EFFECT OF AGE ON CONDUCTANCE

Reg.No.M9315

AN INDEPENDENT PROJECT SUBMITTED AS PART FULFILMENT FOR THE FIRST YEAR M.Sc. (SPEECH AND HEARING) TO THE UNIVERSITY OF MYSORE.

ALL INDIA INSTITUTE OF SPEECH AND HEARING : MYSORE - 570 006.

MY DEAREST SANTHOSH, CHECHI,

CHETTAN AND MY SWEET LITTLE ANGEL

KOCHUTHANKAM

CERTIFICATE

This is to certify that the Independent Project entitled: EFFECT OF AGE ON CONDUCTANCE is a bonafide work, done in part fulfilment for the First Year Degree of Master of Science (Speech and Hearing), of the student with Reg. No,M9315.

Mysore
May 1994

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CERTIFICATE

This is to certify that the Independent Project entitled: EFFECT OF AGE ON CONDUCTANCE has been prepared under my supervision and guidance.

Mysore
May 1994

Dr.(Miss) S.Nikam,
GUIDE

DECLARARTION

I hereby declare that this Independent Project entitled: EFFECT OF AGE ON CONDUCTANCE is the result of my own study under the guidance of Dr. (Miss) S. NIKAM, Professor and Head of the Department of Audiology, and the Director, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any University for any other Diploma or Degree.

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May 1994

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INTRODUCTION

The process of aging individual cells has been subject to extensive research but is still incompletely understood. Effect of aging on the sound conductive mechanism of the middle ear has been studied by Nixon et al. (1962), They found a slight impairment of transmission of sound in the frequencies above 2 KHz with the maximum effect of 12 dB at 4 KHz. They suggested that this inefficiency of sound transmission was due to alterations in the elasticity of the tympanic membrane and changes in the osslcular joints and tendons.

The histological study of the aging peripheral auditory system is hampered by lack of specificity. However, these studies has demonstrated that arthritic changes including fibrous and bony ankylosis of ossicular articulations do occur, even though these changes have no significant effect on hearing, the energy transmission characteristics of middle ear system is disturbed, thereby affecting impedance and admittance of the system. One the ways to consider the energy transfer characteristics of the middle ear system is to measure the energy flow ie the admittance. From instrumentation and computation point of view, it is often easier to measure the acoustic admittance (Y) or energy flow. Acoustic Admittance (Y_A) is the reciprocal of (2A) impedance is $Y_A = \frac{1}{2A}$

We measure the flow in acoustic mhos. The real or in phase component of acoustic admittance Which is called as acoustic conductance (G_A) is plotted on the same axis and direcion as the real component of acoustic impedance. Acoustic conductance is the energy flowing through an acoustic resistance.

NEED FOR THE STUDY:

Recent reports have indicated that the aging process alters selected aural acoustic immittance characteristics of the middle ear transmission system (Handler, Margolis, 1977; Jerger et al. 1972; Thompson et al, 1979, 1980). Thomas A Porter (1972) reported that there is significant difference in conductance between adults and children. The present study is aimed at finding the age effect on conductance in Indian population. This study is tdbe carried out using 226 Hz to compare the following parameters across normal hearing adults and children. The parameters are (1) physical volume (2) peak pressure (3) acoustic conductance at tympanic membrane,

Wiley, Oviatt and Block (1984) found that the static measures for both acoustic admittance components (acoustic susceptance and conductance) and both measurement conditions (peak pressure and ambient pressures) were slightly higher for subjects with notched 660 Hz tympanograms compared to static values of subjects with single peaked 660 Hz tympanograms. So using the parameter conductance at tympanic membrane. Present study is aimed at validating these results at higher and lower probe tone frequencies.

Jerger (1972) reported that males show higher acoustic compliance than females at all ages. Osterhammel and Osterhammel (1979) reported that there was no dependency of compliance values on sex. This study is to validate the above obtained results in the children and adult group and find out the significant difference in values if any in females and males. Present study is aimed at establishing normative data for conductance and admittance in children and adults in Indian population.

AIM OF THE STUDY:

I. To establish normative data for conductance tympanogram and admittance tympanograms in adults and children using Grason Stadler Incorporation 33 version 2 Middle Ear Analyzer.

II. To study the effect of 3 probe tone frequencies such as 226 Hz, 678 Hz and 1000 Hz.
   a) On conductance tympanogram
   b) On conductance at tympanic membrane in males and females, in adults and children.

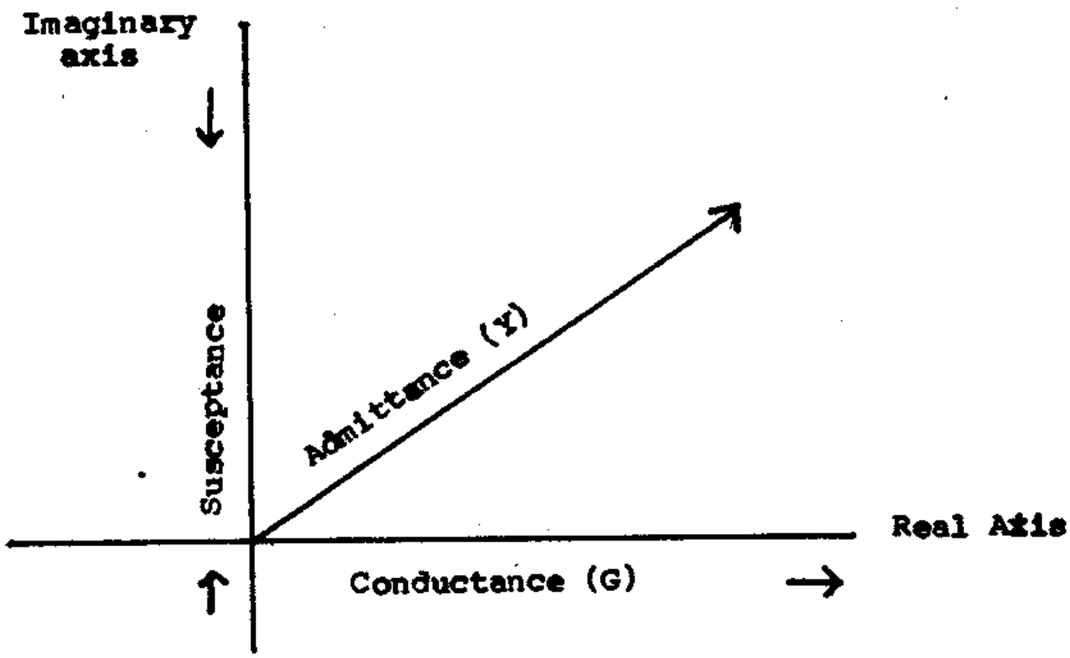
III. To find the effect of age and sex on
   a) Physical volume at 226 Hz
   b) Peak pressure at 226 Hz
   c) Conductance at tympanic membrane at 226 Hz.

REVIEW OF LITERATURE

Admittance is the sum of a real part, conductance (G) and the imaginary part i multiplied by Susceptance (B)

$$Y = G+iB$$

$$Y = G^2 + B^2$$



Complex mechanical systems such as the middle ear mechanism, can be represented by many interconnected mechanical parts that are either resistance elements, masses or springs. The admittance of the whole device can be derived from the combined admittance of each part of the entire system which are as follows:

Resistances $Y = \frac{1}{r}$

Mass: $Y = \frac{-i}{2\pi fM}$

Compliance: $Y = (2\pi fC)i$

Where f is the frequency, M is the mass and C is the compliance and T is the friction.

