Tympanometric Screening Norms for Adults

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The purpose of this study was to reexamine the Margolis and Heller (1987) normative tympanometric data (also American Speech-Language-Hearing [ASHA], 1990 interim norms) using a strict control over subject age and gender. Normative values for peak, compensated static acoustic admittance (Peak $Y_m$), acoustic equivalent volume ($V_{ac}$), and tympanometric width (TW) were determined for 102 young adults with normal hearing. Relative to the Margolis and Heller normative values, significant differences were found for $V_{ac}$ and TW. Although statistically significant, these differences were small and of little clinical importance. However, significant and clinically important gender differences in young adults were observed for each of the tympanometric measures. Compared to males, females had lower Peak $Y_m$ values, smaller $V_{ac}$ values, and higher TW values.

Tympanometric assessment and screening of middle ear function is a routine part of audiologic diagnosis for both children and adults (Martin, Armstrong, & Champlin, 1994). The tympanometric data recommended by the American Speech-Language-Hearing Association (ASHA, 1990) as normal referent criteria in middle ear screening for adults were based on the data of Margolis and Heller (1987). The Margolis and Heller study included males and females ranging in age from 19 to 61 years. Other reports of normative data, however, have indicated that the same tympanometric measures in older adults vary with age and gender (Blood & Greenberg, 1977; Wiley, Cruickshanks, Nondahl, Tweed, Klein, & Klein, 1996)—factors that were not accounted for by Margolis and Heller. Wiley et al. (1996), for example, found lower peak, compensated static acoustic admittance (Peak $Y_m$) values, higher acoustic equivalent volume ($V_{ac}$) values, and lower tympanometric width (TW) values for the older adults in their study relative to the Margolis and Heller adult normative data. Significant gender effects were also reported by Wiley et al. Male participants demonstrated higher Peak $Y_m$ values, higher $V_{ac}$ values, and lower TW values as compared to female participants.

Based on these findings, the inclusion of older participants (48–61 years) and the lack of gender specific data in the ASHA (1990) interim norms may have resulted in criterion values that are inappropriate screening referents for specific adult subgroups, depending on age and gender. This, in turn, may result in decreased diagnostic accuracy for specific measures in adults. Accordingly, the purpose of this study was to reexamine the Margolis and Heller (1987) tympanometric data (ASHA, 1990 interim norms) in young adult participants while employing control over age and gender.

Method

Participants

One-hundred-two young adults (51 males, 51 females) with normal hearing served as participants. All participants were non-Hispanic Caucasian and ranged in age from 20 to 30 years, with a mean age of 23.4 (years:months). Normal hearing was defined as audiometric thresholds ≤ 10 dB HL for tones of 500, 1000, 2000, and 4000 Hz. Each participant had normal otoscopic findings (i.e., normal tympanic membrane appearance, as well as being free of ear canal debris, drainage, middle ear liquid, or any structural abnormalities) and denied any recent or current history of otic disease or disorder.
Procedure

Measures of peak compensated static acoustic admittance (Peak Yₐm), acoustic equivalent volume (Vₑa), and tympanometric width (TW) were obtained in one ear, randomly assigned, for each participant using a screening tympanometer (Grason-Stadler 37 Auto Tympanometer model #37) with a 226-Hz probe tone. The acoustic admittance value at 200 daPa was used as the referent for ear-canal contributions in Peak Yₑa compensation. Pump speed was 600/200 daPa/s. Specifically, pump speed was 600 daPa at extreme pressures, and slowed to 200 daPa/s near the tympanogram peak. The pump speed employed by Margolis and Heller (1987) was constant at 200 daPa/second. Other than this variation in pump speed, the measurement conditions and procedures were consistent with those of Margolis and Heller. The pure tone screening was conducted in a sound-treated booth with a diagnostic audiometer (Grason-Stadler model #16). Both the tympanometer and audiometer were calibrated according to the appropriate American National Standards Institute (ANSI, 1987, 1996) standards.

