EFFECT OF ALTITUDE CALIBRATION ON RESULTS OF TYMPANOMETRY

Reg. No. M0110

Independent Project as a part fulfilment of
First Year M.Sc, (Speech and Hearing),
Submitted to the University of Mysore,
Mysore.

ALL INDIA INSTITUTE OF SPEECH AND HEARING,
MYSORE - 570 006

May, 2002

Certificate

This is to certify that this Independent Project entitled ***"EFFECT OF ALTITUDE CALIBRATION ON RESULTS OF TYMPANOMETRY"*** *is the bonafide work in part fulfilment for the degree of Master of Science (Speech and Hearing) of the student with* ***Register No. M0110.***

Mysore
May, 2002

Dr. M. Jayaram
Director
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Certificate

This is to certify that this Independent Project entitled ***"EFFECT OF ALTITUDE CALIBRATION ON RESULTS OF TYMPANOMETRY"*** *has been prepared under my supervision and guidance.*

Mysore
May, 2002

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DECLARATION

This is to certify that this Independent Project entitled *"EFFECT OF ALTITUDE CALIBRATION ON RESULTS OF TYMPANOMETRY'* is the result of my own study under the guidance of **Dr. C.S. Vanaja,** Lecturer in Audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any University for any other diploma or degree.

Mysore
May, 2002

Reg. No. M0110

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Oh God ! Give me strength to conquer the oddities, the peace of mind to spread the happiness, noble soul to serve the needy. Lead me to the right path. How can I ever thank you.......?

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"God gave me friends

to make me smile

to share & laugh & play

A hand to hold when I need help

To brighten up each day"

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INTRODUCTION

Tympanometry is the measurement of aural acoustic immittance as a function of ear canal volume. With the advances in the technology today, clinical instruments, once quite limited in the choices of measurement parameters, now provide a wide range of alternatives that require the clinician to make decisions about, and understand, many physical dimensions and procedural variables (Margolis and Shanks, 1991). Accuracy of the equipment used in the evaluations is one of the major variables on which validity and reliability of hearing assessment rests and can be tested by performing calibration. Earlier many clinicians believed that 'calibration was something that researchers did and that such calibration procedures were not put into clinical practice.

It has generally been observed that newly procured or installed instruments as well as those which are already in use can show variations in parameters like intensity, frequency, distortion etc. Irrespective of the duration of usage of instrument, a responsible user should either check its calibration personally, or arrange for regular calibration of the equipment by a qualified personnel. The audiologist who has demonstrated that the clinic equipment is "in calibration" can then be confident in reporting the obtained results.

Over the intervening few decades, clinical audiologists have been made aware of the need and importance of equipment calibration. Immittance meters which form an integral part of audiologic clinics should be routinely calibrated. The calibration of basic subsystems of immittance meters includes calibration of probe signal, manometer system, acoustic immittance monitor system and acoustic reflex activator system. Apart from basic subsystems calibration, care should be taken to account for the atmospheric conditions (altitude, barometric pressure etc.) common to specific locations (Lilly and Shanks, 1981, cited in Wiley & Fowler, 1997).

Standard pressure i.e., the average atmospheric pressure at sea level and latitude 45° is 1.012×10^5 N/m^2, or 14.7 $Ib/in.^2$. For ordinary rough calculations, atmospheric pressure can be taken as 15 $Ib/in.^2$ or $megadyne/cm^2$. As one rises above the earth's surface, the barometer reading falls off by 1 in. of mercury per 900 ft rise (Howe, 1948). Also the density of air decreases with elevation above sea level because the pressure decreases (Cromer, 1974). The density of a solid or liquid varies only slightly with changes in temperature and pressure, whereas the density of a gas is strongly temperature - and pressure-dependent (Cromer, 1974).

Inspite of documented effects of interdependence between these atmospheric variables, there is dearth of information regarding altitude calibration of immittance meters.

Need for the study

The present study was undertaken because of the unavailability of information regarding the following aspects :

- Why do a few commercially available immittance instruments have facility of altitude calibration (i.e., facility to set the altitude value of the installation site) and others do not ?
- Would there be a significant error in measurement (of immittance) if altitude value is set to a value different from that of the actual installation site while calibrating the system ?

Aim of the study

To test the need for setting the altitude value of installation site while calibrating the immittance meter.