The admittance of the resistance element does not depend on frequency and has a magnitude of 1/r . The admittance of mass element is purely imaginary with a magnitude of $\frac{1}{2\pi fM}$
mass
Since the admittance of a /only has a negative imaginary part, it's vector will lie along the imaginary axis and point in a negative direction. The magnitude of the admittance of a mass element which is a measure of how much it will vibrate for the fixed applied sound pressure decreases as frequency increases. The admittance of the compliance element is also purely imaginary with the magnitude of $2\pi fC$. This magnitude decreases as frequency decreases.

The acoustic susceptance of the middle ear should be directly calculated by subtracting the acoustic susceptance of the outer ear from that of thetotal ear. Similarly the acoustic conductance can be derived. Then the acoustic admittance of the middle ear can be (Y_{ME}) obtained from the formula. $Y_{(ME)}2 - B_{ME}2 + G_{ME}^2$

Where Y_{ME} Is the static acoustic admittance of the middle ear G_{ME} - static acoustic conductance of the middle ear and $B_{M£}$ is the static acoustic susceptance of the middle ear.

Normative Data Establishment:

There have been few studies carried out to establish normative data in children and adults using otoadmittance meter for admittance and conductance tympanograns.

Porter (1972) took three groups of subjects consisting of 18 adults (18-40 years - mean - 25 years), and 18 children (7-14 years - mean - 9 years) who had normal hearing and 18 children with severe - profound hearing loss. The instrument he used was Model 1720 Otoadmittance meter. The values obtained using 220 Hz and 660 Hz probe frequencies are as follows:

Adults		220 Hz			660 Hz	
		G_A		Y_A	G_A	Y_A
	Mean	0.35	0.79	2.75		2.93
Hearing	SD	*0.08*			1.01	
Children	Mean	0.24	*0.65*	2.06		2.91
	SD	0.06		1.01		

The results showed that there was significant difference between adults and children at 220 Hz, but at 660 Hz, there was no significant difference.

Feldman (1972) studied 100 normal persons, using 2 probe tone frequencies 220 Hz and 660 Hz and gave mean and range of admittance. At 226 Hz the mean was $\simeq$ 0.52 mrnhos with a range extending from $\simeq$ 0.30 to 0.80 mmho. At 660 Hz the mean was 2.6 mmhos with a range of 1.20 to 4.20 mmhos.

Beattle and Leamy (1975) studied 2 groups of subjects, one group consisted of 7 males and 13 females in the age range of 17-29 years with the mean age of 20 years. Group 2 consisted of 20 males in the age range of 60-72 years with the mean age of 65 years. They established normative data for conductance (G) and susceptance (B) at 220 Hz and 660 Hz The values are as follows:

Group I

G	Mean	S.D
220 Hz	0.25	0.38
660 Hz	2.69	1.90

G values at 220 Hz are smaller than the respective values at 660 Hz probe frequencies.

The mean values obtained in Beattie's study are in close relation with the above mentioned Porter's study.

The normative data on admittance for children established by Brooks (1971) and by Jerger and Jerger et al. (1972) for older children and adults are as follows:

I. Y_A (mmhos)

	10%	90%
Jerger et al (1972)	0.39	1.30
Brooks (1971)	0.35	1.05

For adults is as follows (probe frequency 226 Hz used a pump speed of 200 dapa/s).

		200 dapa/s
II. Adults	Lower limit	0.57
	Median	1.08
	Upper limit	2.00

The normative data on the static acoustic middle ear admittance for the 220 Hz probe tone, when the ear canal static acoustic admittance was calculated at +200 dapa as in Table-I shows that it is reasonable to consider the normal static acoustic middle ear admittance range for 80% the school age population (between 10th - 90th percentiles) to be between 0.35 and 1.05 acoustic mmhos normally for older children and adults in Table-I.

From Table-II, it was inferred that the normal static acoustic middle ear admittance ranges for 90% of the adult population to be between 0.57 and 2.00 acoustic mmhos respectively for the 226 Hz probe tone When the ear canal static acoustic immittance is calculated at -400 dapa with a high pump speed (Jerger et al. 1972).

Willey, Oviatt and Block (1987) studied admittance (Y), conductance (6) and susceptance (B) of 77 women and 50 men who had normal hearing. The age ranged from 20-30 years. These values were calculated at 220 Hz and 660 Hz probe tone frequencies, at peak pressure as drum free condition and -250 dapa as drum tight condition.

Peak pressure

		Mean	SD
220 Hz	G_A	0.28	0.14
	Y_A	0.74	0.29
660 Hz	G_A	2.24	1.36
	Y_A	3.06	1.72

At higher probe tone frequencies, notched tympanograms were observed for conductance and susceptance and higher static values for notched tympanograms were also obtained.

Static Immittance:

Static immittance is the immittance of the tympanic membrane alone.

Static immittance can be affected by factors such as age, sex and probe tone frequency.

Effect of age and sex:

Brooks (1971) studied 1053 children, 4-11 years Who had normal hearing. Compliance of each oar and middle ear pressure were computed. The results showed that there was no detectable difference between boys and girls, but there was some indication of an increase of compliance with increasing age. Average value for compliance was 0.70 cm range from 0.35 cm^3 to 1.40 cm^3 and there have been taken as the limits of compliance with increasing age.

Jerger (1972) studied 700 subjects both normal hearing and sensorineural hearing loss cases. The age range was 6-90 years. The subjects were divided by sex and by age decades. For each sex at each age decade, both the mean and SD of the compliance were calculated. Results showed -

1. Women consistently showed a lower average compliance and less variance than men at all ages.

2. There is a pronounced age effect in both sexes, but especially men show a well defined maximum in both mean and variance in the age decade 30-39 years. Above this age decade, the average compliance declines relatively systematically with increasing age for both sexes. The maximum average compliance and SD for men aged 30-39

years might be possibly due to greater noise exposure of men in this range Which inturn might fatigue the intra-aural muscles, thereby increasing compliance.

Zwislocki and Feldman and Bicknill and Morgan noted that women seemed to show lower compliance than men. Bicknell and Morgan also noted that women seemed to show a narrower compliance range. Neither study provided quantitative data on sex difference.

Osterhammel and Osterhammel (1979) studied sex variation for the tympanometric compliance values on 286 normal hearing persons in the age range 10-80 years. They reported that there was no dependency of compliance values on sex.

Static conductance and age:

Few studies have been conducted to find out the relationship between the age and static conductance.

Thompson, Sills, Recke and Bui (1979) measured static conductance static susceptance and static admittance in 60 subjects, twenty through 79 years of age, with normal hearing It was reported that the static values are minimal upto 60 years ie, static conductance at 220 Hz varies little across age whereas static conductance at 660 Hz shows an initial high (relative) value in the sixties and seventies.

Wilson (1981), computed the aural acoustic immittance (admittance and impedance) during the quiescent and reflexive states in 18 subjects with normal hearing in each of the age groups (less than 30 years and greater than 50 years). The results indicated that there was no significant difference between the 2 age groups. The relation between the magnitude changes in conductance from the quiescent to the reflexive state was the same for the 2 groups.

A study by Blood and Breeberg (1976) contradicts this. They reported that the mean of acoustic admittance decreases as the age progresses.

