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Original Article

Wideband Tympanometry Normative Data for Different Age Groups in Turkish Population

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OBJECTIVE: Studies on the use of wideband tympanometry (WBT) for the evaluation of middle ear pathologies have been increasing gradually in recent years. However, studies regarding normative data of WBT are not sufficient. The aim of this study was to determine normative values of WBT for different age groups in Turkish population.

MATERIALS and METHODS: One hundred fifty volunteers from five age-related groups were included in this study. Values of resonance frequency (RF), absorbance percentage according to frequency, maximum absorbance ratio, and maximum absorbance frequency were obtained using WBT. Measurements were recorded at a pressure of 0 decapascal (daPa) using a sound stimulus given at 90±3 decibel sound pressure level (dB SPL).

RESULTS: The RF was detected to be significantly lower only in the group of subjects in the age range of 0–1 month. The absorbance value at 250 Hz was detected to be significantly higher in the age groups of 0–1 month and 1 month–2 years than in the other groups.

CONCLUSION: We believe that the findings obtained in this study would be helpful in determining normative data regarding WBT; by the determination of this normative data, the clinical use of WBT would become widespread.

KEYWORDS: Wideband tympanometry, resonance frequency, absorbance

INTRODUCTION

The transmission of sound through the hearing system depends on the sound transmission properties of the middle ear. Tympanometry, which is used in the evaluation of middle ear sound transmission, is a noninvasive test that provides cost-effective assessment. Tympanometry mainly determines the resistance and permeability of the middle ear system via measuring the response of the middle ear to a sound stimulus using a microphone while pressure is changed along the external auditory canal [1, 2]. However, the evaluation of middle ear pathology with tympanometry alone is not sufficient. Its combination with audiometry/acoustic reflex may be needed when required [3]. For clarity with regard to the use of terminologies, the term absorbance will be used to define the energy that is permitted to pass through the ear. This energy corresponds to 1 minus the reflectance, which is the energy that is not permitted to pass through the ear.

Tympanometry with a frequency of 226 Hz is the most commonly used test for the objective evaluation of conductive-type middle ear pathologies. In 1976, after classical tympanometry with a frequency of 226 Hz was introduced into clinical use, Coletti [4] used multifrequency tympanometry to identify changes in various middle ear diseases. This is a testing procedure that can determine the admittance of the middle ear over a wide spectral range of frequencies (200–2000 Hz). The use of multifrequency tympanometry provides more detailed data about the evaluation of standard middle ear pathologies due to age-related effects on the resonance frequency (RF) of the ear. Because multifrequency tympanometry can demonstrate age-related changes in the structure of the middle ear, the technique has appeared in routine test batteries, particularly for the investigation of infants [5].

Studies have shown that because the stiffness of tissue in the wall of the external ear canal is less in newborns and infants, 226 Hz tympanometry is inconsistent and unreliable in this age group [3, 5, 6]. In adults, an energy reflectance of approximately 100% is seen at low frequencies; this ratio decreases as the frequency increases up to 4 kHz. For higher frequencies, the reflectance increases again. Low reflectance is observed in the range corresponding to the frequencies that are important for speech perception. A decrease in energy reflectance in the frequency range between 2 and 4 kHz is typical for a healthy middle ear. However, for newborns, reflectance at low frequencies is lower than that in adults, which means a higher admittance; however, reflectance is similar at high frequencies [7-11].

More than 90% of infants aged <2 years have previously been affected by the attacks of acute otitis media or otitis media with effusion. Clinicians mostly rely on otoscopic examination and tympanometric evaluation in this age group. However, it is advantageous

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to use wideband tympanometry (WBT), particularly for infants aged <6 months [6, 12].

Wideband tympanometry (WBT) is a recent method for the evaluation of the middle ear. In comparison with classical tympanometry, WBT can obtain more sensitive results in conductive hearing loss. In addition, WBT provides immittance-based evaluation up to a frequency of 10 kHz in adults and 20 kHz in infants [9]. Measurements are performed using wideband stimuli and many sinusoidal waves at different frequencies. In addition, more accurate test results can be obtained with assessments at frequencies of 0.2 kHz–8 kHz at 100-Hz intervals. The results obtained by measuring over wide frequency ranges with small frequency intervals can yield more precise information about middle ear pathologies [12].