REVIEW

Calibration is critical to valid and reliable clinical acoustic immittance measures in human ears failing which errors in the diagnosis might crop up. Checking calibration is necessary to be sure that an equipment produces a stimulus say puretone, at the specified level and frequency, that the signal is present only in the transducer to which it is directed, and that the signal is free from distortion or unwanted noise interference. For example, if the value of ear canal volume for 2 cc cavity is indicated by the instrument as 3.5 cc (say), the chances of erroneously diagnosing a subject as having tympanic membrane perforation are quite high.

The calibration of acoustic immittance instruments involves an evaluation of the basic subsystems such as probe signal, manometer system, acoustic immittance monitor system, acoustic reflex activator system. In each case, the purpose of calibration is to determine that the specifications for each subsystem meet or exceed ANSI specifications. During calibration of immittance meter, the calibration of probe unit which provides an acoustic signal (probe signal) that serves as the reference for acoustic immittance measures is very important. The purpose of calibration for the analysis system is to confirm that the acoustic immittance value indicated by the instrument is accurate. Because tympanogram characteristics for human ears vary with the rate of air pressure change, the specific rate or pump speed must be determined.

It is particularly important that the atmospheric conditions (i.e., altitude and barometric pressure) common to the specific location be accounted for in calibration procedure. The acoustic immittance offered by a given volume of air differs with different geographic locations depending on the altitude and barometric pressure (Wiley and Fowler, 1997). Lilly and Shanks (1981, cited in Margolis and Shanks, 1991) have provided a detailed discussion of the way users may correct for the specific atmospheric condition at their respective facilities. Selected manufacturers provide preset calibrations for each purchaser that account for the local conditions.

The effects or air density changes on acoustic measurement device of a middle ear analyser have been realized since the 1970s. It is known that as the air density becomes less, it is more difficult to transmit sound pressure levels (there is no sound in a vacuum). As a result if the instrument is calibrated at the sea level and shipped to a mountainous region, the calibration would shift (Personal communication with Randy Viellette - Sales Manager, M/s GSI).

Rick Le Cuyer, Sales Manager, M/s GSI, (Personal communication) suggests that altitude calibration may be used for two different reasons. First, if the factory is located near sea level, the standard compliance values are based relative to sea level. The instrument is calibrated and adjusted to the expected volumes of 0.5 and 2.0 in their respective test cavities. Assuming that this instrument is then shipped to Denver, Colorado (elevation 5,280 ft above sea level), when the customer receives the instrument and the same test cavities that were calibrated at sea level, are measured again, the values obtained will be different [attributed to the different atmospheric pressure at his (customer's) altitude]. The cavities will measure 0.6 and 2.4 respectively. This is what they should measure at this altitude, but they may rather have their data relative to all the data that is published relative to sea level. This is where the customer would use the altitude calibration mode, to shift the calibration of their instrument so that it will measure the same volume as they would be measured at sea level. Secondly, if the instrument is calibrated in Denver, it will automatically adjust the volumes to the sea level values, unless one specifically indicates the specified altitude value of installation site. Some purists may want the instrument to indicate the site values instead of using the sea level values.

A survey of the commercially available immittance meters indicates that very few instruments have the facility to set the altitude value of the installation site while calibrating the instrument. Even national / international standards do not specify that "altitude calibration" should be a mandatory feature of the immittance meters. For eg., recommendations for Type I immittance meters by ANSI (1987) do not include facility for adjusting the altitude value as one of the features. It is required to investigate the need for this feature as it would help a clinician in choosing an instrument based on its features and the present study was a preliminary step in this direction.

METHOD

The present study aimed at testing the need for setting the altitude value of installation site while calibrating the immittance meters for which the following methodology was incorporated.

Subject selection criteria

30 subjects (15 males and 15 females) meeting the following conditions participated in the study.

- Age range : 17-35 years
- Hearing thresholds for both ears were within normal audiological threshold limits i.e., less than 15 dBHL at the audiometric frequencies i.e., 250 Hz - 8 kHz with air bone gap (ABG) less than 10 dB.
- Subjects had no history of any otologic or neurologic conditions.