In all these studies children were not included* So the exact effect of age on static conductance is not clear*

INFLUENCE OF PROBE TONE FREQUENCIES:

From different studies conducted it was found that the incidence of w-pattern or W notching increased while going from low probe tone frequencies to high probe tone frequencies. Acoustic conductance at 220 Hz and 660 Hz was found to be symmetrical.

Porter and Winston (1973) studied 16 normal hearing subjects, 5 males and 11 females were tested on 5 separate occassions. Recording of conductance (G) were obtained with pressure increasing from -200 mm H_2o, at standard probe frequencies of 220 Hz and 660 Hz. Mean and standard deviation of the means for conductance (G) in acoustic mmhos at 220 Hz and 660 Hz are as follows:

G 220 Hz		
	Mean	0.4
	S.D	0.19
G 660 Hz		
	Mean	2.41
	S.D	1.59

The values were calculated at maximum conductance as the drum free values. It was found that, test retest correlation coefficient was found to be very high.

Porter and Winston (1973) did one more study using 220 Hz and 660 Hz probe tone frequencies on 32 normal hearing adults. Recordings were done during increasing and decreasing pressure le. ascending and descending directions. Drum free condition was considered to be at maximum conductance and drum tight as at +200 dapa. The mean and standard deviation values are as follows:

G 220 Hz	Mean	0.4
	E.D.	0.24
G 660 Hz		
	Mean	2.9
	S.D.	1.93

From the above mentioned 2 studies it can be seen that that as the probe tone frequency increases, the static conductance also increases.

Shanks and Lilly (1981) studied static values on 4 women and 4 men (age ranging from 23-31 years mean age - 26 years) with normal hearing. The values were obtained at 220 Hz and 660 Hz; ear canal pressure was varied from -400 to 4400 dapa and also at ear canal pressure which produced maximum susceptance (MAX).

Static immittance (mean and SD values) for 220 Hz and 660 Hz probe tones calculated at MAX using recommended procedure (-400 dapa, 660 Hz) are as follows : (SD are given in paranthesis).

	220 Hz	660 Hz
G_A	0.36 (0.15)	2.53 (1.59)
Y_A	0.99 (0.4)	3.09 (1.51)

Wilson, Shanks and Kaplan (1984) studied 24 young Adults probe tones used were 226 Hz and 678 Hz. Static values, mean and median for eight subjects with single peaked tympanogram and eight subjects with notched tympanogram for ascending pressure direction are as follows:

	226 Hz		678 Hz	
Conductance	Single peaked	Notched	Single peaked	Notched
Mean	0.26	0.69	1.36	3.22
SD	0.08	0.52	0.57	1.29

From the above values, it can be seen that there is descripancy in the static conductance values between single peaked and notched tympanograms at 226 Hz and 678 Hz and also it is seen that as the probe tone frequency increases, the static value increases.

PEAK PRESSURE AND AGE:

The measurement of middle ear pressure represents an important diagnostic tool for identifying middle ear disorders. The tympanic membrane best transmits sound energy when the air pressure on both side of the tympanic membrane is equal.

Though most researchers agree regarding the ranqe of tympanic membrane peak pressures consistent with normal middle ear pressure, in adults, they disagree about the range of tympanic membrane peak pressures consistent with normal middle ear pressure in children.

Brooks (1971) studied 1053 children 4-11 years age, middle ear pressure was computed. The results showed the lower limit of the range of tympanic membrane peak pressures consistent with normal middle ears in children is as high as -30 dapa.

Burke and Herer (1972) studied 7 females and 3 males aged 20-24 years (mean 22 years)- and 7 males and 3 females aged

6-11 years (mean - 8 years). All had normal hearing. Measurement of middle ear pressure with otoadmittance meter was done. 2 response curves for each probe frequencies, ie, a conductance curve (6) and a susceptance curve (B) were obtained. Of the 4 curves per ear thus obtained, each seemed to peak at different pressure points. The mean difference ranged from +4 to +22.5 mm H_2o with adults and from -4.5 to +13.5 mm H_2o with children. Comparing the pressure estimates at 220 Hz and 660 Hz, there was significant mean difference at 0.01 level of confidence with the adult group and at the 0.05 level with children group. The values of peak pressure in both adults and children are as follows:

	220 Hz		660 Hz	
Adults	G	B	G	B
	4	11.2	14.8	25.5
Children	.4.5	6.0	4.0	13.5

Jerger (1970) proposed - 100 dapa as the lower limit of normal range of tympanometric peak pressures.

Renvall et al. (1975) found that 90% of their samples of school children Who were presumed to have normal middle ears had tympanometric peak pressures exceeding, -150 dapa. Therefore, they considered -150 dapa to be the lower limit of normal middle ears. The presence of lower tympanometric peak pressure in children than in adults is attributed to the ability of some children to maintain relatively lover middle ear pressures than adults (Brooks, 1980)*

But it was found that if -150 dapa or -170 dapa is used as the lower limit of normal range, as proposed by Renvall et al. (1975) 18% of children's ears with middle ear effusion were missed. If -100 dapa is used as the lower limit of normal range, as proposed by Jerger, false positive rate is increased to 17.8% though false negative rate is reduced.

So it was clear that screening for the presence of middle ear effusion based on tympanometric peak pressures is insufficient in children resulting in either a high false positive or false negative rate depending upon the cut-off tympanometric peak pressures employed.

Brooks (1980) reported tympanometric peak pressure between -50 and +50 dapa in adults with normal middle ears.

PHYSICAL VOLUME:

Physical volume is a measurement of the volume of the external auditory canal as a sealed cavity under a positive pressure of 200 dapa.

Some investigators regard the ear canal volume as pure susceptance (Moller, 1960/ Van Peperstraete, et al. 1972) whereas other Investigators suggest the ear canal volume contributes some finite conductance, Moller (1960) supporting the former, reported that the ear canal has no effect on the real component of admittance (ie. conductance). Cretan (1979) did not assume that the ear canal could be molded as pure susceptance. He reasoned that the hairs and cerumen in the ear canal produce some sound absorption and thus a finite value of ear canal conductance. Both susceptance and conductance at a given ear canal pressure are attributed to the ear canal volume. They further reported that a cavity lined with felt and having dimensions those comparable with those of an ear canal, showed G values lying in the same range as the G in the tails of actual tympanograms. We thus assume the value of G tympanogram to be identical to G_C At 220 Hz a seemingly contradictory difference was found between the ear canal G at high positive and at high negative pressure differences across the drum. Same observation was reported by Margolis and Smith (1977) who used a Grason-Stadler Otoadmittance meter. Measurements of G of hard walled cavities however were found to be proportional to the pressure in the cavity and to its susceptance,

Feldman (1967) studied 33 subjects with normal hearing. Determination of ear canal volume was done for 24 subjects.

The mean value was 0.56 cc and the normal range was 0,4 - 0,6 cc. This mean value does not agree with the mean of 0.8 cc reported by Nixon and Glorig, for four repeated measurements on 13 subjects. Also with the means ranging from 0.72 cc to 0.97 cc reported by Tillman et al.

Northern and Grlmmers (1978) reported that for children the normal volume peripheral to an intact drum is approximately 0.6 cc to 0.8 cc and for adults approximately 1.00 cc to 1.5 cc.