The term RF is used to define the frequency at which the stiffness and middle ear admittance are equal. This is the frequency at which the total value of susceptance is equal to zero and the system vibrates at its natural frequency. Susceptance is defined as the algebraic sum of stiffness and mass elements. The RF can be measured using a susceptance tympanogram. As the mass effect increases in the middle ear, the RF tends to shift toward lower frequencies. However, as the stiffness increases the RF tends to shift toward higher frequencies [1, 12].

Another advantage of WBT in clinical use is its additional facility in the calculation of reflectance or absorbance values compared with conventional tympanometry. Reflectance is the amount of waves reflected from the middle ear when sound pressure or energy is applied through the external ear. The amount that is not reflected by the middle ear but transferred to the inner ear is called absorbance. Reflectance is inversely proportional to absorbance [13].

As has been stated in the Eriksholm Workshop, because there are few data about normative values of WBT, there is a need for further measurements for different age and disease groups [14]. The aim of this study was to determine normative values of WBT from birth to late adulthood in Turkish population.

MATERIALS and METHODS

This study was approved by a local ethics committee (Approval No. 2014/55). Volunteers who were normal on otologic examination and who were not experiencing hearing loss were enrolled in this study.

Participants

In this study, 300 ears of 150 subjects in various age groups were investigated. The participants were divided into five equal groups based on the development of ear structures and age-related hearing changes. The age of the groups ranged from 0 to 1 month (neonates), 1 month to 2 years (infants), 2 years to 20 years (childhood and teenage period), 20 years to 45 years (early adulthood), and >45 years (late adulthood). Thirty participants were investigated in each group. The groups were defined according to the literature on multifrequency tympanometry. Because developmental changes in ear structures were not expected among the adulthood groups, the division was made according to the age at which presbycusis is assumed to begin. The adulthood cut-off point was therefore 45 years of age.

A complete ear, nose, and throat examination was performed on each volunteer. The external ear canal was cleaned out in individuals with cerumen. The criteria for subjects to participate in the study were as follows:

1. Absence of any pathology in the external auditory canal, tympanic membrane, and middle ear on otoscopic examination.
2. Absence of a history of hearing loss.
3. Absence of a history of ear surgery.
4. Tympanogram values in the normal range for the frequencies tested between 226 and 1000 Hz (Type A).
5. An average threshold of 15 dB or better in pure-tone audiometry in adults or children who gave reliable responses; passed test in a transient otoacoustic emission test for children and infants who could not respond to a pure-tone hearing test.

After obtaining informed consent from the participants or parents of infants and children, participants who matched the inclusion criteria were included in the study.

Test Battery

Pure-tone audiometry tests were performed with an AC40 clinical audiometer (Interacoustics; Assens, Denmark) in a double-walled quiet cabin to determine the hearing thresholds of participants. Pure-tone average was taken as the average of thresholds at frequencies of 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz. For infant and child participants who could not adapt to the pure-tone audiometry test, a transient evoked otoacoustic emission test was applied for screening with an Echoport ILO292 USB II otoacoustic emission device (Otodynamics Ltd.; Herts, UK). All candidates were evaluated with an AT235H tympanometry device (Interacoustics; Assens, Denmark) for 226-Hz and 1000-Hz tympanograms. Using a Titan WBT device (Interacoustics; Assens, Denmark), values of RF, absorbance percentage according to frequency, maximum absorbance ratio, and maximum absorbance frequency were obtained. Measurements were made at a pressure of 0 decapascal (daPa) using a sound stimulus given at 90±3 decibel sound pressure level (dB SPL) via an external ear canal probe that was appropriate to the age and structure of the ear canal of the participants. OtoAccess ver. 1.2.1 (Interacoustics; Assens, Denmark) data-recording software was used to record the data and calculate the outcomes.

Statistical Evaluation

The age and sex distributions of the groups were determined from the data collected. In addition, values of RF, absorbance percentage according to frequency, maximum absorbance ratio, and maximum absorbance frequency were determined for each group. For statistical analysis, Statistical Package for Social Sciences (SPSS) for Windows 12.0 software was used (SPSS Inc.; Chicago, IL, USA). To compare right- and left-side ears, the t-test was used. In addition, an analysis of variance (ANOVA) test was used for inter-group data assessments and a Pearson test was used for correlations. Results were assessed at a 95% confidence interval with a significance level of $p<0.05$.

RESULTS

In this study, 300 ears of 150 participants (66 male, 84 female) in five different age groups were evaluated. Age and gender data of the groups are presented in Tables 1 and 2.