Instrumentation

- A calibrated clinical audiometer GSI-61, was used to screen for hearing impairment at the audiometric frequencies, i.e., 250 Hz - 8 kHz.
- Immittance meter GSI-33 version 2 was calibrated for three different altitudes - 2650 ft (altitude of Mysore), 3650 ft and 4650 ft.

The altitude calibration was carried out in the following way :

- In the 'Special Test Mode', option of altitude calibration was chosen.

- The appropriate softkey was selected to record the desired altitude value.
- The cues which appear on the right side of the screen with directions for calibrating selected probe tone were followed :
  - After having set the desired altitude value 'Data Transfer' softkey was pressed to store the data.
  - Probe tone to be calibrated was selected and probe was inserted into 2 cc test cavity, calibration was carried out for 226 Hz and 678 Hz probe tones.
- Once the instrument was calibrated for one altitude value, for each subject, admittance (Y), susceptance (B), and conductance (G) tympanograms for 226 Hz and 678 Hz probe tones were recorded.
- Protocol used for recording the tympanograms was as follows :

Sweep : Backward

Starting pressure : +200 daPa

Ending pressure : -400 daPa

Rate of pressure change : 200 daPa / sec

- Similarly tympanograms were obtained with the instrument calibrated for other two altitude values.
- The Y, B, G tympanograms were obtained randomly for 3 different altitude settings with a rest period of 15-20 minutes between recording of two successive tympanograms.

RESULTS AND DISCUSSION

The aim of the present study was to examine the need for setting the altitude value of installation site while calibrating an immittance meter. For this, the calibration procedure was carried out at customer site. The data obtained from the study was analysed to investigate the aim.

I. Effect of altitude calibration on Ear Canal Volume

		N	Mean	SD	F	Sig.
YECV 226	2650	60	1.1683	.2837	.345	.709
	3650	60	1.2067	.2590		
	4650	60	1.1750	.2672		
BECV 226	2650	60	1.1577	.2703	.349	.706
	3650	60	1.1900	.2621		
	4650	60	1.1567	.2872		

Table A - Ear Canal Volume for three altitude settings

It can be observed from Table A that for 226 Hz probe tone, the mean ear canal volume (ECV) for admittance measures was slightly greater for instrument calibrated to the altitude value of 3650 ft when compared with that for 2650 ft. However when the altitude setting was increased to 4650 ft, there was a slight decrease in ECV. The range of ECV for all the three different altitude settings was similar (0.70 ml to 1.80 ml). Again, for susceptance measures, the mean ECV for altitude 2650 ft and 4650 ft were almost equal whereas mean ECV for 3650 ft was slightly greater than that for other two altitudes. The range was similar for both 2650 ft and 3650 ft (.70 ml to 1.60 ml) whereas it differed slightly for 4650 ft (.70 ml to 1.70 ml). One way ANOVA was done for values of ECV for three different altitude settings (2650 ft, 3650 ft, 4650 ft). The results revealed that setting altitude value has no significant effect on ECV.

Since the altitude calibration was done at same installation site (Mysore) but with different values adjusted in the instrument, there was no significant change in the ECV obtained. If the measurement of ECV was done at different altitudes by shifting the instrument to corresponding elevations (sites), probably there would have been some change in the values thus obtained. As the elevation increases, density and atmospheric pressure decrease and the acoustic impedance of a given volume of air also decreases (Margolis and Shanks, 1991). Therefore, one would expect that when the instrument is calibrated to an altitude value which is different from that of the installation site, there will be a change in the equivalent volume measured. This in turn would be expected to result in erroneous measurement of ear canal volume. However, such a difference was not observed in the present study. This suggests that setting the altitude value of the installation site is probably not an important variable affecting the calibration of the instrument.

II. Effect of altitude calibration on Tympanometric Peak Pressure

		N	Mean	SD	F	Sig.
YTPP 226	2650	60	1.00	10.688	.376	.687
	3650	60	.75	9.821		
	4650	60	2.25	9.33		
BTPP 226	2650	60	-0.666	10.27	.116	.891
	3650	60	-0.833	9.52		
	4650	60	0.00	10.29		
GTPP 226	2650	57	-5.8772	11.14	.204	.816
	3650	58	-4.827	12.28		
	4650	58	-4.569	11.40		