Shanks and Lilly (1981) studied 4 women and 4 men age ranging from 23-31 years (mean-26 years) with normal hearing with no evidence of middle ear pathology. Susceptance and conductance at 220 Hz and 660 Hz were recorded for pressures ranging from -400 to +400 dapa and at peak pressure. Results showed that the largest mean error in estimating ear canal volume from tympanometry occured for probe frequency and pressure, most commonly used to estimate ear canal volume ie. for 220 Hz tone and +200 dapa pressure.

Shanks (1984) reported that the amplitude of tympanograms is inversely related to the volume of the ear canal/ i.e. the tympanometric amplitude is greater for a smaller ear canal volume. The tympanometric amplitude reduces nonlinearly with Increase in ear canal volume. The changes in sound pressure level will be greater and therefore tympanometric amplitude will be greater in smaller ear canals. The larger the ear canal volume becomes, the broader and shallower, the tympanogram becomes.

The descripancy in the mean values of ear canal volume in both adults and children across difference studies can be attributed to the difference of techniques related to the depth of insertion of the speculum. When ear canal volume exceeds the 0.55 to 0.6 cc range, the implication is that the examiner is not inserting the speculum deep enough into the canal.

TYMPANOMETRIC CONFIGURATION - EFFECT OF PROBE FREQUENCY

Alberti and Jerger (1974) described tympanometric pak amplitudes and shapes observed using various probe tones in normal middle ears.

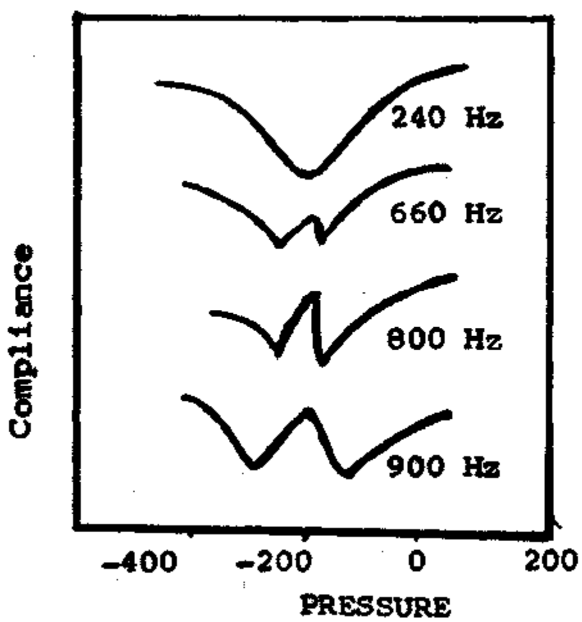


Figure illustrates the relations among peak amplitudes, shape and probe tones. It shows that as probe tone frequency increases, the amplitude also increases. When probe tone frequency approaches 660 Hz, notching of the tympanogram begins to occur. This notching becomes more prevalent as the probe tone frequency increases beyond 660 Hz upto 900 Hz . Alberti and Jerger (1974) referred to the notching shape as "W-shaped". The majority of normal middle ears have W-shaped tympanograms for probe frequencies above 900 Hz.

Liden, Harford and Hallen (1974)stated that since high frequency probe tones around 800 Hz were near the resonance frequency of the middle ear and since ear canal pressure changes cause changes in the resonance characteristics of the middle ear, the W-shaped tympanograms reflect increased interaction among the probe-tone frequencies, resonance characteristics of the middle ear and external ear canal pressure.

Colletti (1976) studied 72 ears - 20 normal and rest pathological ears. All selected ears underwent the multi-frequency tympanometry. The investigation started from 200 Hz and moved towards higher frequencies in 200 Hz steps. In group with normal middle/following types of tympanograms were observed.

1. From 200 Hz to between 650 Hz and 1200 Hz V shape characteristics (Ist range).
2. W shape was present in an interval of around 300 Hz over the frequency previously described (2nd range)•
3. Finally the tympanograms assumed the 'V' inverted shape which began at between 1000 Hz and 1400 Hz and became more evident at higher frequencies (3rd range).

This study supported Liden et al who proposed the usage of 800 Hz probe tone, as tympanometric shape shows clear dependencies on the probe tone frequencies.

Margolis and Popelka (1977) investigated tympanometric assymmetry in 17 normal adult subjects. The data are discussed interms of 5 categories of subjects based on otologic history and shape of the 660 Hz tympanogram. All subjects had single peaked tympanogram at 220 Hz.

Case I - Included 5 audiometrically and otoscopically normal subjects with normal single peaked tympanograms at 660 Hz.

Case II - Included 3 normal subjects with double peaked 660 Hz acoustic susceptance tympanograms.

Case III - Included 2 normal subjects with double peaked acoustic susceptance (B) and acoustic conductance (G) tympanograms at 660 Hz.

As probe tone frequency increased the tympanogram became more assymmetrical with higher B_A values on the positive pressure side of the tympanogram. The mean G_A tympanogram for normal subjects increased in magnitude as probe frequency increased but remained nearly symmetrical around the maximum that occurs near the ambient ear canal pressure.

In the case II and III, the absolute values of absolute values of acoustic reactance and resistance are nearly equal at 660 Hz and these subjects demonstrated substantially lower acoustic reactance than acoustic resistance is the region of ambient ear canal pressure,

Vanhuyae et al and Van Camp et al (1984) developed a classification system for simultaneously recorded susceptance (B) and conductance (6) tympanograms using a high frequency probe tone such as 678 Hz. The susceptance and conductance tympanograms were described according to the number of extreme or direction changes measured. The admittance tympanograms are explained with reference to the relationship between resistance and reactance which exhibit less complex patterns. The 4 basic normal tympanograms are as follows:

I. The single peaked or 1B1G tympanograms as one extremum for each admittance component. This tympanogram is recorded when reactance is negative ie. (ear is stiffness controlled) and resistance is smaller.

II. The 3B1G pattern shows notching of the B tympanogram, although susceptance remains positive for all ear canal pressures. Here, the minimum notched B is slightly more negative than maximum G value. In addition the more positive B max. is larger in amplitude than the negative minimum, Vanhuyse et al attributed this difference to the monotonically reduced resistance tympanogram as a function of ear canal pressure.

III. Notching occurs in both the B&G tympanogram in the 3B3G pattern. The 3B3G tympanogram is recorded When reactance is positive, near zero dapa and when it is negative, for extreme pressures and when resistance is greater than reactance.

