**Research Article**

# Normative Wideband Tympanometry Measures in Birth to 2-Months Iranian Infants: A Preliminary Study

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**Short running title:** Normative Wideband Tympanometry Measures in…

**Highlights:**
- Race, gender, and age affect Wideband Tympanometry (WBT) parameters
- WBT is a more accurate approach to identifying middle ear disorders in infants
- Using separate norms may increase the sensitivity and specificity of the WBT test

**ABSTRACT**

**Background and Aim:** Wideband Tympanometry (WBT) evaluation of the middle ear is a more accurate approach to identifying middle ear disorders, especially in infants and neonates. Therefore, the need to achieve WBT normative values in the infant population seems obvious. This study aims to evaluate the normative wideband tympanometry values measured in birth to 2-months Iranian infants.

**Methods:** Sixty-four infants participated in this study, including 9 girls and 11 boys in the age group of 0–14 days and 17 girls and 27 boys in the age group of 15–60 days.

**Results:** The normative range of the mean resonance frequency in the first and second age groups was between 298–323 Hz and 324–339 Hz, respectively. At the frequencies of 500 Hz and 1000 Hz, the effect of age groups, at the frequency of 2000 Hz, the effect of age groups, gender, and ear side, at the frequency of 6349 Hz, the effect of gender and age groups, and finally at the frequency of 8000 Hz, the effect of gender in different modes was observed. The normative range of the mean ear canal volume in the first and second age groups was between 0.41–0.38 ml and 0.42–0.46 ml, respectively. The normative range of mean peak tympanometric pressure in the first and second age groups was between –21 to 32 daPa and –8 to 25 daPa.

**Conclusion:** The use of separate norms for males and females in different situations may increase the sensitivity and specificity of the wideband tympanometry.
**Keywords:** Wideband tympanometry; normative values; infant

## Introduction

Tympanometry is an objective and suitable test for diagnosing middle ear disorders. Tympanometry with a 226 Hz tone probe has a low sensitivity in identifying middle ear disorders in infants [1, 2]. Of course, tympanometry with a 1 kHz probe tone overcomes this limitation [3-5]. However, several studies have questioned the actual usefulness of 1 kHz tympanometry in infants [6]; Therefore, there is currently no consensus on a gold standard for the diagnosis of middle ear disorders in infants [7].

Wideband Tympanometry (WBT) is a more accurate approach to identifying middle ear disorders, especially in infants. WBT measures energy reflectance or absorbance over a wide range of frequencies (ie. 226–8000 Hz). Energy reflectance is defined as the ratio of reflected energy to incident energy, and energy absorbance is defined as the fraction of incident energy absorbed by the middle ear [8]. WBT has the potential to provide a better description of middle ear function and may be the missing gold standard in the diagnosis of middle ear disorders [7].

The need to achieve norm values based on a specific population for the parameters related to reflectance and absorbance, especially in the infant population, seems obvious. How WBT patterns change in the norm population at different frequencies is partly influenced by demographic characteristics including race, gender, and age [9-11].

Chang et al. reported that the amount of absorbance in the ears of Korean infants was significantly different from the ears of Korean adults and Caucasian infants [8]. Aithal et al provided convincing evidence that Aboriginal Australian infants had significantly lower absorbance values compared to their Caucasian counterparts. More research is needed to determine the factors that may explain the difference in the above test between the two racial groups [12].

Aithal et al found no significant differences between ears or gender for the Wideband Acoustic Immittance (WAI) measures. The results showed that The WAI measures between 1 kHz and 4 kHz may provide the most stable response of the outer and middle ear. WAI measures at frequencies above 4 kHz were more variable [13].

Studies have shown that race, gender, and age influence WBT; On the other hand, the goal of every audiology test is to optimize the sensitivity and specificity of the test [10, 14]. One way to improve the sensitivity and specificity of the test is to reduce the variability and diversity of the norm data. This study investigated the effect of the aforementioned demographic characteristics on WBT values. According to the conducted checks and queries, there are no normative values of wideband tympanometry indicators and parameters for Iranian infants up to 2 months old. Therefore, this research evaluated the normative wideband tympanometry values in birth to 2-month Iranian infants.

## Methods

### Participants

The current study is of a non-interventional (observational) descriptive-analytical applied type. The infants considered for this study were selected from maternity hospitals and hospitals under the supervision of Iran University of Medical Sciences, such as Shahid Akbarabadi Hospital, Hazrat Ali Asghar (AS) Hospital, and clients at the audiology clinic of Iran Rehabilitation Faculty. Parents of 71 babies announced their readiness for this plan. Among these, 7 babies did not meet the inclusion criteria and were excluded from the study. Finally, 64 infants were included in this study, including 26 girls and 38 boys. Infants were divided into two age groups: 0–14 days and 15–60 days. Demographic data can be seen in Table 1.

The inclusion criteria in this study were: 1) Having Iranian nationality (by checking the national card number), 2) "Pass" result in the Automated Auditory Brainstem Response (AABR) test, 3) "Pass" result in the Transient Evoked Otoacoustic Emissions (TEOAEs) test, 4) "Normal" result in the High-Frequency Tympanometry (HFT) test and 5) Declaration of the consent of the baby's parents (by completing the consent form).

In this study, the Otoport Lite TEOAEs and AABR devices of the Otodynamics company, made in England, the AT235h HFT device of the Interacoustics company, made in Denmark, and the Titan WBT device of the Interacoustics company, made in Denmark was used to perform the tests.