Results

Age Comparisons

Table 1 includes the mean and 90% normal range for each of the tympanometric measures (Peak Yₑa, Vₑa, TW) for males and females. The Margolis and Heller (1987) adult data are presented in Table 1 for comparison. A t-test of means was used to compare the data of the present study with the adult data from the Margolis and Heller study. Results for Peak Yₑa did not reveal any difference in means for the present study and that from the Margolis and Heller study [t(187) = 0.04; p > .05]. There were, however, significant differences in the means for Vₑa and TW in the two studies. Specifically, mean Vₑa values were significantly higher [t(187) = 6.19; p < .05] for the present study (1.3 cm³) than for the Margolis and Heller data (1.04 cm³), and mean TW values for the present study (66.86 daPa) were significantly smaller [t(187) = -3.65; p < .05] than for the Margolis and Heller data (76.8 daPa).

A second analysis, the Komogorov-Smirnov Two-Sample Test (Siegel & Castellan, 1988), was performed to compare the distributions of the three tympanometric measures (Peak Yₑa, Vₑa, TW) from the present study with those from Margolis and Heller (1987). The distribution comparisons are shown in Figures 1, 2, and 3 for Peak Yₑa, Vₑa, and TW, respectively. Similar to the comparison of means, significant differences in distributions were found for Vₑa (D₁₂₀.₉₇ = 0.4872; p < .05) and TW (D₁₂₀.₉₇ = 0.2387; p < .05), but not for Peak Yₑa (D₁₂₀.₉₇ = 0.1014; p > .05). Specifically, Vₑa distributions for young adults in the present study extended to higher values and TW distributions extended to lower values relative to the Margolis and Heller sample.

Gender Comparisons

Comparisons of means and 90% ranges for males and females are shown in Figures 4, 5, and 6 for Peak Yₑa, Vₑa, and TW, respectively. Gender comparisons within the present study, based on a t-test of means for each measure, indicated differences for each tympanometric measure (Peak Yₑa, Vₑa, TW). Mean Peak Yₑa values were significantly higher [t(100) = 3.95; p < .05] for males (0.86 mmhos) relative to females (0.57 mmhos). Mean Vₑa values were significantly larger [t(100) = 4.08; p < .05] for males (1.4 cm³) than for females (1.18 cm³). And lastly, mean TW values for males (59.8 daPa) were significantly smaller [t(100) = -4.13; p < .05] than for females (73.92 daPa).

Further analysis of the differences between males and females within the present study and the Margolis and Heller (1987) data was done using a t-test of means for each tympanometric measure (Peak Yₑa, Vₑa, and TW). Comparisons of means and 90% ranges for males and females from the present study and the Margolis and Heller data are shown in Figures 4, 5, and 6 for Peak Yₑa, Vₑa, and TW, respectively. For the present study, the mean Peak Yₑa value was significantly higher [t(136) = 2.26; p < .05] for males (0.86 mmhos) relative to the Margolis and Heller mean (0.72 mmhos), and the mean Peak Vₑa value for females (0.57 mmhos) was significantly lower [t(136) = -2.74; p < .05] than the Margolis and Heller mean (0.72 mmhos). In addition, the mean Vₑa value was significantly larger for males [t(136) = 7.34;
FIGURE 1. Distribution of $Y_{m}$ values from the present study (young adults) and from Margolis and Heller (1987) (ASHA, 1990).

FIGURE 2. Distribution of $V_{m}$ values from the present study (young adults) and from Margolis and Heller (1987) (ASHA, 1990).

FIGURE 3. Distribution of $V_{a}$ values from the present study (young adults) and from Margolis and Heller (1987) (ASHA, 1990).

