideband Absorbance				
Frequency	**226Hz**	**678Hz**	**800Hz**	**1000Hz**
Mean	0.22	0.53	0.62	0.65
Standard deviation	0.16	0.14	0.09	0.08
Children-Wideband Absorbance				
Frequency	**226Hz**	**678Hz**	**800z**	**1000Hz**
Mean	0.20	0.49	0.58	0.62
Standard Deviation	0.14	0.17	0.12	0.11

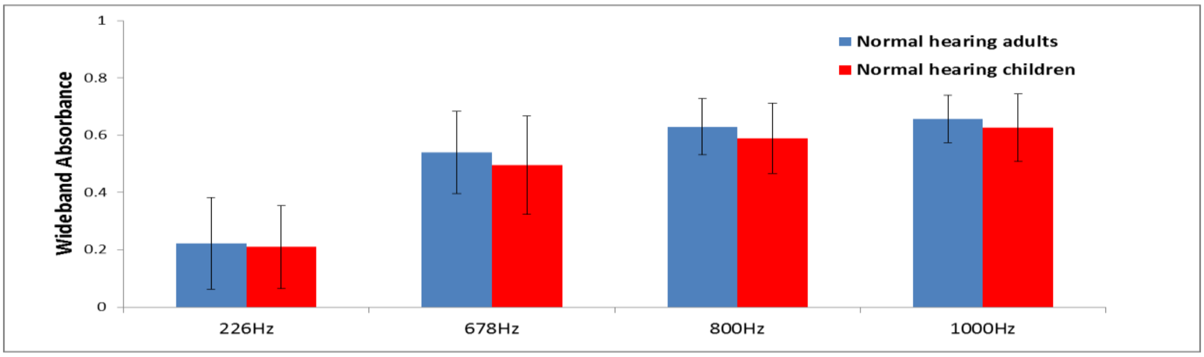

Figure 2: Shows mean and standard deviation of wideband absorbance in normal hearing adults and children at 226,678,80071000Hz.

Pearson's Correlation coefficient test was applied to see the relation between the two measures i.e., static compliance and wideband absorbance in both normal hearing adults and normal hearing children at 226, 678 ,800& 1000Hz frequencies.

Results of Pearson's Correlation coefficient test are mentioned under the following heading:

1. Relation between static compliance and wideband absorbance in both normal hearing adults and normal hearing children at 226 Hz.
2. Relation between static compliance and wideband absorbance in both normal hearing adults and normal hearing children at 678 Hz.
3. Relation between static compliance and wideband absorbance in both normal hearing adults and normal hearing children at 800Hz.
4. Relation between static compliance and wideband absorbance in both normal hearing adults and normal hearing children at 1000 Hz.

Relation between static compliance and wideband absorbance in both normal hearing adults and normal hearing children at 226 Hz.

At 226Hz there was a significant correlation between static compliance and wideband absorbance in normal hearing adults (r = 0.96). However, in normal hearing children there was no correlation between static compliance and wideband Absorbance (r =0.52).

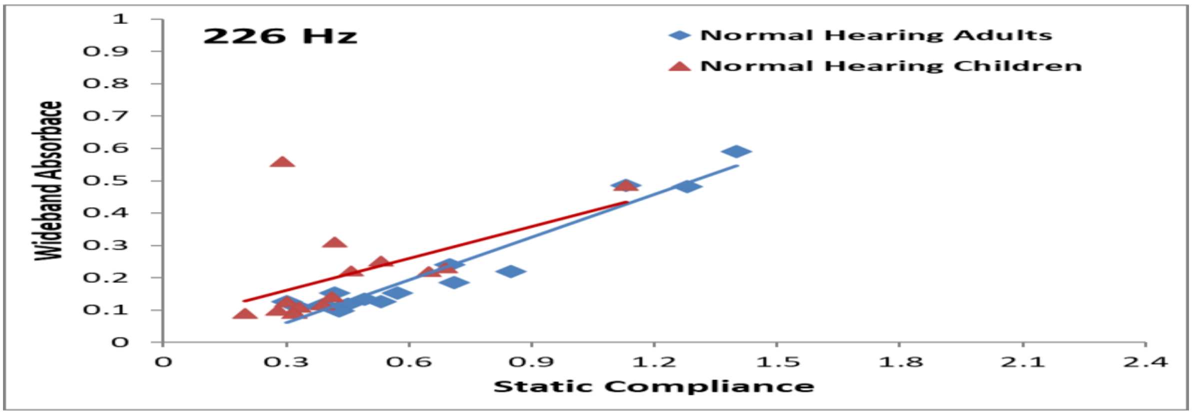

Figure 3: Shows the correlation between static compliance and wideband absorbance at 226Hz frequency.