## Wideband tympanometry recording approach

After choosing the appropriate size probe tip, the probe was inserted into the baby's ear canal and the absorbance values at different frequencies and Resonance Frequency (RF) were measured in each ear. To take into account the variability of the results (absorbance values at different frequencies and RF in each ear), the WBT test was performed twice and the results were averaged. Meanwhile, in addition to reporting the findings related to the present study, additional variables such as Ear Canal Volume (ECV) and Tympanometric Peak Pressure (TPP) have also been investigated.

## Statistical analysis

Collected data were analyzed in SPSS v.17 software (IBM Corp., USA). The normality of data distribution was examined using the Kolmogorov-Smirnov test. According to the analytical goals, wherever the findings had a normal distribution, the parametric independent t-test and wherever the findings did not have a normal distribution, the non-parametric synonymous test was used. The significance level in this study is $p<0.05$.

## Results

This study has evaluated normative WBT measures in a population of Iranian infants living in Tehran and provides useful information about the effect of factors such as gender, ear side, and age on variables such as RF, the amount of absorbed energy at different frequencies, ECV, and TPP. The present study aimed to obtain standard information regarding the variables considered in the wideband tympanometry of the above-mentioned infant population, and the next aim was to compare the obtained results with the norm values of the WBT Titan Interacoustics device in the intended age range. With the correspondence that took place with the alleged researchers of the device about the norm values recorded in it, due to their lack of cooperation, it was impossible to obtain the statistical information of the device, and as a result, it was not possible to achieve this goal; However, the normative WBT measures of Tehran's infants were performed and its results were compared with other studies in this field.

### Resonance frequency

The mean and standard deviation of RF can be seen in Table 2. As can be seen, the normative range of the mean RF in the first age group is between 298–323 Hz, and in the second age group between 324–339 Hz. There are differences in RF between the different modes, which are mentioned in the section below.

### Wideband tympanometry absorbance

The mean and standard deviation of WBT absorbance can be seen in Tables 3 and 4. In addition, the 10th, 25th, 50th, 75th, and 90th percentiles of WBT are shown in Tables 5 and 6. Figure 1 shows the pattern of mean and standard deviation of absorbance and Figure 2 shows the pattern of 10th, 50th, and 90th percentiles of WBT absorbance.

### Ear canal volume

The mean and standard deviation of ECV can be seen in Table 2. As can be seen, the normative range of ECV in the first age group is between 0.41–0.38 ml, and in the second age group between 0.42–0.46 ml. There are differences in ECV between the different modes, which are mentioned in the discussion section.

### Tympanometric peak pressure

The mean and standard deviation of TPP can be seen in Table 2. As can be seen, the range of the mean TPP norm in the first age group is between –21 to 32 daPa, and in the second age group between –8 to 25 daPa. According to the standard deviation obtained, there is a large dispersion between the data.

## Discussion

### Resonance frequency

There was a significant difference between the RF of the left ear of the female and the RF of the right ear of the female, and the RF of the left ear of the female and the RF of the left ear of the male in the first age group ($p=0.040$ and $p=0.038$, respectively). In the first group, the female's right ear RF (319 Hz) was higher than the female's left

ear RF (298 Hz) and the male's left ear RF (323 Hz) was higher than the female's left ear RF (298 Hz). Therefore, the effect of ear side on the RF of females in the first group and the effect of gender on the RF of the first group were observed.
The findings of our study are similar to some studies and different from others. André et al evaluated the RF of infants' ears using WBT during two-time stages of 0–12 days and 72–84 days. No significant difference was observed between 0–12 days and 72–84 days (as in our study) and between ears [15]. He et al investigated the ear RF of 61 infants in three age groups: 3–7 days, 8–14 days, and 15–21 days. As in our study, there were no significant differences between the three age groups. Furthermore, no significant differences were observed between gender and between ears [16]. Since some of the results of the studies are different from each other, it is suggested to perform the evaluations in infants with similar age groups.