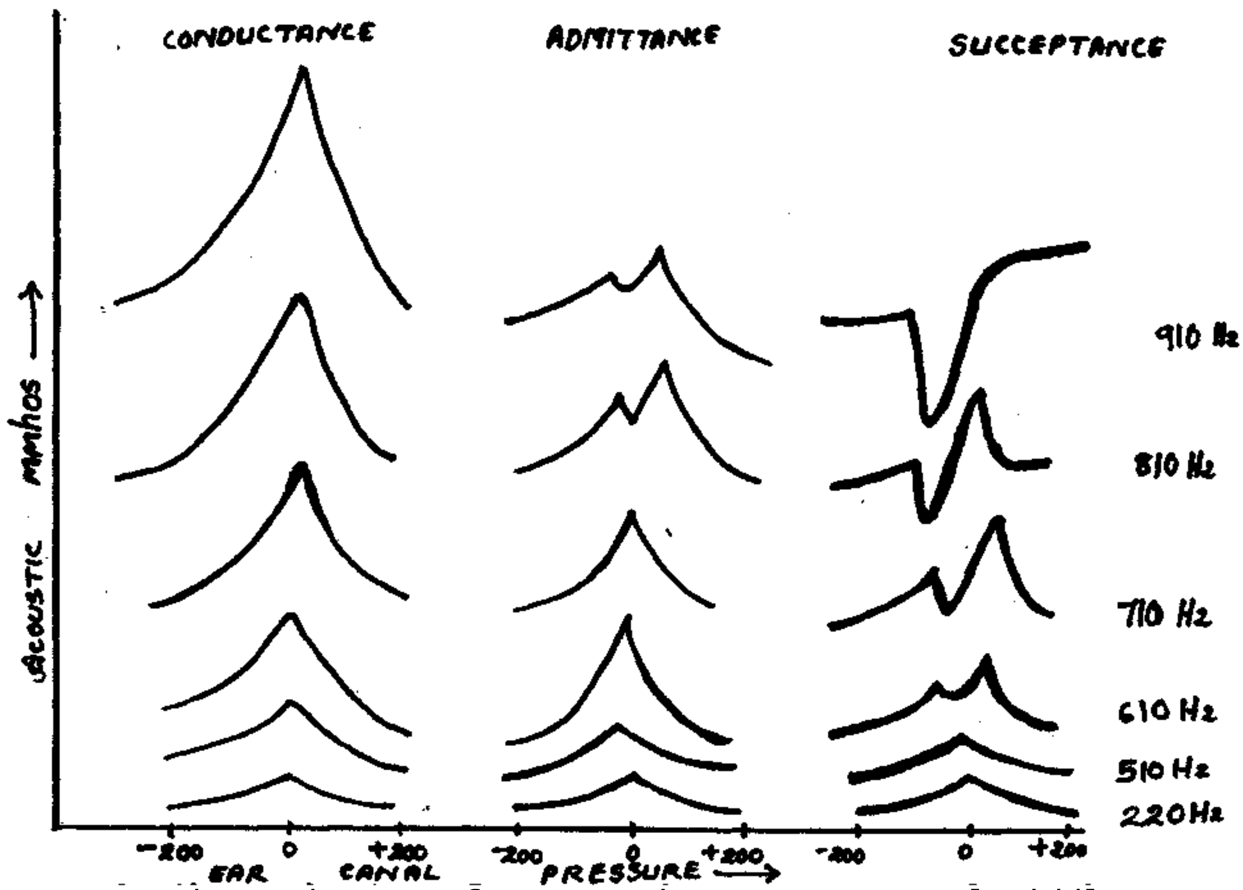
The most complex pattern 5B3G is also found When the middle ear system is mass controlled. In contrast to the 3B3G pattern, the reactance in 5B3G pattern is greater than resistance near ambient air pressure.

(1984)
According to Vanhuyse et al./the normally notched tympanogram must meet the following criteria:

1. The number of extreme must not exceed 5 for B and 3 for G tympanograms,
2. The distance between the outermost maxima must not exceed 75 dapa for tympanograms with 3 extrema (ie, 3B 3G) and must not exceed 100 dapa for tympanograms with 5 extrema (5B 3G).

Margolis, Van Camp, Wilson and Creten (1965) described the amplitude and shape of susceptance, conductance and admittance tympanograms obtained from young adults with normal middle ears using probe tone frequencies varying between 220 Hz and 910 Hz and an absolute acoustic immittance device.
Susceptance
Conductance/and admittance tympanograms from one normal subject at 6 probe frequencies and positive and negative directions are as shown in the figure.

In the figure the peak amplitude on all the susceptance tympanogram is greater than that on the conductance tympanogram and the peak amplitude on the admittance tympanogram is only slightly greater than that on the susceptance tympanograms for 220 Hz probe tone. This relation between the 3 components occurs at 220 Hz as the resistance of the middle ear is very small here.



As the probe tone frequency increases, normal middle ears start to demonstrate notching in the B, G and Y tympanograms. Margolis et al. (1985) attributed the changes in the susceptance and conductance tympanometric patterns with probe frequency changes, to the shift in acoustic reactance from large negative values to small positive values.

METHODOLOGY

The methodology of the present study is described under the following headings:

1. Subjects:

Criteria for selection of subjects:

Adults - Totally 30 normal hearing adults whose PTA of both ears within 20 dB HL in octave frequencies from 250 Hz to 8 KHz (ANSI 1969) were selected. The subjects were 15 males and 15 females age ranging from 18-26 years.

Children - 30 normal hearing children Whose PTA of both ears lie within 20 dB HL in octave frequencies from 250 Hz to 8 KHz (ANSI 1969) were selected. This group consisted of 3 age groups ie 8 years, 10 years and 12 years respectively. Each age group had 10 subjects ie. 5 females and 5 males.

In order to meet the criteria for selection the subjects should have an 'A' type tympanogram with the reflexes present on an immittance Instruments which would indicate the absence of any middle ear pathology.

Justification:

1. The occurrence of middle ear pathology after the age of 8 years is less.

2. Significant difference in terms of physical volume peak pressure and static admittance values are not expected between the adjacent age groups. Hence children in the age group of 8, 10 and 12 years were selected.

2. Instrumentation:

The Grason Stadler Middle Ear Analyzer 33 version 2 was used for the present study. It is a microprocessor based admittance audiometer which has facilities for complete automatic or manual diagnostic testing for analysis of middle ear function. Admittance (Y) and its components susceptance (B) and conductance (G) can be measured with probe tone frequencies of 226 Hz, 678 Hz and 1000 Hz.

An audiometer namely Madsen OB 822 calibrated according to ISO Standards was also used to check the behavioural thresholds (air conduction using earphone TDH 39 and bone conduction using bone vibrator ,radio ear B-71) at octave frequencies using the Modified Hugh son-West lake Procedure.

3. Calibration:

The Grason Stadler Middle Ear Analyzer 33 version 2 has been calibrated according to the standards specified in the manual.

The audiometer has been calibrated using a Sound Level Meter - B&K 2230 and a microphone - B&K 4144. The calibration of earphone output has been accomplished with the help of artificial ear - B&K 4152, along with the sound level meter and microphone of one inch and earphone (TDH 39) •

4. Test environments

The test was conducted in an air conditioned sound treated room. The noise levels were measured using a Sound Level Meter (B&K 2209) an Octave Filter Set (B&K 1613) and a Condensor Microphone (B&K 4165) and the noise levels were within the permissible limits as given in ANSI Standards (1969).