Relation between static compliance and wideband absorbance in both normal hearing adults and normal hearing children at 678 Hz.

At 678Hz there was a significant correlation between static compliance and wideband Absorbance in both normal hearing adults (r =0.72) and normal hearing children (r =0.80). The correlation was stronger relation in normal hearing children when compared to normal hearing adults.

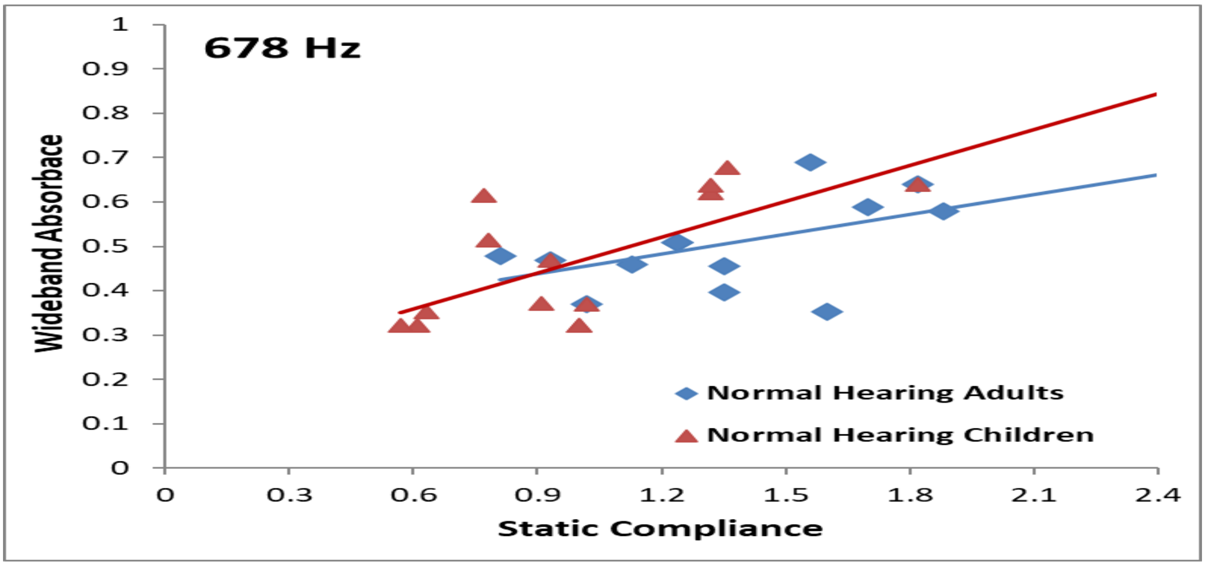

Figure 4: Shows correlation between static compliance and wideband absorbance at 678Hz frequency.

Relation between static compliance and wideband absorbance in both normal hearing adults and normal hearing children at 800Hz.

At 800Hz there was a significant correlation between static compliance and wideband Absorbance in normal hearing adults (r = 0.72) and in normal hearing children (r = 0.78).

The correlation was stronger relation in normal hearing children when compared to normal hearing adults.