**Wideband tympanometry absorbance**

The absorbance curve pattern in both age groups had similarities with each other. In both age groups, the absorbance curve showed two peaks, the first peak occurred between 1259 Hz and 2000 Hz (with maximum absorbance at 1587 Hz), and the second peak between 5039 Hz and 8000 Hz (with maximum absorbance at 6349 Hz frequency). The lowest amount of absorbance was observed in the frequency range of 3174 Hz and 4000 Hz. These findings of our study are consistent with the findings of Aithal et al. [13, 17]. In addition, the lowest amount of absorbance in our study occurred in the frequency range of 3174 Hz and 4000 Hz. This finding is slightly different from the results of the studies of Aithal et al.; so, in these studies, the lowest amount of absorbance is seen both in the frequency range of 3174 Hz and 4000 Hz and in 400 Hz and 600 Hz [13].
The amount of WBT absorbance in different frequencies except for the frequencies of 500 Hz, 1000 Hz, 2000 Hz, 6349 Hz, and 8000 Hz was not significantly different considering the different modes of age groups, gender, and ear side. At the frequency of 500 Hz, the absorbance amount of the right ear of the female in the first group (0.43) was statistically lower compared to the right ear of the female in the second group (0.47) and the effect of age groups was observed (p=0.021, F=6.073, df=24). At the frequency of 1000 Hz, the absorbance amount of the left ear of the male in the first group (0.75) was statistically higher compared to the left ear of the male in the second group (0.72), and the effect of age groups was observed (p=0.046, F=4.267, df=36). At the frequency of 2000 Hz, the absorbance amount of the male's left ear (0.72) compared to the male's right ear (0.84) in the first group, and the absorbance amount of the male's left ear (0.72) compared to the female's left ear (0.86) in the first group was statistically lower, and the effect of ear side and gender were observed respectively (p=0.004 and p=0.012). In addition, the absorbance amount of the left ear of the male in the first group (0.72) was statistically lower compared to the left ear of the male in the second group (0.83) and the effect of age groups was observed (p=0.045). At the frequency of 6349 Hz, the absorbance amount of the left ear of the female (0.64) compared to the left ear of the male (0.47) in the first group, and the absorbance amount of the right ear of the female (0.66) in the first group compared to the right ear of the female (0.59) in the second group was statistically higher and the effect of gender and age groups was observed, respectively (p=0.007, F=9.427, df=18 and p=0.019, F=6.348, df=24). Finally, at the frequency of 8000 Hz, in the second group the absorbance amount of the female's right ear (0.47) compared to the male's right ear (0.54) was statistically lower and the effect of gender was observed (p=0.026, F=5.324, df=42). It is worth mentioning that the statistical analysis of WBT absorbance was performed in 16 frequencies and considering 3 different modes (age groups, gender, and ear side), and the effect of ear side was observed only in one frequency and one mode; Therefore, the effect of ear side on absorbance was very insignificant.
The absorbance values of WBT in infants and newborns considering different modes have been investigated in several studies. The results of study of Chang et al showed that in the gender comparison, the absorbance amount of females compared to males was statistically higher at frequencies of 3150 Hz, 4000 Hz, and 5000 Hz. Comparing the ear side, the absorbance amount of the left ear compared to the right ear was statistically higher at the frequencies of 2500 Hz and 3150 Hz [8]. However, Aithal et al. reported that some studies showed no significant difference in the absorbance amount between the right and left ears at any of the frequencies. Conversely, some other studies showed that at frequencies below 1400 Hz, the left ear has less absorbance than the right ear, while at frequencies above 1400 Hz, the left ear has more absorbance than the right ear. Hence, the effect of ear side on WBT measurements in infants seems ambiguous. There were also different and ambiguous results regarding significant gender differences in WBT absorbance values [13].

Possible interpretations and explanations for the difference between the results of the present study and the mentioned studies can be the difference in the sample size, the statistical population of the studies and age of infants. Another reason for this variation can be the difference in the equipment and methods used for calibration, and the type of probe tip used.

**Ear canal volume**

The left ECV of males and the right ECV of females in the first group compared to the second group had a significant difference and the effect of age groups was observed (p=0.013, F=6.896, df=36 and p=0.007, F=8.860, df=24, respectively). The left ECV of the male in the first group (0.39) was lower compared to the second group (0.42) and the right ECV of the female was lower in the first group (0.40) compared to the second group (0.46). Considering the growth of the baby's ear canal with age, this statistical difference was expected. Hunter et al evaluated the average area of the ear canal in 182 infants at birth, 1, 6, 9, and 12-month visits. The estimated ear canal area at the tip of the probe regularly increased from 0.06 $cm^2$ at birth to 0.22 $cm^2$ at 12 months [18].

**Tympanometric peak pressure**

Based on the statistical analysis, no significant differences in TPP were observed between age groups, gender and ear side. As in our study, Palmu et al no statistically significant changes in TPP were observed with increasing age [19]. Contrary to our results, Hunter et al reported that, with increasing age, a significant statistical effect was observed in TPP. One of the complications of a newborn baby's ear is that positive air pressure within the ear canal tends to open the ear canal wider due to its extremely compliant walls, and negative air pressure tends to close the ear canal. Thus, the TPP estimate in the newborn ear may be confounded by ear canal volume changes, or ear canal wall collapse. Therefore, more research is needed to interpret TPP in infant ears [18].

The limitation of the current study was that, unfortunately, due to the outbreak of the Coronavirus pandemic, it was not possible to evaluate with a wider statistical population.

**Conclusion**

Wideband Tympanometry (WBT) is one of the new methods to assess the condition of the middle ear with high sensitivity and reliability compared to conventional tympanometry. However, the use of this method is currently not common in clinical evaluations. Many researchers have tried to obtain normative data, which is a standard measure for each evaluation, and to obtain relevant information regarding the structural characteristics of the ears of each race. This is the first study in which WBT was performed on Iranian infants to obtain the norm data of RF, absorbance, Ear Canal Volume (ECV), and TPP in two age groups of 0–14 days and 15–60 days and the differences with taking into account the different modes of age groups, gender, and ear side was investigated.

Based on the statistical analysis that was done, the effect of some different modes of age groups, gender, and ear side on resonance frequency, absorbance, and ECV was evident. Therefore, it can be concluded that using separate norms for males and females in different modes may increase the sensitivity and specificity of the test and have diagnostic value.

**Ethical Considerations**

**Compliance with ethical guidelines**

The study was approved by the Ethical Committee of Iran University of Medical Sciences (IR.IUMS.REC.1400.807).

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**Authors' contributions**

ES: Study design, acquisition of data, interpretation of the results, statistical analysis, and drafting the manuscript; HHN: Study design, interpretation of the results, drafting the manuscript, and supervising the manuscript; MM: Study design and statistical analysis; MM: Revision and editing.

