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Comparison of probe tone and click stimulus at 226 Hz frequency on acoustic ımmittance measurement in normal hearing adults: a cross-sectional study

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Abstract

Objectives Acoustic immittancemetry measurement is made using a probe tone or click stimulus at a frequency of 226 Hz, which is included in the audiological test battery. This study aims to compare tympanometric peak pressure (TPP), static acoustic admittance (Y_{tm}), equivalent external ear canal volume (V_{ea}) and tympanometric width (TW) values measured with probe tone and click stimulus at 226 Hz frequency.

Design Measurements were made with a probe tone and click stimulus at frequency of 226 Hz in 60 ears of 30 adult individuals with normal hearing between the ages of 18–26. In the measurements TPP, Y_{tm}, V_{ea} and TW values were determined for both ears.

Results In two different tympanogram measurement results using 226 Hz click stimulus and 226 Hz probe tone were a statistically significant difference was found between Y_{tm}, V_{ea} and TW values in the left ear ($p < 0.05$) and a statistically significant difference was found between Y_{tm} and V_{ea} values in the right ear ($p < 0.05$). There was no significant difference between the right ear TPP and TW values, left ear TPP value ($p > 0.05$).

Conclusıon The current findings show that the comment of right and left ear tympanogram results should be evaluated according to two different measurement results using 226 Hz click stimulus and 226 Hz probe tone.

Keywords Tympanometry, 226 Hz, Click stimulus, Probe tone

Background

Acoustic immitancemetry is among the most frequently used objective and non-invasive audiological evaluations in the field of Audiology [1]. The concept of acoustic immittance consists of the combination of impedance and admittance components. Impedance and admittance measurements are called acoustic immittancemetry. Acoustic immittancemetry can be used for electro-acoustic evaluations of the outer ear and middle ear in all age groups, including newborns and pediatric groups [2]. Acoustic immittance measurement generally includes tympanometry, acoustic reflex measurement, and other subtests that indirectly evaluate middle ear function [3].

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Tympanometry is defined as the objective, electroacoustic evaluation of acoustic admittance, which is a function of air pressure in the outer ear [4]. Tympanometric test a suitable probe is placed in the patient's external ear canal before the measurement [5–7]. There are three parameters evaluated in the conventional tympanometric measurement performed at 226 Hz probe tone 85 dB SPL intensity sound level. These parameters are tympanometric peak pressure (TPP), static acoustic admittance (Y_{tm}), equivalent external ear canal volume (V_{ea}) value. At the pressure that changes between + 200 daPa and -400 daPa with the probe inserted in the outer ear canal, the change in compliance occurring in the middle ear is measured and a graph is formed so that there is a single peak. This peak is called the tympanic peak pressure. This peak pressure value is used to determine the tympanometric peak pressure (TPP). The unit is daPa. The static acoustic admittance (Y_{tm}) value is evaluated by the vertical plane value of the tympanogram curve at the maximum pressure of the middle ear and its unit is mmho [8]. The measurement of the equivalent external ear canal volume (V_{ea}) is obtained by measuring the volume between the probe placed in the external ear canal and the eardrum,and its unit is cm^3 [4]. In the measurement made using a 226 Hz probe tone, the tympanometric width (TW) value is also calculated and its unit is daPa [9].

With conventional tympanometer (CT), the admittance of the middle ear system at varying pressure is usually measured using a single frequency 226 Hz probe tone. Apart from conventional tympanometers, a wide band tympanometer (WBT) is used as another system that evaluates the middle ear system [10]. The working principle and measurement time of the WBT are the same as the CT. However, unlike CT, WBT measures the absorbance of the middle ear system in a wide frequency range by using narrow-band click stimuli with a frequency range of 226–8000 Hz. Thanks to this method, a tympanogram curve can be obtained in the measured frequency of 226–8000 Hz [11]. This measurement is performed over a wide frequency and provides us with detailed information about the acoustic-mechanical properties of the middle and outer ear [1]. In this measurement, the results are obtained in 3D graphics using 96 dB SPL stimulus in infants and 100 dB SPL stimulus in adults [12].

The working principle of the WBT is similar to the CT and is separated due to the different type of stimulus used. Since it can be measured at 226 Hz at the same time, it allows the comparison of normative and clinical findings. In addition, TPP, Y_{tm}, V_{ea} and TW values evaluated by CT can also be evaluated by WBT made by giving clinical stimulus at 226 Hz frequency [11].

CT results clinically, tympanogram types are evaluated according to the Jerger classification. The parameters that should be considered for the type of tympanogram in this interpretation are TPP and Y_{tm} values [13]. By measuring WBT, middle ear-related diseases in addition to using clinical evaluation, it can also be used for conditions such as superior semicircular canal dehiscence, discrete middle ear lesions in newborns and infants, early monitoring of middle ear conditions after otological surgeries [14]. WBT, which has been widely studied in middle ear diseases, is reported to be superior to CT in many respects [15].