Table B : Tympanometric Peak Pressure for three altitude settings

Table B reveals that for 226 Hz probe tone, for admittance measures, the mean tympanometric peak pressure (TPP) for instrument calibrated to an altitude value of 3650 ft was slightly less than that for 2650 ft. Mean TPP for instrument calibrated to altitude value of 4650 ft was almost twice than that for 2650 ft. The range of TPP for three conditions was comparable (-30 daPa to 25 daPa for 2650ft; -20 daPa to 30 daPa for 3650 ft; -15 daPa to 35 daPa for 4650 ft). For susceptance measures, the mean TPP for instrument calibrated to the altitude values of 2650 ft and 3650 ft was -0.66 daPa and -0.833 daPa respectively, whereas mean TPP for 4650 ft was 0 daPa. The ranges were comparable for the three altitude settings -25 daPa to 25 daPa for 2650 ft; -20 daPa to 25 daPa for 3650 ft and -20 daPa to 35 daPa for 4650 ft. For conductance measures, mean TPP was obtained for 57 ears for 2650 ft, 58 ears for 3650 ft and 4650 ft and was found to be negative (i.e., less than zero), being greatest for 4650 ft (-4.56 daPa) followed by mean TPP for 3650 ft (-4.827 daPa) and least for 2650 ft (-5.877 daPa). However, ranges were comparable for all the three altitude settings -35 daPa to 20 daPa for 2650 ft; -25 daPa to 25 daPa for 3650ft and -30 daPa to 30 daPa for 4650 ft. The reason for having obtained TPP values for < 60 ears is that the tympanograms for conductance measures were flat in a few cases such that the peak could not be identified. Data treated with one way ANOVA revealed no significant difference among values obtained for three different conditions.

It is a well known fact that the pressure in the middle ear will change in an individual only when there is an actual change in the altitude. However, TPP obtained will definitely depend on the calibration of the instrument. If the air pressure system in an immittance meter is not calibrated, it will lead to erroneous measurements. Theoretically, when the altitude value in an immittance meter is set to a value different from that of the installation site, the instrument should not get calibrated to the atmospheric condition of the installation site, by itself. In other words, if the altitude value is set to a value which is higher than value of the installation site, the air pressure built by the instrument should be lesser than the actual air pressure at the installation site. This is expected to result in a change in the measured tympanometric peak pressure. However, the results of the present study indicated that there is no significant change in TPP when the altitude value set in an instrument differs from that of the installation site by 1000 ft or 2000 ft.

III Effect of altitude calibration on Immittance at the tympanic membrane

		N	Mean	SD	F	Sig.
YSC226	2650	60	.8298	.3121	.015	.985
	3650	60	.8262	.2942		
	4650	60	.8355	.2965		
YSC 678	2650	60	2.1727	1.3910	.267	.766
	3650	60	2.1107	1.2561		
	4650	60	2.0040	1.1838		
BSC 226	2650	60	.7607	.2552	.046	.955
	3650	60	.7687	.2525		
	4650	60	.7540	.2850		
BSC 678	2650	60	1.2367	.7481	1.429	.242
	3650	60	1.4123	.6357		
	4650	60	1.4212	.6330		
GSC 226	2650	58	.4190	.2348	.125	.882
	3650	58	.4026	.1360		
	4650	58	.4091	.1443		
GSC 678	2650	60	2.5260	1.8748	.410	.664
	3650	60	2.4578	1.5282		
	4650	60	2.2465	1.8657		

Table C Innittance at the tympanic membrane for three altitude settings

Table C shows that for admittance measure for 226 Hz probe tone, the mean admittance at tympanic membrane for the instrument calibrated to an altitude value of 2650 ft was nearly equal to that for 3650 ft whereas both differed slightly from that for 4650 ft, latter being slightly greater than the former two. The range of admittance at the tympanic membrane for three altitude values was comparable (.50 mmhos to 1.80 mmhos for 2650 ft and 3650 ft, and 0.50 mmhos to 1.70 mmhos for 4650 ft). For probe tone 678 Hz, the mean admittance values at tympanic membrane were almost similar for all three conditions, the ranges too showed slight variability in their values, being 1.06 mmhos to 7.52 mmhos for 2650 ft; .92 mmhos to 7.65 mmhos for 3650 ft and 1.20 mmhos to 6.92 mmhos for 4650 ft.