**Conflict of interest**

The authors declare that there is no conflict of interest to be reported.


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Table 1. Demographic data of participants

| ؟ | Age groups variables | 0–14 days | 15-60 days | Total |
|---|---|---|---|---|
| **Number** | Infants | 20 | 44 | 64 |
| | Ears | 40 | 88 | 128 |
| **Gender** | Male | 11(55%) | 27(61%) | 38(59%) |
| | Female | 9(45%) | 17(39%) | 26(41%) |
| **Chronological age (days)** | Minimum | 4 | 15 | 4 |
| | Maximum | 14 | 60 | 60 |
| | Mean | 11.63 | 26.91 | 22.30 |
| | Standard deviation | 2.91 | 12.86 | 12.90 |
| **Birth weight (g)** | Minimum | 1900 | 1500 | 1500 |
| | Maximum | 4200 | 4100 | 4200 |
| | Mean | 3064.12 | 3005.92 | 3023.90 |
| | Standard deviation | 632.04 | 745.63 | 707.13 |
| **Gestational age (weeks)** | Minimum | 34 | 30 | 30 |
| | Maximum | 40 | 41 | 41 |
| | Mean | 37.70 | 37.59 | 37.64 |
| | Standard deviation | 1.96 | 2.42 | 2.28 |
| **Mode of delivery** | Vaginal | 15(75%) | 26(59%) | 40(62%) |
| | Cesarean | 5(25%) | 18(41%) | 24(38%) |
| **Hospitalization** | Well-baby | 17 | 32 | 49 |
| | NICU | 3 | 12 | 15 |

Table 2. Descriptive findings of resonance frequency, ear canal volume and tympanometric peak pressure

| Age groups | Gender | Ear side | RF (Hz) | | ECV(ml) | | TPP (daPa) | |
|---|---|---|---|---|---|---|---|---|
| | | | Number of ears | Mean(SD) | Number of ears | Mean(SD) | Number of ears | Mean(SD) |
| **First age group (0–14 days)** | **Male** | **Right** | 11 | 310(24) | 11 | 0.41(0.10) | 11 | -16(111) |
| | | **Left** | 11 | 323(23) | 11 | 0.39(0.09) | 11 | 32(139) |
| | **Female** | **Right** | 9 | 319(30) | 9 | 0.40(0.06) | 9 | -21(79) |
| | | **Left** | 9 | 298(23) | 9 | 0.38(0.10) | 9 | -15(92) |
| **Second age group (15–60 days)** | **Male** | **Right** | 27 | 327(46) | 27 | 0.42(0.12) | 27 | -8(104) |
| | | **Left** | 27 | 335(84) | 27 | 0.42(0.14) | 27 | 0(100) |
| | **Female** | **Right** | 17 | 324(30) | 17 | 0.46(0.14) | 17 | 25(93) |
| | | **Right** | 17 | 339(65) | 17 | 0.43(0.13) | 17 | 17(109) |

RF; resonance frequency, ECV; ear canal volume, TPP; tympanometric peak pressure

Table 3. The mean and standard deviation of wideband tympanometry absorbance in the age group of 0–14 days.

| | Mean(SD) | | | |
|---|---|---|---|---|
| | Male | | Female | |
| **Frequency (Hz)** | **Right ear** | **Left ear** | **Right ear** | **Left ear** |
| **226** | 0.45(0.11) | 0.48(0.12) | 0.35(0.14) | 0.43(0.11) |
| **324** | 0.46(0.07) | 0.49(0.09) | 0.38(0.08) | 0.46(0.07) |
| **385** | 0.47(0.07) | 0.48(0.10) | 0.40(0.05) | 0.45(0.06) |
| **500** | 0.47(0.09) | 0.46(0.10) | 0.43(0.05) | 0.44(0.06) |
| **629** | 0.51(0.10) | 0.50(0.10) | 0.46(0.05) | 0.46(0.08) |
| **793** | 0.61(0.11) | 0.61(0.12) | 0.58(0.08) | 0.56(0.11) |
| **1000** | 0.75(0.12) | 0.75(0.10) | 0.74(0.09) | 0.70(0.11) |
| **1259** | 0.90(0.09) | 0.90(0.06) | 0.87(0.06) | 0.85(0.09) |
| **1587** | 0.96(0.03) | 0.93(0.05) | 0.95(0.03) | 0.94(0.06) |
| **2000** | 0.84(0.10) | 0.72(0.09) | 0.90(0.09) | 0.86(0.14) |
| **2519** | 0.44(0.16) | 0.35(0.10) | 0.53(0.19) | 0.56(0.25) |
| **3174** | 0.26(0.12) | 0.23(0.13) | 0.28(0.14) | 0.34(0.24) |
| **4000** | 0.32(0.12) | 0.29(0.17) | 0.29(0.13) | 0.34(0.20) |
| **5039** | 0.56(0.15) | 0.44(0.17) | 0.57(0.16) | 0.54(0.24) |
| **6349** | 0.60(0.15) | 0.47(0.10) | 0.66(0.16) | 0.64(0.26) |
| **8000** | 0.57(0.17) | 0.43(0.16) | 0.63(0.18) | 0.55(0.26) |