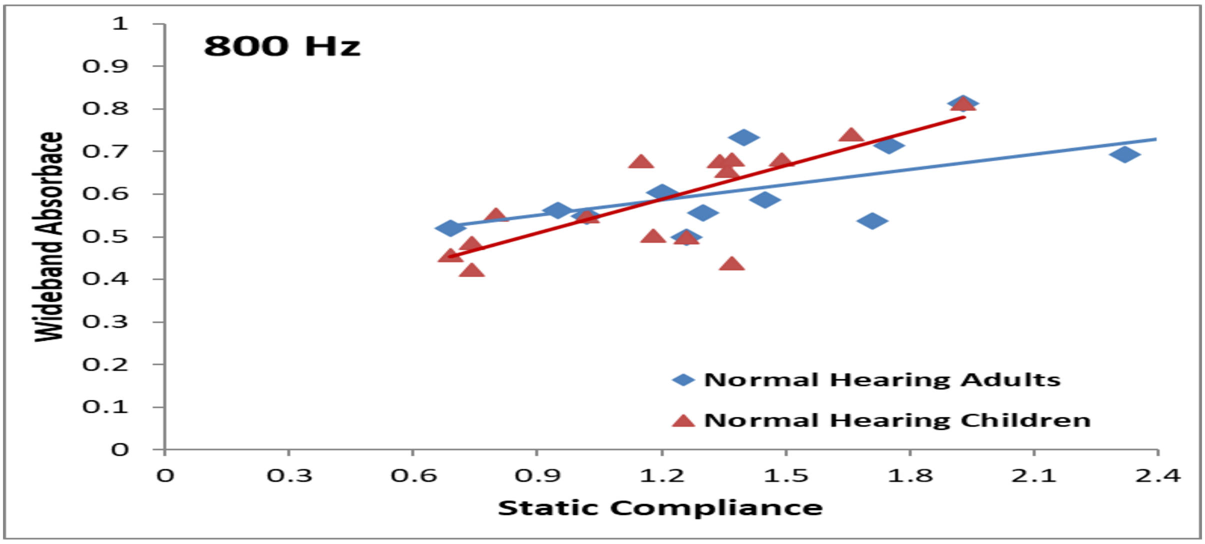

Figure 6: Shows correlation between static compliance and wideband absorbance at 800Hz frequency.

Relation between static compliance and wideband absorbance in both normal hearing adults and normal hearing children at 1000Hz.

At 1000Hz there was a significant correlation between static compliance and wideband Absorbance in normal hearing adults (r =0.62) and in normal hearing children (r =0.70. Normal hearing children had stronger correlation in children when compared to normal hearing adult.

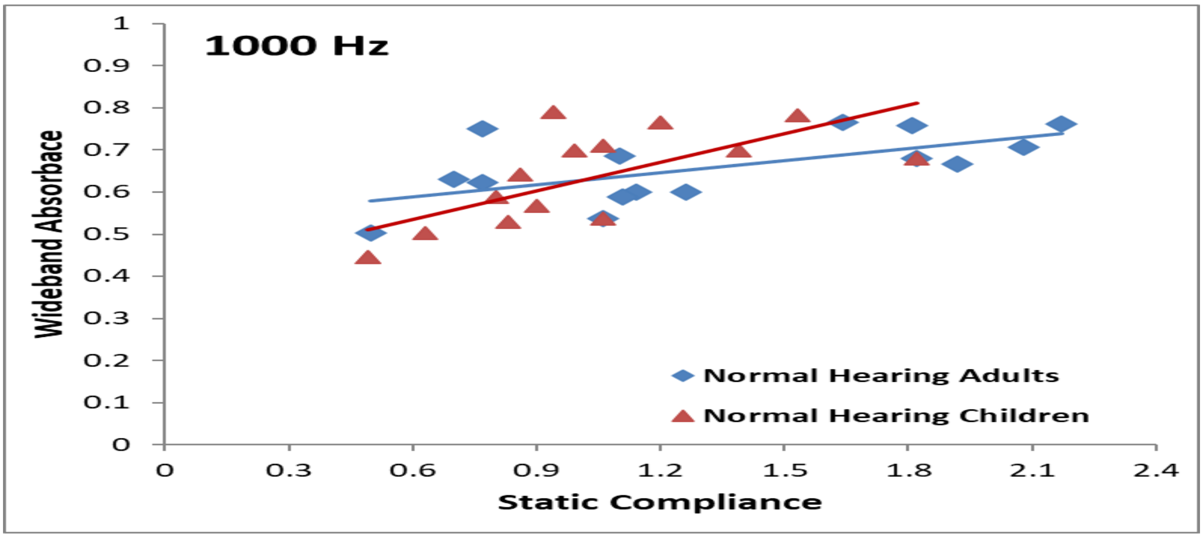

Figure 5: Shows the correlation between static compliance and wideband absorbance at 1000Hz frequency.