In our literature review, it is seen that the number of studies comparing the results of CT using a 226 Hz 85 dB SPL probe tone and WBT using a 226 Hz clik stimulus is limited. Ocak [12] reported that, as the results of comparing 226 Hz CT with WBT with 226 Hz clik stimulus, TPP values and V_{ea} value were not statistically significant, but Y_{tm} values were different.

When other studies in the literature are examined, it is seen that comparisons are made using a 226 Hz probe tone and a 1000 Hz probe tone in studies conducted on newborns [16, 17]. In addition to existing studies, our study aims to compare the results of two measurements made using the 226 Hz frequency value. In this study investigated to the difference between CT and WBT measured at 226 Hz frequency with the Interacoustics brand Titan Broadband Tympanometer instrument, which is used to evaluate the middle ear system in Audiology clinics.

Methods

Subjects

This is a cross-sectional study which was approved by the Ethics Committee of the KTO University's Faculty of Medicine (Decision no: 2023/037). The study was conducted in accordance with the principles set out in the Declaration of Helsinki. G-Power analysis was used to determine the number of participants in the study and it was found that it was necessary to conduct the study with at least 23 individuals with a power value of 95%. 30 individuals (mean age 20,7 ± 4,2) and 60 ears a normal pure tone average were included in the study. The necessary audiological examinations were performed for the study of individuals at the KTO Karatay University Yunus Mermer Audiology Clinic.

The individuals involved in the study were made to sign an informed consent form and provided oral information about the study. Individuals with no history of otological or neurological diseases and ototoxic drug use, who were not exposed to noise, whose pure tone average of the right and left ears was ≤ 20 dB HL according to audiological test results, and who had Type A tympanogram as

a result of acoustic immunometry test performed using 226 Hz probe tone were included in the study. The 226 Hz acoustic immittance measurements of the participants in the study were performed in random order and randomization was achieved.

Acoustic immittansmetric evaluations

The external auditory canal and tympanic membrane of individuals with normal pure tone average were evaluated by otoscopic examination. Individuals with normal otoscopic examination were included in the study. Right and left ear acoustic immittance measurements of the individuals included in the study were evaluated using an Interacoustics brand Titan Broadband Tympanometer. TPP, Y_{tm}, V_{ea} and TW values in the tympanograms measured between + 200 and -400 daPa were recorded first using a probe tone at 226 Hz and 85 dB SPL, and then using a click stimulus at a frequency of 226 Hz.

Pure tone hearing threshold assessment

The right and left ear pure tone audiometry tests of the individuals included in the study were performed in a quiet cabin prepared in accordance with ISO 8253 standards. Right and left ear air conduction hearing thresholds and bone conduction hearing thresholds were measured with an AC-40 clinical audiometer using the Hughson-Westlake procedure between 500–4000 Hz. Telephonics brand TDH-39 standard headphones were used to determine air conduction hearing thresholds, and Radioear brand B-71 bone vibrator was used to determine bone conduction hearing thresholds.

Statistical analysis

Data management and all statistical analyses were evaluated using SPSS version 25.0 (IBM, Armonk, NY, USA). The normality assumption of quantitative variables was checked with the "Kolmogorov Smirnov" test. When a quantitative variable shows a normal distribution, it is given as mean ± standard deviation ($\bar{x} \pm SD$), and when it does not show a normal distribution, it is given as the median[interquartile range] (median[IQR]). To evaluate the differences between different measurements of quantitative variables in the right and left ears separately, the "Paired Sample t Test" was used when the prerequisites of the parametric test were met; In cases where the prerequisites of the parametric test were not met, the "Wilcoxon Test" was used. In statistical evaluations, p values below 0.05 was considered significant.

Results

In the study, the right immittansmetric measurement results of the individuals for the 226 Hz probe tone and the 226 Hz click stimulus are given in Table 1. When the findings regarding TPP value, Y_{tm} value, TW value and V_{ea} value are examined; There was no statistically significant difference in TPP values and TW values ($p > 0.05$), but a statistically significant difference was found in Y_{tm} values and V_{ea} volume values ($p < 0.05$). In the statistical analysis of the study; TPP and Y_{tm} values were obtained higher when measured using a 226 Hz probe tone, and the V_{ea} and TW values were obtained higher when measured using a 226 Hz click stimulus.