Table 4. The mean and standard deviation of wideband tympanometry absorbance in the age group of 15–60 days

| Frequency (Hz) | Mean(SD) | | | |
|---|---|---|---|---|
| | Male | | Female | |
| | Right ear | Left ear | Right ear | Left ear |
| **226** | 0.39(0.13) | 0.43(0.15) | 0.46(0.13) | 0.41(0.13) |
| **324** | 0.43(0.10) | 0.46(0.12) | 0.48(0.10) | 0.44(0.11) |
| **385** | 0.46(0.10) | 0.48(0.12) | 0.49(0.10) | 0.45(0.10) |
| **500** | 0.47(0.10) | 0.49(0.12) | 0.47(0.11) | 0.46(0.11) |
| **629** | 0.50(0.11) | 0.52(0.13) | 0.49(0.11) | 0.48(0.11) |
| **793** | 0.58(0.14) | 0.59(0.15) | 0.58(0.13) | 0.55(0.11) |
| **1000** | 0.71(0.15) | 0.72(0.16) | 0.73(0.14) | 0.70(0.14) |
| **1259** | 0.85(0.13) | 0.86(0.12) | 0.86(0.14) | 0.83(0.15) |
| **1587** | 0.92(0.10) | 0.93(0.08) | 0.92(0.11) | 0.90(0.12) |
| **2000** | 0.83(0.14) | 0.83(0.13) | 0.78(0.16) | 0.78(0.12) |
| **2519** | 0.56(0.24) | 0.54(0.27) | 0.46(0.27) | 0.44(0.24) |
| **3174** | 0.36(0.22) | 0.36(0.26) | 0.32(0.28) | 0.32(0.27) |
| **4000** | 0.37(0.22) | 0.41(0.25) | 0.36(0.26) | 0.35(0.21) |
| **5039** | 0.55(0.24) | 0.54(0.22) | 0.53(0.24) | 0.47(0.20) |
| **6349** | 0.65(0.20) | 0.63(0.19) | 0.59(0.26) | 0.60(0.22) |
| **8000** | 0.54(0.17) | 0.53(0.21) | 0.47(0.26) | 0.51(0.26) |

Table 5. The 10th, 25th, 50th, 75th and 90th percentiles of wideband tympanometry absorbance

| | First age group (0–14 days) | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Male | | | | | | | | | | Female | | | | | | | | | |
| | Right ear | | | | | Left ear | | | | | Right ear | | | | | Left ear | | | | |
| **Frequency (Hz)** | **90th percentile** | **75th percentile** | **50th percentile** | **25th percentile** | **10th percentile** | **90th percentile** | **75th percentile** | **50th percentile** | **25th percentile** | **10th percentile** | **90th percentile** | **75th percentile** | **50th percentile** | **25th percentile** | **10th percentile** | **90th percentile** | **75th percentile** | **50th percentile** | **25th percentile** | **10th percentile** |
| **226** | 0.60 | 0.52 | 0.46 | 0.37 | 0.25 | 0.64 | 0.59 | 0.47 | 0.42 | 0.28 | 0.54 | 0.47 | 0.35 | 0.22 | 0.14 | 0.59 | 0.47 | 0.47 | 0.36 | 0.20 |
| **324** | 0.56 | 0.51 | 0.46 | 0.43 | 0.33 | 0.63 | 0.56 | 0.47 | 0.40 | 0.36 | 0.51 | 0.45 | 0.37 | 0.30 | 0.28 | 0.59 | 0.48 | 0.47 | 0.40 | 0.36 |
| **385** | 0.58 | 0.52 | 0.44 | 0.42 | 0.39 | 0.65 | 0.58 | 0.43 | 0.40 | 0.35 | 0.48 | 0.45 | 0.41 | 0.36 | 0.31 | 0.58 | 0.49 | 0.45 | 0.40 | 0.39 |
| **500** | 0.61 | 0.52 | 0.48 | 0.43 | 0.29 | 0.62 | 0.59 | 0.46 | 0.38 | 0.30 | 0.50 | 0.46 | 0.44 | 0.40 | 0.34 | 0.55 | 0.49 | 0.46 | 0.40 | 0.35 |
| **629** | 0.60 | 0.57 | 0.54 | 0.46 | 0.31 | 0.63 | 0.61 | 0.50 | 0.42 | 0.33 | 0.53 | 0.52 | 0.47 | 0.43 | 0.37 | 0.57 | 0.54 | 0.46 | 0.38 | 0.36 |
| **793** | 0.73 | 0.69 | 0.65 | 0.51 | 0.38 | 0.80 | 0.67 | 0.61 | 0.50 | 0.43 | 0.69 | 0.64 | 0.59 | 0.53 | 0.43 | 0.78 | 0.62 | 0.50 | 0.48 | 0.47 |
| **1000** | 0.89 | 0.83 | 0.78 | 0.69 | 0.50 | 0.92 | 0.82 | 0.75 | 0.67 | 0.62 | 0.85 | 0.84 | 0.73 | 0.68 | 0.57 | 0.90 | 0.81 | 0.64 | 0.61 | 0.57 |
| **1259** | 0.97 | 0.96 | 0.92 | 0.89 | 0.70 | 0.98 | 0.97 | 0.90 | 0.87 | 0.80 | 0.98 | 0.91 | 0.87 | 0.81 | 0.80 | 0.93 | 0.92 | 0.86 | 0.78 | 0.68 |
| **1587** | 0.99 | 0.98 | 0.97 | 0.94 | 0.91 | 0.99 | 0.97 | 0.95 | 0.87 | 0.85 | 0.98 | 0.98 | 0.95 | 0.94 | 0.90 | 0.99 | 0.98 | 0.95 | 0.92 | 0.78 |
| **2000** | 0.98 | 0.94 | 0.83 | 0.73 | 0.72 | 0.87 | 0.82 | 0.70 | 0.65 | 0.60 | 0.99 | 0.97 | 0.89 | 0.85 | 0.70 | 0.99 | 0.97 | 0.94 | 0.73 | 0.61 |
| **2519** | 0.68 | 0.55 | 0.47 | 0.25 | 0.23 | 0.57 | 0.37 | 0.35 | 0.29 | 0.23 | 0.85 | 0.65 | 0.57 | 0.38 | 0.23 | 0.91 | 0.80 | 0.59 | 0.31 | 0.21 |
| **3174** | 0.44 | 0.37 | 0.25 | 0.16 | 0.06 | 0.43 | 0.33 | 0.22 | 0.09 | 0.07 | 0.56 | 0.32 | 0.28 | 0.19 | 0.07 | 0.73 | 0.57 | 0.27 | 0.11 | 0.08 |
| **4000** | 0.51 | 0.40 | 0.34 | 0.21 | 0.13 | 0.62 | 0.37 | 0.26 | 0.17 | 0.09 | 0.59 | 0.35 | 0.26 | 0.20 | 0.14 | 0.65 | 0.51 | 0.31 | 0.17 | 0.07 |
| **5039** | 0.75 | 0.68 | 0.59 | 0.42 | 0.34 | 0.76 | 0.55 | 0.43 | 0.27 | 0.22 | 0.89 | 0.64 | 0.56 | 0.44 | 0.36 | 0.86 | 0.78 | 0.60 | 0.32 | 0.22 |
| **6349** | 0.85 | 0.73 | 0.59 | 0.55 | 0.35 | 0.65 | 0.51 | 0.48 | 0.39 | 0.32 | 0.96 | 0.77 | 0.67 | 0.53 | 0.40 | 0.99 | 0.88 | 0.65 | 0.39 | 0.23 |
| **8000** | 0.87 | 0.72 | 0.53 | 0.43 | 0.41 | 0.71 | 0.59 | 0.38 | 0.32 | 0.19 | 0.95 | 0.78 | 0.61 | 0.49 | 0.42 | 0.95 | 0.72 | 0.62 | 0.29 | 0.17 |