FIGURE 4. Mean $Y_{m}$ values (solid lines) and 90% ranges (bars) for males ($n = 51$) and females ($n = 51$) in the present study, and for the Margolis and Heller (1987) adult data ($n = 87$).
FIGURE 5. Mean $Y_m$ values (solid lines) and 90% ranges (bars) for males ($n = 51$) and females ($n = 51$) in the present study, and for the Margolis and Heller (1987) adult data ($n = 87$).

$$p < .05$$ and for females [$t(136) = 3.27; p < .05$] as compared to that from Margolis and Heller. In the case of TW, the mean was significantly smaller [$t(136) = -5.28; p < .05$] for males relative to the Margolis and Heller mean, but there was no significant difference in the mean for females [$t(136) = -0.9; p > .05$] relative to the Margolis and Heller value.

Discussion

The initial concern regarding the Margolis and Heller (1987) data (ASHA, 1990 interim norms) was the large age range (19–61 years) for participants, which may have resulted in inappropriate normative values for some adults. When data from the present study were combined across gender, the mean Peak $Y_m$ and the distribution of Peak $Y_m$ values did not differ from the Margolis and Heller normative data. The same data sets for $V_a$ and TW, however, indicated significant differences in the means and distributions from the present study relative to the Margolis and Heller data. The differences in $V_a$ and TW values across the two studies, although significant, were small and likely of little importance in clinical applications. If screening criteria were based on data combined across gender, the small differences in the overall means of the two samples, likely attributable to age differences, would have minor effects on clinical screening decisions.

The issue of age effects on the same tympanometric measures (Peak $Y_m$, $V_a$, and TW) also has been studied in older adults (Holte, 1996; Wiley et al., 1996). Table 1 includes the mean and 90% normal ranges for each of the tympanometric measures (Peak $Y_m$, $V_a$, and TW) combined across gender from these studies in older adults. It is difficult to make comparisons across studies because of differences in gender and age distributions for each study. However, some general comparisons are possible. The mean Peak $Y_m$ value and 90% normal range for Holte's (1996) group, which was exclusively male, is strikingly similar to the means and 90% normal range of Peak $Y_m$ for males in the present study.

When data were combined across gender, the mean values of Peak $Y_m$ for the present study, for Margolis and Heller (1987), and for Wiley et al. (1996) were similar. In terms of $V_a$ measures combined across gender, the mean for young adults in the present study (1.30 cm$^2$) agrees favorably with those reported by Wiley et al. in older adults (1.36 cm$^2$). Overall, relative to data from the present study, 90% normal ranges were greater for each tympanometric measure in the Holte (1996) and Wiley et al. studies, suggesting greater variability among older adults. This greater variability may result in an unnecessarily large number of inappropriate referrals based on the three measures recommended by ASHA (1990) if the 90% normal ranges for younger adults were used as referral criteria for older adults. In this instance, the differences in the distributions between young and older adults may have effects on clinical screening decisions.

Of particular interest in the present study were the significant gender differences observed for Peak $Y_m$, $V_a$, $T$,
and TW. Compared to males, females had significantly lower Peak \( Y_m \) values, significantly lower \( V_m \) values, and significantly higher TW values. These findings are consistent with previous investigators (Wiley et al., 1996), who have also reported significant differences in Peak \( Y_m \), \( V_m \), and TW values for older adult males and females. Margolis and Goycoolea (1993), however, reported no significant gender differences in the same acoustic admittance measures. This disparity across studies may be due, at least in part, to differences in sample size across studies. The Margolis and Goycoolea study was based on a smaller sample size (14 males, 14 females) relative to the present study (51 males, 51 females) and the work of Wiley et al. (825 males, 1,322 females).

In the case of Peak \( Y_m \), the gender differences observed in the present study were small and the lower end of the 90% normal range was similar for males and females. Accordingly, accounting for gender differences in Peak \( Y_m \) for screening criteria would likely not improve screening sensitivity appreciably over the use of Peak \( Y_m \) norms combined across gender. Combining data across males and females for \( V_m \) and TW, however, may result in a loss of test sensitivity in screening applications.