T-test was applied to study adult-children difference for static compliance and wideband absorbance at 226, 678, 800 and 1000 Hz. Independent sample T-test showed significant difference (at 5% level of significance) between normal hearing adults and normal hearing children for static compliance at all the frequencies; 226 Hz [t (28) = 4.003, (p = 0.042); Figure 7], 678 Hz [t (28) = 2.128, (p = 0.031; Figure 8], 800 Hz [t (28) = 1.974, (p = 0.04300; Figure 9] and 1000 Hz [t (28) = 1.913, (p = 0.038); Figure 10].

In term of wide band absorbance there was no significant difference between normal hearing adults and normal hearing children for static compliance at all the frequencies; 226 Hz [t (28) = 0.230, (p = 0.713); Figure 11], 678 Hz [t (28) = 0.773, (p = 0.264; Figure12], 800 Hz [t (28) = 1.008, (p = 0.230); Figure 13] and 1000 Hz [t (28) = 0.844, (p = 0.072); Figure 14].

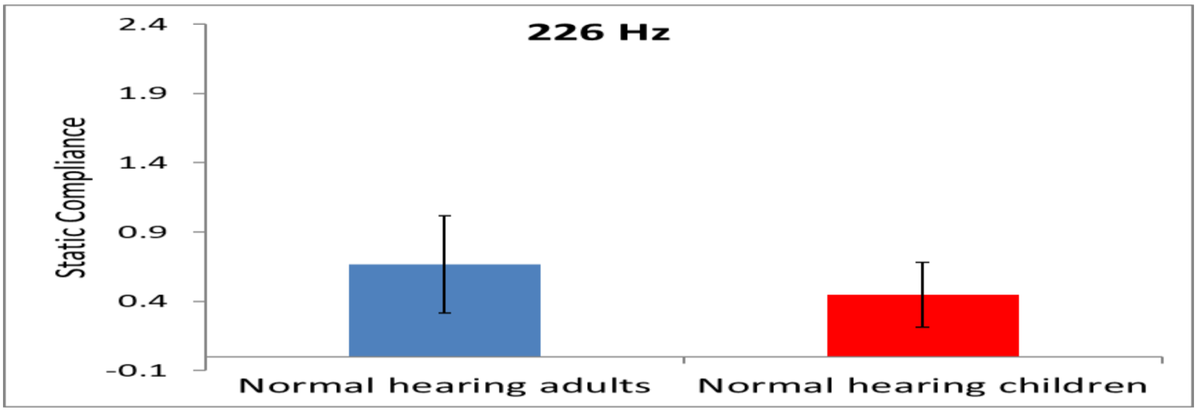

Figure 7: Shows comparison of static compliance in adults and children at 226Hz.

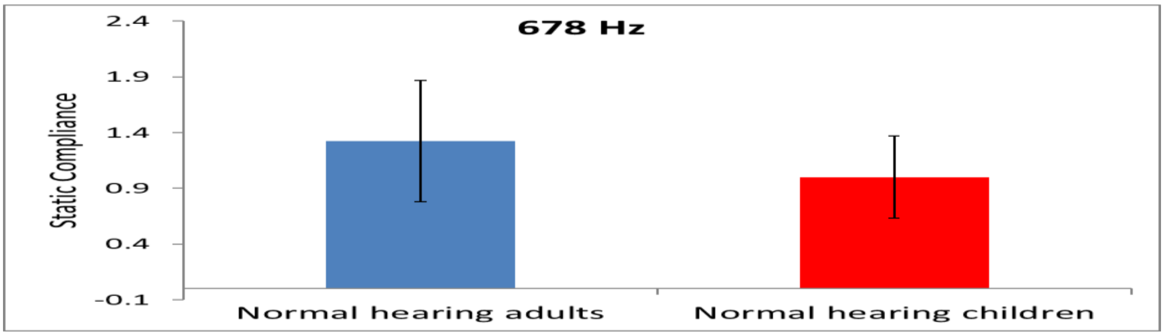

Figure 8: Shows comparison of static compliance at 678Hz frequency in adults and children.