Table 6. 10th, 25th, 50th, 75th and 90th percentiles of wideband tympanometry absorbance

| | Second age group (15-60 days) | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Male | | | | | | | | | | Female | | | | | | | | | |
| | Right ear | | | | | Left ear | | | | | Right ear | | | | | Left ear | | | | |
| **Frequency (Hz)** | **90th percentile** | **75th percentile** | **50th percentile** | **25th percentile** | **10th percentile** | **90th percentile** | **75th percentile** | **50th percentile** | **25th percentile** | **10th percentile** | **90th percentile** | **75th percentile** | **50th percentile** | **25th percentile** | **10th percentile** | **90th percentile** | **75th percentile** | **50th percentile** | **25th percentile** | **10th percentile** |
| **226** | 0.57 | 0.50 | 0.41 | 0.30 | 0.21 | 0.64 | 0.55 | 0.44 | 0.32 | 0.21 | 0.60 | 0.55 | 0.49 | 0.35 | 0.25 | 0.57 | 0.51 | 0.41 | 0.27 | 0.24 |
| **324** | 0.57 | 0.52 | 0.43 | 0.37 | 0.27 | 0.60 | 0.54 | 0.45 | 0.36 | 0.30 | 0.60 | 0.57 | 0.50 | 0.42 | 0.31 | 0.57 | 0.51 | 0.48 | 0.33 | 0.26 |
| **385** | 0.58 | 0.53 | 0.46 | 0.39 | 0.33 | 0.62 | 0.55 | 0.47 | 0.39 | 0.34 | 0.63 | 0.57 | 0.47 | 0.41 | 0.36 | 0.59 | 0.51 | 0.47 | 0.39 | 0.28 |
| **500** | 0.59 | 0.51 | 0.48 | 0.38 | 0.35 | 0.69 | 0.55 | 0.51 | 0.40 | 0.32 | 0.63 | 0.57 | 0.48 | 0.40 | 0.29 | 0.60 | 0.52 | 0.49 | 0.39 | 0.27 |
| **629** | 0.65 | 0.58 | 0.49 | 0.46 | 0.35 | 0.68 | 0.60 | 0.53 | 0.41 | 0.31 | 0.65 | 0.57 | 0.51 | 0.43 | 0.28 | 0.65 | 0.54 | 0.49 | 0.43 | 0.30 |
| **793** | 0.76 | 0.69 | 0.59 | 0.51 | 0.39 | 0.78 | 0.70 | 0.61 | 0.48 | 0.36 | 0.75 | 0.69 | 0.62 | 0.48 | 0.39 | 0.71 | 0.63 | 0.57 | 0.46 | 0.35 |
| **1000** | 0.92 | 0.83 | 0.73 | 0.57 | 0.51 | 0.90 | 0.86 | 0.73 | 0.60 | 0.45 | 0.89 | 0.88 | 0.77 | 0.61 | 0.47 | 0.87 | 0.80 | 0.76 | 0.54 | 0.49 |
| **1259** | 0.98 | 0.97 | 0.88 | 0.77 | 0.61 | 0.97 | 0.95 | 0.91 | 0.79 | 0.67 | 0.98 | 0.96 | 0.91 | 0.80 | 0.55 | 0.97 | 0.94 | 0.91 | 0.69 | 0.57 |
| **1587** | 0.99 | 0.97 | 0.96 | 0.90 | 0.76 | 0.99 | 0.99 | 0.98 | 0.91 | 0.75 | 0.99 | 0.99 | 0.98 | 0.85 | 0.71 | 0.99 | 0.97 | 0.95 | 0.82 | 0.68 |
| **2000** | 0.98 | 0.95 | 0.85 | 0.75 | 0.63 | 0.98 | 0.96 | 0.83 | 0.68 | 0.65 | 0.99 | 0.91 | 0.80 | 0.64 | 0.53 | 0.99 | 0.87 | 0.79 | 0.66 | 0.61 |
| **2519** | 0.93 | 0.73 | 0.57 | 0.36 | 0.28 | 0.95 | 0.81 | 0.51 | 0.32 | 0.22 | 0.95 | 0.65 | 0.44 | 0.19 | 0.13 | 0.95 | 0.54 | 0.36 | 0.27 | 0.22 |
| **3174** | 0.66 | 0.50 | 0.39 | 0.19 | 0.12 | 0.72 | 0.48 | 0.25 | 0.18 | 0.16 | 0.73 | 0.56 | 0.30 | 0.06 | 0.03 | 0.79 | 0.41 | 0.23 | 0.12 | 0.06 |
| **4000** | 0.72 | 0.48 | 0.28 | 0.17 | 0.10 | 0.78 | 0.53 | 0.31 | 0.24 | 0.15 | 0.75 | 0.60 | 0.33 | 0.12 | 0.05 | 0.64 | 0.51 | 0.33 | 0.16 | 0.10 |
| **5039** | 0.85 | 0.78 | 0.58 | 0.35 | 0.21 | 0.91 | 0.70 | 0.49 | 0.41 | 0.26 | 0.86 | 0.75 | 0.49 | 0.31 | 0.20 | 0.78 | 0.67 | 0.39 | 0.30 | 0.25 |
| **6349** | 0.90 | 0.80 | 0.69 | 0.46 | 0.36 | 0.92 | 0.72 | 0.66 | 0.52 | 0.30 | 0.94 | 0.90 | 0.49 | 0.40 | 0.25 | 0.92 | 0.82 | 0.57 | 0.40 | 0.34 |
| **8000** | 0.83 | 0.63 | 0.51 | 0.42 | 0.31 | 0.83 | 0.69 | 0.49 | 0.42 | 0.24 | 0.94 | 0.66 | 0.40 | 0.27 | 0.12 | 0.96 | 0.75 | 0.41 | 0.28 | 0.25 |