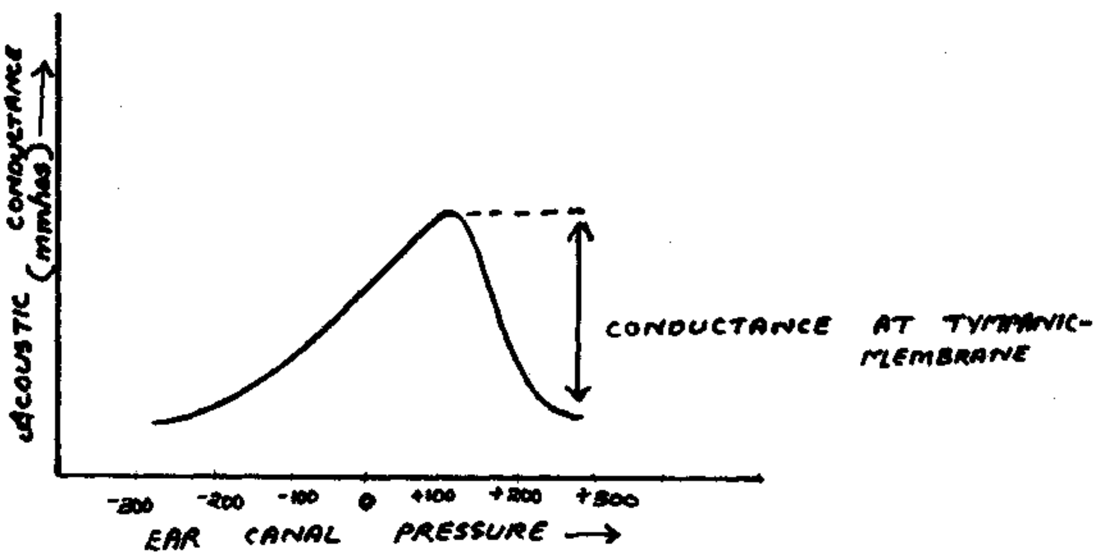
5. Test procedure:

The patient was seated comfortably. The probe box was attached to the velcrostrip on the shoulder mount or clothes clip and position on the patient. Then the presence of obstructive cerumen in the ear canal was checked. The correct size of the ear tip was selected and positioned on the probe. Then it was securely inserted into the ear canal to obtain an airtight seal. The probe tone of interest 226 Hz was selected and the pump speed was selected as 200 dapa* Then the ' start' button was pressed.

The pressure was varied from -400 dapa to +200 dapa to obtain a tympanogram. Since the instrument was an automatic one the tympanometric values including the values of the physical volume, peak pressure and admittance at tympanic membrane was displayed on the screen after getting the tympanogram. Tympanograms at 678 Hz and 1 KHz were obtained using a similar procedure.

Conductance tympanograms were then obtained for 226 Hz, 678 Hz and 1KHz using a similar procedure.

The conductance tympanogram obtained at 226 Hz is represented as shown below:



From the above tympanogram, the middle ear pressure, physical volume and peak compensated acoustic conductance at tympanic membrane.

Physical volume test:

The physical volume which is the. volume of the ear canal was calculated at high positive pressure (ie) +200 dapa which was built in the ear canal. The immittance value estimated at this pressure provided an estimate of physical volume.

Peak pressure:

The ear canal pressure corresponding to the tympanometric peak was considered as the estimate of peak pressure.

Peak compensated acoustic conductance at tympanic membrane :

The conductance of the middle ear without the effects of the ear canal was estimated from the tympanogram. The following steps were used in calculating conductance at tympanic membrane.

1. Acoustic conductance was calculated with the ear pressurised to +200 dapa, the value that resulted in minimum value (G_{min})

2. Acoustic conductance calculated at the ear canal pressure corresponding to the tympanometric peak gave the peak value for single peaked tympanogram (G_{max}). F*or* notched conductance tympanogram this value was calculated at the ear canal pressure corresponding to the minimum in the susceptance notch.

3. The pressure change was done from -400 da to +200 dapa, Conductance at tympanic membrane was calculated using the equation: $G_{TM} - G_{MAX} - G_{MIN}$

RESULTS AND DISCUSSION

One of the main aim of the study was to find out the effect of probe frequency on conductance tympanogram in males and females in both adults and children. At lower as well as at higher probe tone frequencies, single peaked tympanograms were obtained for conductance tympanograms, for majority of ears. Only 10% of ears of 12 years old male children had notched tympanograms at 1000 Hz.

Effect of probe tone frequency on admittance tympanogram was also found. The percentage of occurrence of notched tympanograms in males and females in both adults and children for conductance and admittance tympanograms are given in Table-1.

	Subjects	Admittance tympanoaram		Conductance tympanogram	
		678 Hz	1000 Hz	678 Hz	1000 Hz
Adults	Males	0	30%	0	20%
	Females	0	50%	0	20%
Children	8 years				
	Males	0	10%	0	0
	Females	0	20%	0	0
	10 years				
	Males	0	30%	0	0
	Females	0	0	0	0
	12 years				
	Males	0	20%	0	10%
	Females	0	10%	0	0

The Table-1 shows that notches occured for admittance and conductance tympanograms only at 1000 Hz, The notched tympanograms were more frequent in adult males for admittance tympanograms. The frequency of occurrence of notched tympanograms was same in adult males and females for conductance tympanograms at 1000 Hz. Less number of children had notches when compared to adults. Only 10% of the subjects in the 12 years old male group showed notched tympanograms. None of the subject in the 10 year old females group showed notched admittance tympanograms.

Overall percentage of occurrence of notch was greater in admittance tympanograms than that in conductance tympanograms. Present study supports the study by Margolis et al. (1985) who reported that as the probe frequency increases, occurrence of notching is more in admittance tympanogram than in conductance tympanograms.

One of the aim of the present study was to establish normative data for admittance and conductance tympanograms for adults and children of both sexes. Mean, S.D., and normal range for physical volume, peak pressure and measurements at tympanic membrane are given in tabular form in the following pages.

Statistical analysis was done using unpaired and paired t-test to find the significant difference between males and females in both adults and children at 0.05 level for the following parameters.

1. Physical volume at 226 Hz in conductance tympanogram.
2. Peak pressure at 226 Hz in conductance tympanogram.
3. Conductance at tympanic membrane.

Table-2: Shows the mean, SD and range for physical volume for admittance and conductance tympanogram at 226 Hz, 678 Hz and 1000 Hz for males and females in adults.

Parameter	Probe frequency in Hz.	Mean		SD		Range	
		M	F	M	F	M	F
Admittance	226	1.14	1.48	0.16	0.26	0.8.1.5	1-2.2
	678	3.46	4.35	0.45	0.76	2.5-4.6	2.8-5.3
	1000	5.75	7.3	0.63	1.41	4.4-7.1	4.22-9.7
Conductance	226	0.28	0.41	0.25	0.33	0.11-1.21	0.17-1.6
	678	0.44	0.75	0.16	0.76	0.11-0.73	0.16-4.5
	1000	0.62	0.70	0.31	0.37	-0.28-1.25	0.1-1.92

Table-3: shows the mean, SD and range for physical volume for admittance and conductance at 226 Hz, 678 Hz and 1000 Hz for males and females in children.

Subjects	Probe frequency in Hz.	Mean		SD		Range		Mean		SD		Range	
		M	F	M	F	M	F	M	F	M	F	M	F
CHILDREN	**8 Years**												
	226	0.87	0.83	0.24	9.49	0.62-1.3	0.7-1	0.17	0.16	3.37	4.77	0.13-0.24	0.11-0.24
	678	2.67	2.58	0.89	0.36	1.81-4.7	2.1-3.1	0.39	0.41	0.21	0.11	0.15-0.82	0.27-0.54
	1000	4.31	3.99	1.86	0.52	3-8.9	3.4-5	0.66	0.72	0.52	0.21	-0.14-1.81	0.47-1.07
	10 years												
	226	0.96	0.72	0.16	0.13	0.8-1.2	0.5-0.9	0.19	0.15	0.04	2.67	0.13-0.26	0.1-0.19
	678	3.04	2.22	0.53	0.35	2.4-3.7	1.8-2.8	0.38	0.35	0.13	7.35	0.22-0.64	0.23-0.46
	1000	5.21	3.82	0.79	0.45	4.2-6.3	3-4.3	0.66	0.47	0.21	0.11	0.35-1.04	0.26-0.62
	12 years												
	226	0.96	0.98	0.17	0.12	0.7-1.2	0.6-1.2	0.19	0.17	4.72	0.04	0.12-0.25	0.11-0.24
	678	3.02	2.96	0.5	0.59	2.3-3.8	1.9-3.6	0.46	0.39	0.19	8.67	0.18-0.78	0.22-0.52
	1000	5.11	4.88	1	0.96	3.8-6.7	3.3-5.9	0.51	0.38	0.31	0.17	0.1-0.92	0.08-0.74

Table-4: Showing the mean, SD, t-value and probability of physical volume between adults and children at 226 Hz in conductance tympanogram.