Resonance Frequency

There was no statistically significant difference in terms of RF between right and left ears or by gender ($p>0.05$). Data for RF by age groups are presented in Table 3.

Table 1. Age data according to age group

	0–1 month (days)	1 month–2 years (months)	2–20 years (years)	20–45 years (years)	>45 years (years)
Mean age	12.9±6.3	9.9±8.2	10.8±5.8	30.0±8.2	55.4±7.3
Lower–upper age	5–30	2–24	3–20	21–45	46–77

Table 2. Gender data according to group

	0-1 month	1 month-2 years	2-20 years	20-45 years	>45 years
Male	14	13	16	17	6
Female	16	17	14	13	24

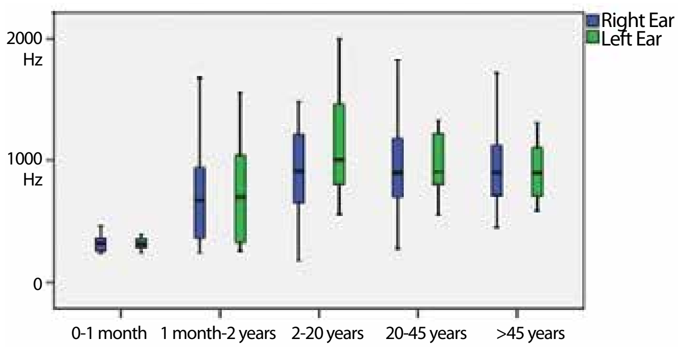

Figure 1. Mean resonance frequency according to age group

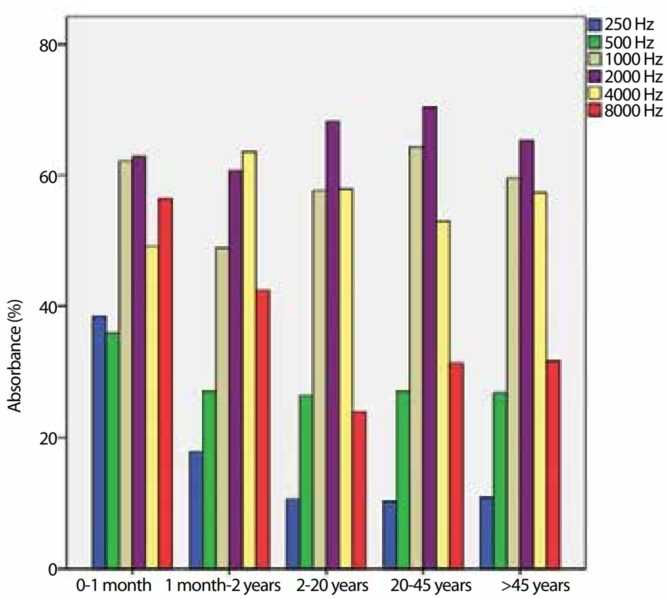

Figure 2. Frequency-specific absorbance rate according to age group

With respect to RF according to age group, only the group of neonates was found to have significantly lower values compared with the other age groups (comparison with infants p<0.04 and with the other groups p<0.001). During analysis of the groups, when the infants were investigated the difference in RF before and after 6 months of age was significant. It was higher in infants aged >6 months (p=0.008). In addition, the difference in RF was also significant between the 0 to 1 month and 1 month to 6 months age groups, with higher values for the group of infants (p<0.001). A graph of RF according to age group is presented in Figure 1.

Frequency-Specific Absorbance Values

The differences between values of frequency-specific absorbance according to ear side and gender were not significant (p>0.05). Values of frequency-specific absorbance are presented in Table 4.

The values of frequency-specific absorbance of neonates and infants at 250 Hz were statistically significantly higher compared with the other age groups (p<0.001). When comparing the values of frequency-specific absorbance derived from subjects in these two groups, the value of absorbance at 250 Hz was significantly higher in the neonates group (p<0.001). Rates of frequency-specific absorbance by age group are presented in Figure 2.

Maximum Absorbance Ratio and Maximum Absorbance Frequency

There was no significant difference in the sample groups in terms of data for maximum absorbance ratio and maximum absorbance frequency between ear sides and by gender (p>0.05). Values of the average maximum absorbance ratio by age group and maximum absorbance frequency are presented in Table 5.