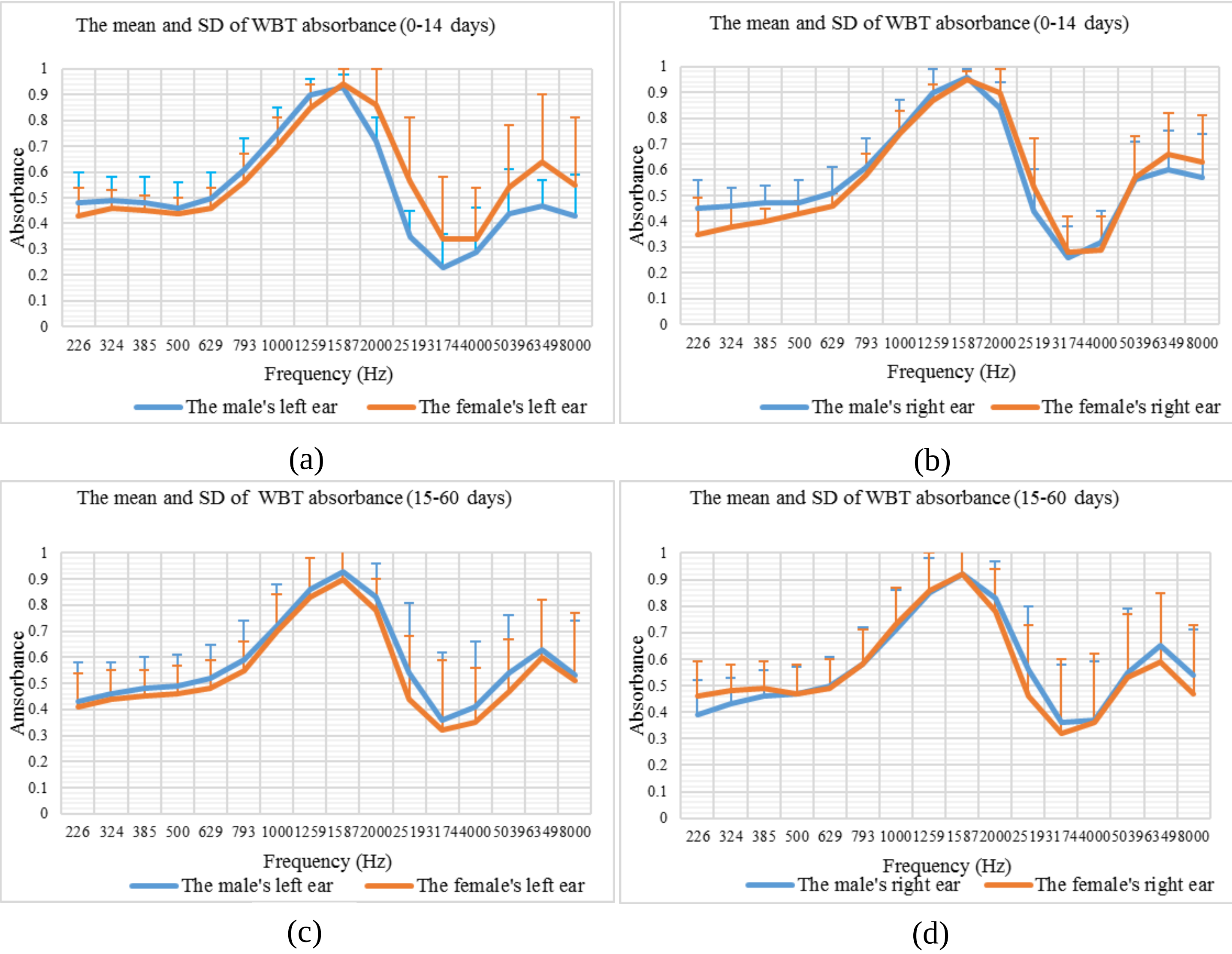


Figure 1. The mean and standard deviation of wideband tympanometry absorbance. WBT; wideband tympanometry