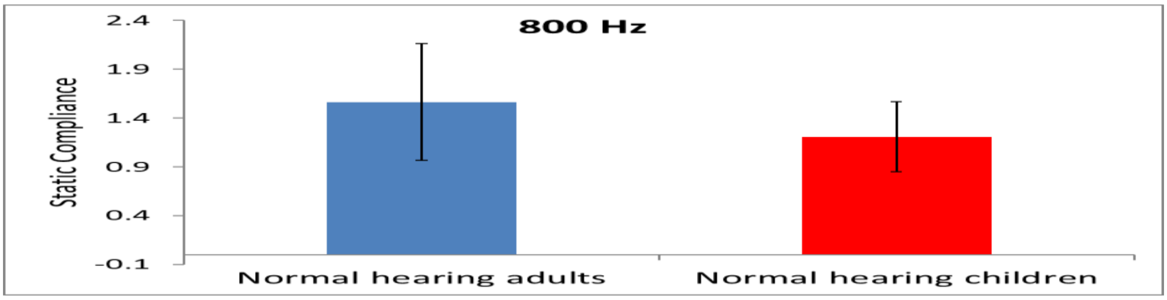

Figure 9: Shows the comparison of static compliance at 800Hz frequency in adults and children.

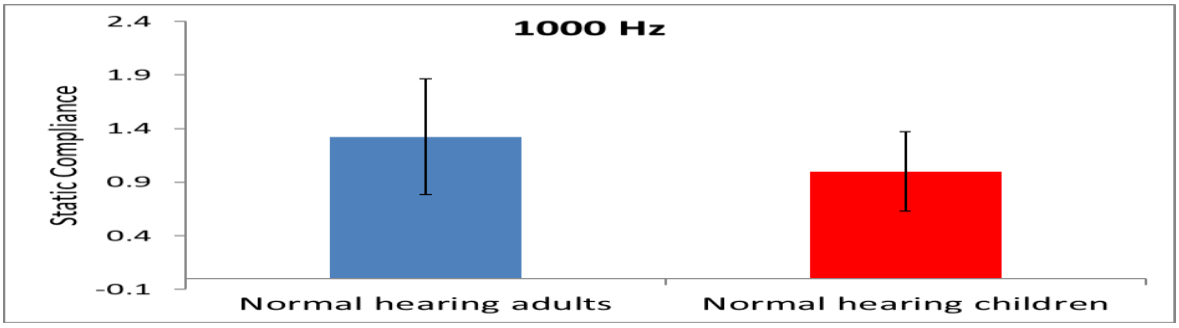

Figure 10: Shows the comparison of static compliance at 1000Hz frequency in adults and children.

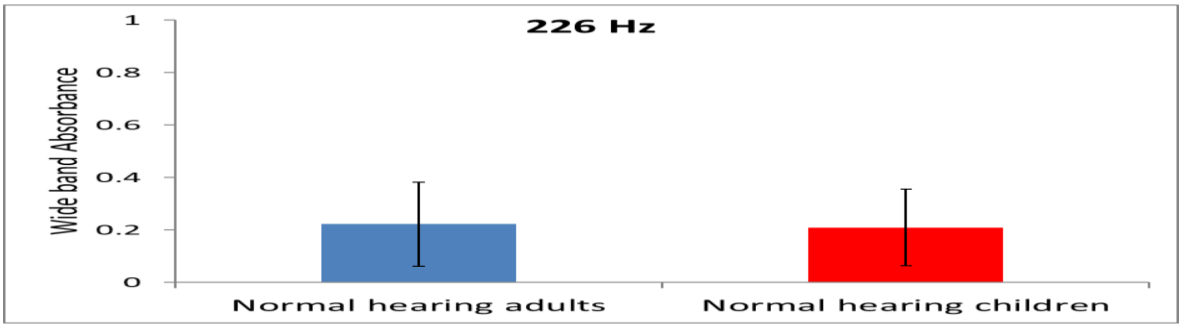

Figure 11: Shows comparison of wideband absorbance at 226Hz in adults and children.