There was no significant difference observed in the maximum absorbance ratio and maximum absorbance frequency among age groups (p>0.05). In the childhood and teenage age group, a significant correlation was detected between RF and maximum absorbance frequency (p<0.001). There was no significant correlation in the other groups (p>0.05).

DISCUSSION

By introducing WBT into clinical use, compared with classical tympanometry with a frequency of 226 Hz and multifrequency tympanometry, a wider range of frequencies began to be scanned faster. Absorbance and reflectance measurements can also be performed [9, 13]. Because normative and disease-specific data have not been finalized yet, use of this technique is not widespread. There have been very few studies conducted with WBT in the literature.

In studies to determine normative data of WBT in groups of healthy newborns and children, ear side and gender were found to have no effect on tympanometric findings [6, 15]. In terms of right–left ear side and gender effects the results of the present study correlate with those of previous studies in the literature.

Wideband tympanometry was found to be more sensitive compared with conventional 226 Hz tympanometry in studies that evaluated conductive hearing loss, particularly in infants [9]. Similarly, in previously published case series that evaluated middle ear pathologies that cause mild conductive hearing loss in the adult population, findings were normal in 226 Hz tympanometry; however, lower values of absorbance were demonstrated in WBT [16]. In multivariate analysis for the detection of conductive hearing loss, particularly when the air–bone gap was in the range of 15–20 dB, multifrequency evaluation with the aid of WBT was shown to be superior to conventional single-frequency evaluation. However, the adequacy of WBT in determining the size of the air–bone gap has not yet been demonstrated by existing studies [17]. To show the effectiveness of multifrequency evaluation as provided

Table 3. Values of resonance frequency (Hz) according to age group

	0–1 month	1 month–2 years	2–20 years	20–45 years	>45 years
Resonance frequency of the right ear; Average±SD (min-max)	330.4±93.4 (238-713)	706.6±413.4 (240-1677)	1036.0±669.8 (178-3566)	1010.5±528.9 (275-2695)	1050.8±604.7 (449–3174)
Resonance frequency of the left ear; Average±SD (min–max)	347.6±128.3 (242–826)	784.0±563.0 (252–2986)	1184.0±599.4 (558–3451)	1211.5±725.5 (554–2978)	1121.7±728.2 (587–3505)

Table 4. Values of frequency-specific absorbance according to age group*

	0–1 month	1 month–2 years	2–20 years	20–45 years	>45 years
Absorbance of the right ear at 250 Hz (%)	38.5±10.5 (12–56)	17.8±14.8 (0–54)	10.5±7.8 (2–40)	10.2±6.3 (2–24)	10.8±6.3 (2–26)
Absorbance of the left ear at 250 Hz (%)	39.5±13.7 (6–66)	23.1±17.4 (2–72)	8.1±6.6 (0–28)	10.1±7.7 (0–36)	9.8±7.3 (0–30)
Absorbance of the right ear at 500 Hz (%)	35.8±11.7 (2–66)	27.1±13.7 (6–60)	26.3±16.3 (6–72)	27.1±13.5 (2–54)	26.8±14.4 (5–64)
Absorbance of the left ear at 500 Hz (%)	35.2±9.4 (22–54)	32.4±15.2 (8–68)	21.6±14.5 (0–58)	25.7±15.5 (4–70)	26.4±15.2 (2–66)
Absorbance of the right ear at 1000 Hz (%)	62.2±17.3 (2–90)	48.9±20.5 (10–86)	57.7±17.9 (24–85)	64.3±18.7 (20–94)	59.5±21.1 (4–90)
Absorbance of the left ear at 1000 Hz (%)	61.4±18.4 (22–92)	53.7±18.0 (22–84)	58.4±20.6 (15–86)	62.3±16.1 (28–92)	69.0±17.4 (28–96)
Absorbance of the right ear at 2000 Hz (%)	62.9±25.8 (2–94)	60.7±23.1 (2–95)	68.1±16.2 (26–98)	70.4±15.3 (34–94)	65.2±18.7 (22–96)
Absorbance of the left ear at 2000 Hz (%)	64.4±23.6 (5–94)	61.6±20.8 (20–96)	72.8±14.7 (38–96)	73.0±17.2 (32–98)	69.0±17.4 (28–96)
Absorbance of the right ear at 4000 Hz (%)	49.1±15.5 (20–98)	63.6±21.7 (20–98)	57.8±24.1 (22–92)	52.9±19.6 (10–84)	57.4±19.6 (10–90)
Absorbance of the left ear at 4000 Hz (%)	56.4±15.2 (30–80)	69.1±23.8 (20–98)	62.4±22.8 (24–98)	52.1±22.1 (8–95)	57.4±20.3 (0–96)
Absorbance of the right ear at 8000 Hz (%)	56.4±23.1 (15–96)	42.5±24.4 (14–96)	23.9±15.2 (10–82)	31.3±13.3 (14–70)	31.6±16.1 (14–90)
Absorbance of the left ear at 8000 Hz (%)	58.0±23.1 (5–90)	35.2±22.2 (10–88)	24.3±12.0 (12–65)	32.8±17.2 (14–92)	31.4±14.8 (14–80)