Table 1 Right ear immittance measurement results

Variable	n	226 Hz probe tone $\bar{x} \pm SS$	226 Hz clik stimulus $\bar{x} \pm SS$	*p*
TPP (daPa)	30	-9[5,11]#	-13,5[12, 0]#	0,179[b]
Y_{tm} (mmhos)	30	0,60[0,31]#	0,50[0,25]#	0,030[b*]
V_{ea} (cm^3)	30	1,32 ± 0,25	1,39 ± 0,28	0,002[a*]
TW (daPa)	30	91,1 ± 28,3	97,8 ± 21,6	0,076[a]

* $p < 0,05$

median[IQR], [a]:Paired Sample t Test, [b]: Wilcoxon Test

Table 2 Left ear immittance measurement results

Variable	n	226 Hz probe tone $\bar{x} \pm SS$	226 Hz clik stimulus $\bar{x} \pm SS$	*p*
TPP (daPa)	30	-11,9 ± 11,0	-13,7 ± 12,8	0,306[a]
Y_{tm} (mmhos)	30	0,60[0,33]#	0,50[0,34]#	0,010[b*]
V_{ea} (cm^3)	30	1,31 ± 0,28	1,40 ± 0,33	0,030[a*]
TW (daPa)	30	87,4 ± 22,5	96,2 ± 23,8	0,002[a*]

* $p < 0,05$

median[IQR], [a]:Paired Sample t Test, [b]: Wilcoxon Test

In the study, the left immittansmetric measurement results of the individuals for the 226 Hz probe tone and the 226 Hz click stimulus are given in Table 2. When the findings regarding TPP value, Y_{tm} value, TW value and V_{ea} value are examined; There was no statistically significant difference in TPP values ($p > 0.05$), but a statistically significant difference was found in Y_{tm} values, V_{ea} values and TW values ($p < 0.05$). In the statistical analysis of the study; TPP and Y_{tm} values were higher when measured using a 226 Hz probe tone, and the V_{ea} and TW values were higher when measured using a 226 Hz click stimulus.

Discussion

CT is a way to measure how the acoustic immittance of the middle ear system changes with the pressure changing from + 200 daPa to -400 daPa in the external ear canal, using an 85 dB SPL probe tone at a frequency of 226 Hz [18].The reason why the conventional tympanometer is used only at 226 Hz frequency is that it is easy to calibrate since the admittance value of 1 cm^3 of air is

equal to 1 ml. However, it is predicted that false negative responses may occur in measurements made using only a 226 Hz probe tone, such as obtaining a Type A tympanogram instead of the Type A_s tympanogram expected to be seen in patients with otosclerosis. Recently, in the evaluation of the middle ear, in order to prevent false negative responses and to evaluate a wide frequency range with one measurement, a 3D graph showing the amount of absorbance has begun to be used as a WBT measurement using a narrow band click stimulus in the frequency range of 226–8000 Hz [19].

WBT measurement in adult individuals provides more detailed information about the middle ear and middle ear-related pathologies than conventional tympanometry [20]. Margolis et al. [21] reported that WBT is not only used in the evaluation of the middle ear for adults, but also has high absorbance values at varying frequencies in WBT measurements from birth to 3 years of age, especially in the pediatric group with middle ear effusion. Hunter et al. [22] reported that WBT measurement provides more information about the middle ear than measurement using a 226 Hz probe tone and has the potential to be used for diagnosis. Callaham et al. [23] reported that in the pediatric group, WBT measurement has the potential to be used in the diagnosis of middle ear effusions in the future to determine the type of middle ear effusions identified.

In our study, acoustic immittance measurement results obtained with 226 Hz probe tone and 226 Hz click stimulus in the right and left ears were compared. It was observed that Y_{tm} and V_{ea} values in the right ear and Y_{tm}, V_{ea} and TW values in the left ear may vary as a result of both measurements. This situation may indicate that the Y_{tm} value used in deciding the type of tympanogram should be reconsidered in future acoustic immittance measurements made with the use of probe tone and click stimuli at a frequency of 226 Hz.

Kavruk [24] in his study in which 32 people aged 20–40 participated and a total of 64 ears were included, reported that the TPP value was -5.11 ± 11.14, the Y_{tm} value was 0,79 ± 0,33, the V_{ea} value was 1,30 ± 0,26 and the TW value was 83,72 ± 20,50 in acoustic immittance measurements made with a 226 Hz probe tone. Şahin [25] in his study in which 20 people aged 20–29 participated and a total of 40 ears were included, reported that the TPP value was -5.02 ± 13.59, the Y_{tm} value was 0.75 ± 0.36, the V_{ea} value was 1.18 ± 0.24 and the TW value was 80.47 ± 23.78 in acoustic immittance measurements made with a 226 Hz probe tone. İn our study in which 30 people aged 18–29 participated and a total of 60 ears were included, we found that in the right ear the TPP value was -9[11.5], the Y_{tm} value was 0.60[0.31], the V_{ea} value was 1.32 ± 0,25 and the TW value was 91.1 ± 28.3, in the left ear the TPP value was -11.9 ± 11.0, the Y_{tm} value was 0.60[0.33], the V_{ea} value was 1.31 ± 0.28 and the TW value was 87.4 ± 22.5, in acoustic immittance measurements made with a 226 Hz probe tone.