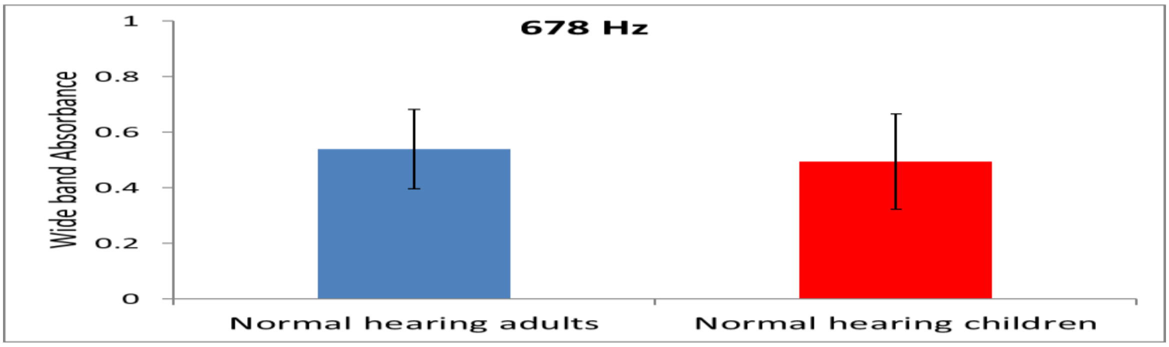

Figure 12: Shows comparison of absorbance at 678Hz in adults and children.

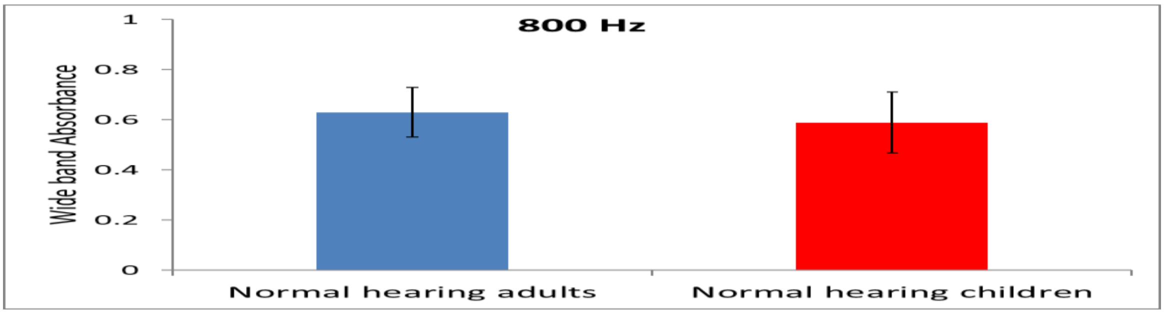

Figure 13: Shows comparison of absorbance at 800Hz in Adults and Children.

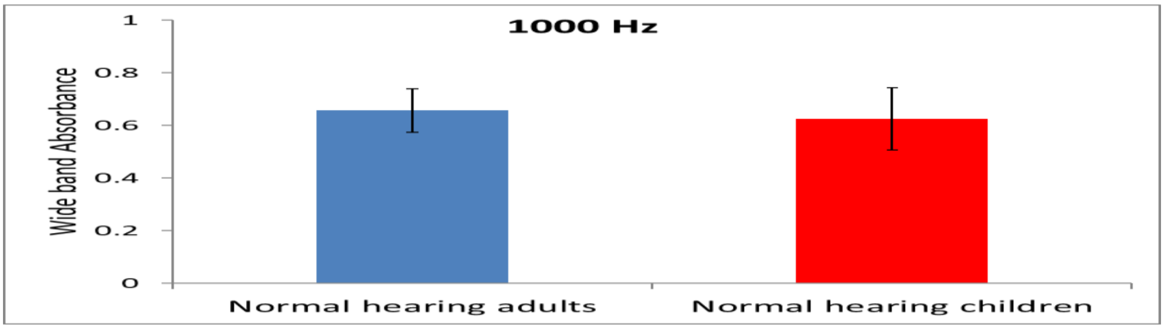

Figure 14: Shows comparison of absorbance at 1000Hz in adults and children.

DISCUSSION

This study was undertaken to see the relation between traditional immittance measure of static compliance and wideband absorbance measure at different frequencies i.e., 226, 660, 800 and 1000 Hz. The two measures were also compared between normal hearing adults and normal hearing children at 226, 660, 800 and 1000 Hz. The results are discussed under the following headings:

1. Relation between static compliance and wideband absorbance measure at 226, 660, 800 and 1000 Hz
2. Comparison of traditional immittance measure of static compliance and wideband absorbance between normal hearing adults and normal hearing children at 226, 660, 800 and 1000 Hz.