The upper and lower ends of the 90% range for both \( V_m \) and TW measures differed for males and females in the present study. This, in turn, may result in different diagnostic decisions if data are combined across gender. Consider the specific case of \( V_m \) measures, which is used in the identification of patients with potential perforations of the tympanic membrane. Based on the findings in the present study, a \( V_m \) value of 2.1 cm\(^3\) for males is within the 90% normal range. The upper end of the 90% normal range for females, however, was 1.6 cm\(^3\). Thus, \( V_m \) values within the upper range of normal for males might be considered characteristic of a tympanic membrane perforation for females if the tympanometric norms are combined across gender.

Additionally, as might have been expected based on the significant differences in measures for males and females within the present study, significant differences also were present when data for males and females were compared separately with the Margolis and Heller (1987) data. In general, males had higher Peak \( Y_m \) values and females had lower Peak \( Y_m \) values than in the Margolis and Heller study. Both males and females exhibited larger \( V_m \) values than those in the Margolis and Heller study. And finally, males had smaller TW values than those in the Margolis and Heller study. Overall, these findings suggest that the Margolis and Heller normative data are not an accurate representation of expected measures for either males or females. And, collapsing data across gender for these measures may result in a loss of test sensitivity for both males and females.

Considering the previous example of \( V_m \), the upper end of the 90% normal range for the males in the present study was considerably higher than the mean from Margolis and Heller (1987) (Figure 5). The Margolis and Heller mean was similar to that for females in the present study. A \( V_m \) value of 2.1 cm\(^3\) for males in the present study is within the 90% normal range. The upper end of the 90% normal range for the Margolis and Heller data, however, was 1.46 cm\(^3\). Thus, \( V_m \) values within the upper range of normal for young adult males might be considered characteristic of a tympanic membrane perforation for the same population of males if the Margolis and Heller data were used.

Furthermore, it could be argued that the differences in Peak \( Y_m \) for young adult males and females are likely not important in screening applications because typically only low Peak \( Y_m \) abnormalities are the focus of attention. However, the difference in the upper end of Peak \( Y_m \) distributions for males and females may be important in other diagnostic applications such as the identification of ossicular abnormalities (Figure 4). Similarly, the same argument can be used for TW. For example, given the higher 90% upper end in TW for females relative to males, what is normal TW for females may diagnostically be abnormally wide for young adult males (Figure 6).

The observed differences between the present study and that of Margolis and Heller (1987) may, in part, be due to differences in pump speed for each study. Different rates of pump speed have been shown to result in different values for Peak \( Y_m \) (Margolis & Heller, 1987; Shanks, Lilly, Margolis, Wiley, & Wilson, 1988). An automated screening instrument with a variable pump speed (600/200 daPa/s) was chosen for the present study because it is typical of current screening units. In addition, this specific instrument model has been used in a large-scale population study with reported high dependability and reliability (Nondahl, Cruickshanks, Wiley, Tweed, Klein, & Klein, 1996). The pump speed (200 daPa/s) in the vicinity of the tympanogram peak in the present study was the same as the pump speed (200 daPa/s) used by Margolis and Heller. It is possible, however, that as the pump speed reduces from that at the extrema (600 daPa/s) to a lower speed in the vicinity of the peak (200 daPa/s), differences in Peak \( Y_m \) values are produced. The fact that the mean Peak \( Y_m \) value from the present study and that from the Margolis and Heller study were identical, however, suggests that any observed differences in Peak \( Y_m \) values due to pump speed were small. Nevertheless, it should be understood that the applicability of the normative values from the present study are most appropriate when applied to young adults (20 to 30 years), and when using a screening instrument such as the one used here.

The overall findings of the present study suggest that the use of gender-specific norms may improve the sensitivity of middle ear screening measures in young adults. Specifically, individual norms for males and females could potentially reduce some of the variability that is associated with acoustic immittance measures, subsequently improving test sensitivity. Accordingly, based on the findings of the present study and our view that gender differences often have not been accounted for in many areas of diagnostic audiometry, there is a need for gender-specific research in the standardization of diagnostic measures that are most sensitive to hearing disorders and pathologies. Further, the issue of gender effects at all age levels should be considered in future research on diagnostic measures.
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