Subjects	Mean	SD	t-value	Probability	Significance
Adults	0.351	0.303	4.343	0.0001	S
Children	0.171	4.07			

Table-5: Showing the mean, SD, t-value and probability of physical volume between males and females in both adults and children group at 226 Hz in conductance tympanogram.

Subjects	Mean	SD	t-value	Probability	Significance
Adults					
H	0.28	0.25	1.64	0.1075	NS
P	0.41	0.33			
8 years					
M	0.17	3.37	0.23	0.8238	NS
P	0.16	4.47			
10 years					
M	0.19	0.04	2.65	0.0162	S
F	0.15	2.67			
12 years					
M	0.19	4.72	0.63	0.536	NS
F	0.17	0.04			

From Table-2 it could be seen that for adults males and females as the probe tone frequencies increases physical volume also increases in both admittance and conductance tympanogram.

From Table-3 it could be inferred that in children group, as the probe frequency increases. there is increase in physical volume, within each age group in both males and females. It was observed both in admittance and conductance tympanograms. Between the children group. there was increase in physical volume in 10 years and 12 years males and females when compared to 8 years group. But there was no definite difference between 10 and 12 years group in both admittance and conductance tympanograms.

As shown in Table-4 from paired t-test it was found that there was significant difference between adults and children in conductance tympanogram at 226 Hz.

As shown Table-5, from unpaired t-test, it was found that there was no significant difference between males and females in adults, 8 years, and 12 years children. In 10 year group, there was significant difference between males and females.

Table-6: Shows mean, SD and range for peak pressure of 226 Hz, 678 Hz, and 1000 Hz in admittance and conductance tympanograms in females and males in adults.

Parameters	Probe frequency in Hz	Mean M	Mean F	SD M	SD F	Range M	Range F
Admittance							
	226	2.66	0	12.29	12.18	-45-25	-30-45
	678	3.83	5.5	10.64	13.73	-25-35	-15-50
	1000	-4.93	-3.33	25.51	37.63	-80-20	-125-60
Conductance							
	226	-3.66	2.6	13.58	26.46	-35-25	-95-40
	678	2.5	11.6	13.37	19.02	-35-30	-5-50
	1000	1	9.6	10.78	19.52	-35-15	-20-60

Prom Table-6, it could be seen that the normal range for males at 226 Hz in admittance tympanogram is -45 to 25 dapa and that for females is -30 to 45 dapa.

Brooks (1980) reported the normal range for tympanometric peak pressures between -50 dapa to +50 dapa in adults. The results of the present study supports this range.

In conductance tympanogram at 226 Hz, the normal range for males is -35 to 25 dapa and that for females is -95 to 40 dapa.

Table-7: Shows mean/ SD, and range for peak pressure at 226 Hz, 678 Hz and 1000 Hz in admittance and conductance tympanograms in females and males in children

Subjects	Probe frequency in Hz.	Mean		SD		Range	
		M	P	M	F	M	F
Admittance							
8 years	226	-7	-11.5	23.24	23.10	-50 - 10	- 60 - 10
	678	-4.5	-8	21.79	20.78	-50 - 10	-55 - 10
	1000	5.5	-6	30.77	21.83	-65— 50	-50 - 15
10 years	226	1.5	-12	8.33	22.51	-15 - 15	-60 - 5
	678	14	-9	13.08	21.58	-10 - 30	-55 - 10
	1000	12	0.5	24.74	22.66	-35 - 35	-50 - 20
12 years	226	5.5	0.5	15.71	8.32	-20 - 25	-15 - 10
	678	12,5	4.5	29.74	11.65	-10 - 95	-5 - 35
	1000	17.5	15	26.59	22.61	0 - 9 0	-5 - 70
Conductance							
8 years	226	-13-5	-2	24.50	10.33	-65 - 10	-20 - 15
	678	7	2	21.76	7.53	-50 - 10	-10 - 10
	1000	6	2	24.01	6.75	-60 - 10	-10 - 10
10 years	226	2	-21.5	10.59	23.93	-25 - 10	-60 - 15
	678	4	-25.5	9.66	26.50	-15 - 20	-10 - 5
	1000	7.5	-14	19.18	21.06	-25 - 25	-50 - 15
12 years	226	5.5	- 5.5	16.41	9.46	-30 - 15	-20 - 10
	678	3	3	17.98	10.05	-25 - 30	-10 - 25
	1000	1	7	18.68	12.29	-30 - 25	-10 - 30

Table-8: Showing mean, SD, probability and t-value of peak pressure between adults and children at 226 Hz in conductance tympanogram.

Subjects	Mean	SD	t-value	probability	Significance
Adults	.0.818	20.49	2.25	0.0282	3
Children	-0.33	17.79			

Table-9: Showing mean, SD, t-value and probability between males and females at 226 H_z in conductance tympanogram.

Subjects	Mean	SD	t-value	Probability	Significance
Adults					
M	-3.66	13.58	1.13	0.2628	MS
F	2.6	26.46			
8 Years					
M	-13.5	24.50	-1.37	0.8238	NS
F	-2	10.33			
10 years					
M	-2	10.59	2.36	0.0162	S
F	-21.5	23.93			
12 years					
M	-5.5	16.41	0	1	NS
F	-5.5	9.26			

From table-7, in admittance tympanogram at 226 Hz, the normal range becomes narrower for both males and females in children. In conductance tympanogram, in males children at 226 Hz, the range becomes narrower as the age increases, unlike females children.

The normal range for children in admittance tympanogram at 226 Hz is -50 to 10 dapa and that for conductance is -65 to 15 dapa* Brooks (1971) proposed that the lower limit of normal range of peak pressure in children could be -30 dapa. In the present study the lower limits exceeds beyond that of Brook's study. This difference might be due to the number of subjects selected, the age range and the criteria taken for selection of subjects, as follows:

1. In Brook's study, number of subjects was 105 3 and in the present study number was 30.

2. In Brook's study, the age range was 4 to llyears, whereas in present study it was 8, 10 and 12 years.

3. In Brook's study, the criteria was all the subjects had normal hearing. In the present study, the criteria were as follows: (a) PTA within 20 dB (b) Normal BD thresholds from 250 Hz to 4 KHz (c) A type tympanogram in the impedance audiometry.

As shown Table-8, paired t-test showed that there was significant difference between adults and children in peak pressure in conductance tympanogram at 226 Hz,

, As shown in Table-9, from impaired t-test it was found that there was no significant difference between males and females in adults, 8 years group and £2 years group. But there was significant difference between males and females in 10 year group.