* Values are given as X±SD (min–max)

Table 5. Values of maximum absorbance ratio and maximum absorbance frequency according to age group*

	0–1 month	1 month–2 years	2–20 years	20–45 years	>45 years
Maximum absorbance ratio of the right ear (%)	87.6±11.7 (42–98)	86.8±13.0 (34–98)	87.7±10.3 (52–98)	84.8±10.9 (60–98)	86.3±10.6 (58–98)
Maximum absorbance ratio of the left ear (%)	87.9±11.5 (45–98)	84.1±18.8 (14–98)	90.3±8.4 (60–98)	84.4±13.3 (54–98)	85.5±9.3 (68–98)
Maximum absorbance frequency of the right ear (Hz)	2236.9±1291.0 (1000–8000)	2539.4±1203.0 (816–5039)	2199.6±1041.0 (793–5039)	2675.2±1501.2 (890–8000)	2569.8±1213.9 (648–6727)
Maximum absorbance frequency of the left ear (Hz)	1988.3±1430.1 (971–6536)	2503.5±958.9 (865–4039)	2702.0±999.9 (916–4896)	2720.5±1218.9 (771–6924)	2348.1±1417.2 (707–8000)

*Values are given as X±SD (min–max)

by WBT, there is a need for normative data for various age groups with studies on larger groups. The current study presents normative values of WBT obtained from a sample of Turkish population and the distribution of these values according to age groups.

Studies of RF commonly use multifrequency tympanometry. The value of RF was found to be in the range of 800 Hz to 1100 Hz in adults. The variability of the middle and external ear structure, which depends on age and genetic features, is considered to be the reason for the variation in RF [18]. In another study of multifrequency tympanometry performed on adults in Turkey, the value of RF was found to be 999.6±134.9 Hz [19]. No effects of ear side and gender have been shown in RF studies. In this study, the value of RF was found to be significantly lower in the 0 to 1 month age group in statistical analysis ($p<0.05$). Conversely, the remaining age groups did not exhibit such a significant age-related difference ($p>0.05$). In a study of infants who were 4, 12, and 24 weeks of age, Sanford et al. [20] found that the average value of reflectance was higher in the 4 weeks group than the other two groups. Palva et al. [21] attributed this mainly to amniotic fluid filling the middle ear during the first month of life. After aeration occurs in the middle ear development continues until 6 months of age.

In a study of young adults, Caucasians demonstrated significantly lower values of absorbance than Chinese participants. Differences in body structure were proposed as a reason for this but the study group did not give information about the body structure of the groups [22]. In the present study, the values of absorbance at a frequency of 250 Hz were significantly higher in the 0 to 1 month and 1 month to 2 years groups compared with the other groups ($p<0.05$).

Although the findings we have obtained have made a significant contribution to the determination of normative data of WBT, factors such as the small number of subjects and the fairly wide age range, particularly for the younger age groups, limited the effectiveness of our study. Detailed studies about WBT in newborns and infants are available in the literature [9, 11, 20]. Therefore, the age range was kept fairly wide in this age group. However, there are few data in the literature regarding the findings that we have obtained for subjects above 2 years of age.

In conclusion, we suggest that the determination of normative values of WBT would enable its widespread use. This study provides preliminary data for values of maximum absorbance ratio and maximum absorbance frequency over a wide frequency range. Future studies that provide more data about normative values may contribute to the clinical usefulness of WBT.

Ethics Committee Approval: The approval of local Institutional Review board has been obtained (2014/55).

Informed Consent: Written informed consent has been obtained from all participants.

Peer-review: Externally peer-reviewed.

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