For susceptance measures, for probe tone 226 Hz, the mean value of susceptance at tympanic membrane for instrument calibrated to installation site 2650 ft was (.7607 mmhos) almost equal to that for 3650 ft (.7687 mmhos), whereas there was minimal lowering in the value of susceptance when the instrument was calibrated for 4650 ft (.754 mmhos). Immittance values ranged between .46 mmhos to 1.63 mmhos for 2650 ft, .51 mmhos to 1.79 mmhos for 3650 ft and .29 mmhos to 1.52 mmhos for 4650 ft. For 678 Hz probe tone, the mean susceptance value for instrument calibrated to 3650 ft was same as that for 4650 ft (i.e., 1.4 mmhos) with a slight decrease for 2650 ft (1.2 mmhos). The range for 2650 ft was -1.4 mmhos to 3.25 mmhos; -.17 mmhos to 3.20 mmhos for 3650 ft and .51 mmhos to 3.20 mmhos for 4650 ft.

For conductance measures, for 226 Hz probe tone, the mean conductance values for instrument calibrated to 3650 ft and 4650 ft were almost equal i.e., .402 mmhos and .409 mmhos respectively. The immittance value obtained for instrument calibrated to 2650 ft was 0.419 mmhos. The ranges were comparable for 3650 ft and 4650 ft. It was .19 mmhos to .72 mmhos and .20 mmhos to .80 mmhos respectively, whereas it differed to a relatively greater extent for 2650 ft (.16 mmhos to 1.90 mmhos). The mean conductance values for 678 Hz probe tone were quite similar for three different altitudes (2.52 mmhos for 2650 ft; 2.45 mmhos for 3650 ft and 2.24 mmhos for 4650 ft). Range for 2650 ft was .77 mmhos to 11.72 mmhos, for 3650 ft range was .90 mmhos to 9.33 mmhos and .28 mmhos to 11.92 mmhos for 4650 ft. One way ANOVA was employed which revealed no significant effect of altitude calibration.

The middle ear is not affected by air density, that is, an ear with an immittance value of 1.0 mmhos should measure the same at sea level as it would at a high altitude as long as the air pressure on both sides of the tympanic membrane is equal (Personal communication with Randy Viellette - Sales Manager, M/s GSI). However, while the immittance at the tympanic membrane is being measured, the calibration of the instrument is important. If the instrument is measuring a 2cc cavity as 2.2 cc cavity, then the immittance measures obtained would be erroneous. However, in this experiment there was no significant change in the ear canal volume when the instrument was calibrated to three different altitude values. Hence there was no difference in the values obtained for immittance at the tympanic membrane for three different conditions.

To summarize, the results of the present study showed that there was no change in immittance measured when the altitude set while calibrating the instrument was different from that of the installation site. This suggests that probably the instrument automatically takes into consideration the atmospheric conditions at the installation site irrespective of the altitude value set while calibrating the instrument. The other possibility is that, probably a difference of 2000 ft in altitude is not significant enough to result in a change in immittance parameters.

SUMMARY AND CONCLUSIONS

Calibration of immittance instrument plays a characteristic role in day to day clinical practice failing which the accuracy of diagnosis may be hampered. Today with many immittance instruments commercially available in the market and new ones coming up, there has been an increase in the novel features added to these instruments. One of such features is facility of 'altitude calibration'. The present study aimed at testing the need to set the exact value of altitude of installation site while calibrating the immittance meter and its effects on the results of tympanometry, if any.

A total of 30 subjects (15 males and 15 females) whose hearing thresholds were within normal limits and who had no history of middle ear problems were included in the study. The immittance meter GSI 33 version 2 was calibrated at Mysore (altitude of 2650 ft) with the altitude values set to three different values i.e., 2650 ft (the actual altitude of installation site, Mysore), 3650 ft and 4650 ft. The measurement of ear canal volume (ECV), tympanometric peak pressure (TPP) was carried out for 226 Hz probe tone, whereas immittance at the tympanic membrane was measured for 226 Hz and 678 Hz probe tones.

The data thus obtained was statistically analysed by employing one way ANOVA which revealed that there was no significant difference in the values obtained for three different conditions. These results indicate that the immittance meter automatically takes into consideration the atmospheric conditions irrespective of the altitude value set in the instrument, at least when the difference between the altitude value of installation site and the altitude value set is less than 2000 ft.

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