Relation between traditional immittance measure of static compliance and wideband absorbance measure at 226, 660, 800 and 1000 Hz

This study showed a positive correlation between static compliance and wideband absorbance in both normal hearing children and normal hearing adults at all the frequencies (226, 678, 800 and 1000 Hz) expect at 226 Hz in normal hearing children at which the correlation was absent. The presence of correlation between static compliance and wideband absorbance shows that the two measures are related to each other in describing the functioning of middle ear functioning. Static compliance is the measure of the ease of flow of energy through the middle ear while wideband absorbance estimates how much energy is absorbed by the middle ear. Physiologically more is the static compliance of middle ear higher should be the energy absorption [12] the same relation if found in most of the measuring condition i.e., different frequency stimuli in this study.

At low frequency, 226 Hz, normal hearing adults had a strong correlation between static compliance and wideband absorbance where as normal hearing children showed no correlation. Reason for the presence of stronger correlation in adults could be the fact that middle ear system in adults is stiffness dominated.[13] Stiffness component of the static compliance affects the flow of low frequency not he higher ones. Therefore, in adults the measurement of static compliance with lower frequency provided a more accurate estimate due to which it was correlating with another measure of the middle ear functioning i.e., wide band absorbance.

There was no correlation between static compliance and wideband absorbance in children at 226 Hz. There are many studies in literature that have reported that the use of low frequency such at 226 Hz do not provide a reliable measure of static compliance.[14] This because the middle ear system of children in mass dominated [3] and such mass component in the middle ear system do not affect the flow of low frequencies and therefore may provide inaccurate measure. That could be the reason behind why the children did not have correlation between static compliance and wideband absorbance in children at 226 Hz.

At higher frequency, however, the correlation between static compliance and wideband absorbance was present in both normal hearing adults and normal hearing children. Contrary to static compliance at low frequency, the correlation between static compliance and wideband absorbance was stronger in normal hearing children when compared to normal hearing adults. As explained above there are several studies that have suggested the use of high frequency in making measurement of static compliance in children.[3] The reason for this is the presence of mass dominated system in children which affect the flow of higher frequency like 678, 800 and 1000 Hz but not 226 Hz and therefore more accurate static compliance in children may be measured with these higher frequencies.

Traditional instrument measuring static compliance, measure it as the change in the intensity of a signal presented at the tympanic membrane. The change corresponds to the amount of flow of that particular signal which indirectly provide the measure of static compliance. The signal used in these measurements are pure tones of different frequency. It is mentioned above that stiffness dominated system mainly affects the flow of low frequency while not the flow of high frequency and mass dominated system affect the flow of higher frequency but not low frequency. Further in the presence of system which is not affecting the flow of other frequency, if we present (for measurement) the same frequency it will show in accurate result, for example, 226 Hz in children. This description is important to understand the explanation provided above.

The presence or absence of correlation between static compliance and wideband absorbance is explained by taking static compliance as the factor. Wideband absorbance is the measure of the total absorption of energy presented at a particular frequency. Therefore, the type of middle ear system does not affect the interpretation of the results of correlation in this study.

Comparison of traditional immittance measure of static compliance and wideband absorbance between normal hearing adults and normal hearing children at 226, 660, 800 and 1000 Hz.

Static compliance was significantly different in normal hearing adults and normal hearing children at all the frequencies. Normal hearing adults had higher static compliance values at all the frequency when compared to the normal hearing children. Similar results have been abundantly available in literature.[3][15] Although there was no significant difference between normal hearing adults and normal hearing children in terms of absorbance but the mean wideband absorbance was always higher in normal hearing adults when compared to normal hearing children. Previous studies have also shown the similar results.[12] These differences could be because of the anatomical differences in the middle ear of normal hearing adults and normal hearing children.

Clinical Implications

Wideband Absorbance is a valuable clinical tool for assessing the conductive pathway. Wideband Absorbance had higher test performance against composite test batteries compared to single test reference standards in identifying disorders of the conductive system. Wideband Absorbance could be used as a single clinical tool with test performance which is as good as the test battery reference standards. It provides more detailed information on the status of middle ear. It provides clinical information on the range of frequencies crucial for speech perception. Wideband absorbance could be used as an adjunct tool to reduce false positive results.

Limitations of study

- Results could be more generalised if a greater number of participants would have taken.
- Test-retest reliability was not tested
- Gender Differences were not considered
- Study did not consider older age group

Future Implications

Future studies can be done by increasing the age group, increasing the number of groups and also can compare with disordered population.

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