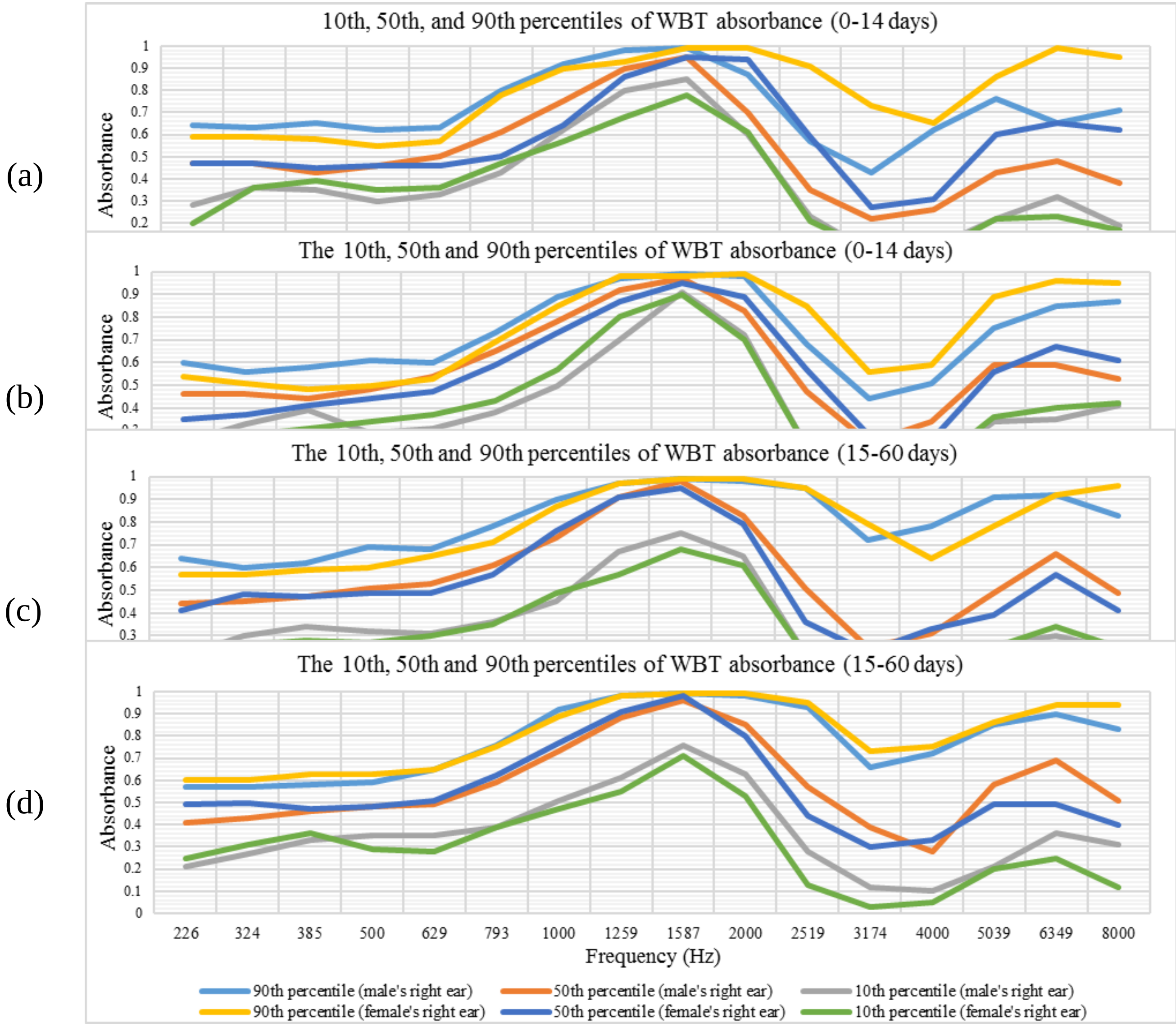


Figure 2. 10th, 50th and 90th percentiles of wideband tympanometry absorbance. WBT; wideband tympanometry