Polat et al. [26] reported that in their WBT measurements with 59 young adult females and 51 young adult males using a 226 Hz click stimulus, the TPP value was –0.57 ± 24,89, the Y_{tm} value was 0,57 ± 0,24, the V_{ea} value was 1,16 ± 0,27, the TW value was 95,26 ± 31,40 in male individuals and the TPP value was –8,58 ± 13,82, the Y_{tm} value was 0,51 ± 0,19, the V_{ea} value was 0,93 ± 0,23, the TW value was 95,93 ± 31,14 in female individuals. Şahin [25] reported that the Y_{tm} value was 0.63 ± 0.30, the V_{ea} value was 1.15 ± 0.25, and the TW value was 89.50 ± 20.05. İn our study in which 30 people aged 18–29 participated and a total of 60 ears were included, we found that in the right ear the TPP value was -13,5[12,0], the Y_{tm} value was 0,50[0,25], the V_{ea} value was 1,39 ± 0,28 and the TW value was 97,8 ± 21,6, in the left ear the TPP value was -13,7 ± 12,8, the Y_{tm} value was 0,50[0,34], the V_{ea} value was 1,40 ± 0,33 and the TW value was 96,2 ± 23,8, in acoustic immittance measurements made with a 226 Hz click stimulus.

In a study in which 124 ears of 62 people were included in the study using a 226 Hz probe tone and a 226 Hz click stimulus in their right and left ears, it was reported that there was no statistically significant difference in TPP and V_{ea} values, but a statistically significant difference was found in Y_{tm} values [12]. In our study, which we conducted using a 226 Hz probe tone and a 226 Hz click stimulus in the right and left ears of individuals, in which 30 people participated and a total of 60 ears were included, it was observed that there was a statistically significant difference in the Y_{tm} and V_{ea} values of the right and left ears, as well as the TW value of the left ear. Although the current literature supports this study because the TPP value does not differ and the Y_{tm} value does differ in two different measurements, it does not support it because the V_{ea} values differ.

Conclusions

This study demonstrated that CT using a 226 Hz probe tone and WBT measurements using a 226 Hz click stimulus can be used in the evaluation of middle ear functions, but some variables may cause differences when the stimulus type changes. In particular, when the TPP and Y_{tm} values used to determine the type of tympanogram were examined, it was determined that there was no difference in the TPP value, but there was a difference in the Y_{tm} value.This result shows that when the stimulus type is changed, it is necessary to look especially at the Y_{tm} value when deciding on the tympanogram type. The study also determined that there was

a difference in the V_{ea} value in the right and left ears when the stimulus type changed. While the presence of a Type B tympanogram gives a significant finding in terms of middle ear effusion, the clinical interpretation of the V_{ea} value for values outside the normative range (if the V_{ea} value is more than the upper limit, there is the presence of eardrum perforation etc.; if the V_{ea} value is less than the lower limit, there is a earwax etc.) is used. In our study, it was observed that the V_{ea} value differed in the right and left ears when the stimulus type changed. This result shows that it is necessary to look at the V_{ea} value when the stimulus type changes in the clinical interpretation of the Type B tympanogram. It was determined that although the TW value, another determining parameter of middle ear effusion, differed in the left ear when the stimulus type changed, it did not differ in the right ear. Although the TW value differs depending on the change in stimulus in the left ear, it is thought that it may not be clinically significant because it is lower than the accepted normative value for middle ear effusion. If the TW value is to be used when evaluating middle ear effusion, it is thought that it is necessary to look at the normative range for both ears. It is recommended that further research be conducted to examine the middle ear system in the pediatric population, in different age groups, and in populations with different types of hearing loss, using probe tone and click stimuli at a frequency of 226 Hz.

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Authors' contributions
M. P. and F. S. designed and performed the study; M.P., B.Ş., S. N. T., İ. N. T. and R.K collected the data; M. P. analyzed the data, and F. S. contributed to the interpretation of the analysis; M. P., F. S., B. Ş., S. N. T., İ. N. T. and R.K wrote and edited the article; all authors discussed the results and approved the submission of the article.

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Availability of data and materials
Data are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study was conducted in the Department of Audiology with the approval of the Ethics Committee of the KTO Karatay University's Faculty of Medicine (Decision no: 2023/037). The informed consent form and detailed anamnesis were obtained from all participants. The manuscript adheres to the ethical standards according to the Declaration of Helsinki.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing ınterests.

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