Table-10 Shows the mean, SD and range for admittance and conductance at tympanic membrane at 226Hz, 678 Hz and 1000 Hz in admittance and conductance tympanogram for males and females in adults.

Parameters	Probe Frequency in Hz	Mean		SD		Range	
		M	F	M	F	M	F
Admittance	226	0.93	0.76	0.59	0.27	0.3-3.1	0.4-1.6
	678	1.96	2.44	1.19	0.99	0.64-5.4	0.39-3.64
	1000	1.56	1.39	0.90	0.92	-0.41-3.62	-0.6-1.62
Conductance	226	0.85	0.65	0.27	0.25	0.53-1.72	0-1.12
	678	3.63	3.72	1.79	1.79	1.46-8.36	1.22 8.42
	1000	4.78	5.02	1.66	1.39	2.36-8.94	1.78 7.61

Table-11 Shows the mean, 3D and range for admittance and conductance at tympanic membrane at 226 Hz, 678 Hz and 1000 Hz in admittance and conductance tympanogram for males and females in children •

Subjects	Probe frequency in Hz.	Mean		SD		Range	
		M	F	M	FP	M	F
Admittance							
8 rears	226	0.54	0.45	0.14	0.11	0.4 - 0.9	0.,3 - 0.6
	678		1.44		0.46		0.,56 - 1.9
	1000	2.46	1.88	0.77	0.72	0.9 - 3.1	0.,6 - 2.9
10 years	226	0.56	0.39	0.13	0.17	0.4 - 0.8	0,,1 - 0.6
	678	1.78	1.18	0.67	0.32	0.98 - 3.17	0.,8 - 1.8
	1000	1.74	1.82	0.59	0.42	0.9 - 2.8	1.,24 - 2.5
12 years	226	1.02	0.53	0.69	0.29	0.4 - 2.2	0,•2 - 1.2
	678	2.22	1.51	1.49	1.33	0.66 - 5.37	0.,35 - 4.8
	1000	5.08	1.74	9.45	1.21	0.66 - 3.18	0,,56 - 3.66
Children Conductance							
8 years	226	0.52	0.41	0.09	7.46	0.38 - 0.67	0,,25 - 0.54
	678	1.93	1.89	0.89	0.51	0.9 - 4.2	1,.02 - 2.53
	1000	3.7	3.65	1.88	1.09	1.83 - 7.7	1,.71 - 5.04
lO years	226	4.28	0.39	11.85	0.09	0.34 - 0.38	0,.25 - 0.51
	678	1.99	1.58	0.79	0.32	1.27 - 3.89	0,.84 - 1.9
	1000	4.81	3.18	1.69	0.57	2.25 - 7.25	1,.9 - 3.6
12 years	226	0.6S3	0.48	0.21	0.20	0.39 - 1.17	0(.1 - 0.36
	678	2.87	2.83	2.08	1.93	1.64 - 7.72	1,.01 - 2.08
	1000	4.56	2.92	1.83	1.98	1.88 - 8.37	1,.05 - 2.9

Table-12 Showing mean, SD, t-values and probability of conductance and tympanic membrane between adults and children at 226 Hz, 678 Hz and 1000 Hz.

Subjects	Frequency in Hz.	Mean	SD	t value	Proba-bility	Signi-ficance
Adults	226	0.751	0.27	-0.59	0.557	NS
Children		1.111	4.84			
Adults	678	3.67	1.78	-5.99	0.0001	S
Children		2.06	1.17			
Adults	1000	4.90	1.52	3.46	0.0001	S
Children		3.92	1.70			

Table-13: Showing mean, SD,t-value and probability of conductance at tympanic membrane between males and females at 226 Hz, 678 Hz and 1000 Hz.

Subject	Frequency in Hz	Mean	SD	t-value	Probability	Significance
Adults						
M	226	0.85	0.29	-2.99	0.004	S
F		0,65	0.25			
M	678	3.63	1.79	0.198	0.844	S
F		3.72	1.79			
M	1000	4.78	1.66	0.61	0.544	NS
		5.02	1.39			
8 Years						
M	226	0.52	0.09	3.09	0.0063	S
F		0.41	7.46			
M	678	1.93	0.89			
F		1.89	0.51	0.144	0.887	NS
M	1000	3.7	1.88			
F		3.65	1.09	7.86	0.938	NS
10 years						
M	226	4.28	11.85			
F		0.39	0.09	1.03	0.314	NS
M	678	1.99	0.79			
F		1.58	0.32	1.55	0.139	NS
M	1000	4.81	1.69			
F		3.18	0.57	1.32	0.0101	S
12 years M	226	0.61	0.21			
F		0.48	0.20	1.32	0.204	NS
M	678	2.87	2.05			
F		2.83	1.92	1.005	0.328	NS
M	1000	4.56	1.83			
F		2.92	1.98	0.98	0.339	NS

Table-14 showing t-value and probebility of conductance at tympanic membrane between 226 Hz and 678 Hz, 678 and 1000 Hz and 226 and 1000 Hz in males and femU.es for both adults and children.

Subj ects	226 Hz and 678 Hz t-value	Probabi-lity	Signi-ficance	678 Hz and 1000 Hz t-value	Probabi-lity	Signi-ficance	226 Hz and 1000" Hz t-value	Proba-bility	Signi-ficance
Adults									
M	-9,307	0.0001	S	-4.639	0.0001	S	-13.88	0.0001	S
F	-9.897	0.0001	s	-4.342	0.0002	S	-18.46	0.0001	S
3 Years									
M	-5.241	0.0001	s	-3.765	0.0045	S	-5.39	0.004	S
F	-9.091	0.0001	s	-6.414	0.0001	S	-9.508	0.0001	S
10 years									
M	0.596	0.566	NS	-6.561	0.0001		-0.131	0.898	NS
F	-14.072	0.0001	S	-10.402	0.0001		-16.79	0.0001	S
12 years									
M	-3.749	0.0046		-2.045	0.0712		-6.740	0.0001	S
F	-4.189	0.0023		-4.269	0.0021		-4.47	0.0015	S

SUMMARY

The present study was carried out on 30 normal hearing adults, 15 males and 15 females, age range ranging from 18-26 years and 30 normal hearing children of 3 age groups (8, 10 and 12 years) consisting of 5 males and 5 females in each age group. Using Grason Stadler Incorporation 33 version-2 Kiddle Ear Analyzer physical volume peak pressure and conductance at tympanic membrane curve obtained and normative data for conductance and admittance tympanograms were established. Statistical analysis using paired and unpaired t-test was done for the above mentioned parameters.

CONCLUSION

The following conclusions were drawn from the present study:

1. The tympanograms show notching as the probe tone frequency is increased and the notching is more pronounced in admittance tympanograms than in conductance tympanograms.
2. As the age increases physical volume increases.
3. In conductance tympanogram, at 226 Hz the normal tympanometer peak pressure for males, adults, ranges from -35 dapa to 25 dapa, for adult females is from -95 to 40 dapa and that for children is from -65 dapa to 15 dapa.
4. Conductance at tympanic membrane increases at higher probe tone frequencies, as the age increases.
5. There is significant difference between adults children in conductance at tympanic membrane at 678 Hz and 1000 Hz.

LIMITATION:

The present study has limited domain in the following aspects :

1. Eventhough simple random sampling was done for selection of subjects, the number of subjects were less.
2. Children less than 8 years were not considered.

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