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ORIGINAL RESEARCH

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Computed tomography Scan Size Analysis of stapedius and tensor tympani muscles in middle ear myoclonic tinnitus

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Abstract

Objectives: To analyze the sizes of the stapedius and tensor tympani (TT) muscles using a temporal bone CT (TBCT) scan in patients with middle ear myoclonic tinnitus (MEMT) and investigate their value for the diagnosis of this rare cause of tinnitus.

Methods: Medical records and TBCT of patients with MEMT or vascular tinnitus (VT) at Seoul St. Mary's Hospital from January 2012 to December 2022 were reviewed. The stapedius and TT muscles were analyzed.

Results: Thirty-eight patients with unilateral MEMT and 39 patients with VT were included. More males were in the MEMT group compared to the VT group (MEMT: $n = 24$, VT: $n = 8$, $p = .001$). The mean age of the MEMT group was younger compared to the VT group (MEMT: 35 ± 12 years, VT: 44 ± 14.3 years, $p = .005$). The mean BMI for the MEMT group was less than the VT group (MEMT: 22.3 ± 2.5, VT: 24.8 ± 4.36, $p = .010$). The mean length and width of the stapedius in the MEMT group were larger than those of the VT group (*Length* MEMT: 1.47 ± 0.60 mm, VT: 0.98 ± 0.24 mm, $p = .001$; *Width* MEMT: 0.89 ± 0.32 mm, VT: 0.72 ± 0.19 mm, $p = .009$). The mean length and width of the TT in the MEMT group were larger than that of the VT group (*Length* MEMT: 3.10 ± 0.50 mm, VT: 2.27 ± 0.42, $p = .001$; *Width* MEMT: 2.02 ± 0.36, VT: 1.75 ± 0.26 $p = .001$).

Conclusion: The mean length and width of the stapedius and TT muscles measured in the MEMT group were longer and wider than the VT group. This suggests the use TBCT scan as a diagnostic tool for MEMT. Further studies with a larger study group to validate the results of this study are recommended.

Level of Evidence: 4.

KEYWORDS
case–control study, middle ear, radiology, tinnitus

1 | INTRODUCTION

Tinnitus is a phenomenon of auditory perception without an external stimulus affecting millions worldwide, frequently causing a substantial reduction in quality of life. It is a symptom that comprises different types and pathophysiologic origins. Among these, middle ear myoclonic tinnitus (MEMT) is a rare and unique cause of tinnitus that merits a deeper understanding.[1]

The tinnitus caused by MEMT has a characteristic rhythmic pattern postulated to be due to the repetitive movements of the stapedius and tensor tympani muscles in the middle ear.[2] The patient often experiences tinnitus associated with crackling, buzzing, or audible clicking sounds within the affected ear. On the other hand, vascular tinnitus (VT) is hypothesized to be caused by vascular structures transmitting sound to the cochlea.[3] For both causes of tinnitus, a temporal bone CT (TBCT) scan is a valuable diagnostic tool for an otologist. The TBCT can give important insights into the anatomic origins of tinnitus and provide guidance in various surgical considerations.[4]

Few studies have focused on the dimensions of the stapedius and tensor tympani muscles seen in TBCT and their possible clinical value for the management of MEMT. For patients with chronic and intractable MEMT due to the muscular myoclonic nature of the disease, we hypothesized that the stapedius and tensor tympani muscles would be enlarged enough to be noticeable in TBCT.[5] Furthermore, very few studies have explored the possible correlation between these muscle dimensions and their impact on multiple clinical characteristics (e.g., symptom duration, tinnitus VAS score, etc.). Thus, this study aims to analyze the sizes of the stapes and tensor tympani muscles using a TBCT scan in patients with MEMT for the first time and to investigate its clinical value for diagnosing this rare cause of objective tinnitus. As a sub-analysis, we investigated the potential correlations between the sizes of these muscles with various clinical factors such as the tinnitus handicap inventory (THI), tinnitus visual analog scales (VAS), and symptom duration of tinnitus.

2 | MATERIALS AND METHODS

This is a case–control, retrospective study of patients with chronic MEMT who underwent middle ear tendon resection (METR) for intractable tinnitus. The diagnosis of MEMT was done by a thorough history presenting as a crackling, buzzing, or audible clicking tinnitus, endoscopic confirmation of tympanic membrane motion on sound provocation, and impedance audiometric testing. A thorough evaluation was also done to exclude other possible origins of tinnitus such as palatal myoclonus, sensorineural tinnitus, and vascular tinnitus. Patients with vascular tinnitus were used as a control group. The diagnosis of vascular tinnitus was made by a history of pulsatile tinnitus described as throbbing, rushing, or humming. A complete physical examination was performed including otoscopy, auscultation of the ear canals, and a full head and neck examination. The patient's pulse was checked and confirmed if it was synchronous with the tinnitus sound. A TBCT was done to confirm the vascular origin of the pulsatile which was most often due to a high-riding jugular bulb. These two groups of tinnitus patients were chosen due to the distinct etiologies of their tinnitus of which both groups will answer similar questionnaires and undergo TBCT as a part of their evaluation. VT was chosen as the control due to it having a specific anatomic origin of the pulsatile tinnitus which can also be confirmed with a TBCT. As stated previously, we hypothesized that there would be a noteworthy enlargement in the dimensions of the stapedius and tensor tympani muscles noticeable in TBCT for patients with chronic and intractable MEMT due to the muscular myoclonic nature of the disease.

The medical records and TBCT scans of patients with chronic intractable MEMT who were eventually managed with METR, and those of the patients diagnosed with VT at Seoul St. Mary's Hospital from January 2012 to December 2022 were retrospectively reviewed. Patients with prior temporal bone surgery, temporal bone trauma, or congenital temporal bone anomalies were excluded from the study. This study was approved by the Institutional Review Board at Seoul St. Mary's Hospital and conducted in accordance with the declaration of Helsinki (KC23RISI0513).

The TBCT scans were taken using CT scan machines of Siemens Healthineers SOMATOM Force and Siemens SOMATOM Definition edge with slices of 1 mm. They were hosted in the hospital's Picture Archiving and Communications System (PACS) viewer. The imaging studies' multiplanar views (axial, and coronal planes) were evaluated in the bone window (width 4000, level 700) using the hospital's PACS viewer.

As it is hard to completely delineate the muscle and tendon of the small middle ear muscles (stapedius and tensor tympani), we will use the term, muscle, to refer to the combined muscle-tendon complex of the middle ear muscles throughout this study. Furthermore, we highlight the specific protocols that were used to measure our values in the subsequent paragraph.

The length and width of the stapedius and tensor tympani muscles of the affected side for both MEMT and VT groups were measured at the axial and coronal planes of the TBCT. First, the stapedius muscle length and width were measured using the axial plane. The lateral semicircular canal, stapes ossicle, and pyramidal eminence were used as anatomic landmarks to locate the stapedius muscle prior to measurement (Figure 1A). Once located, the length of the stapedius muscle was measured from its origin at the pyramidal eminence to its insertion into the stapes (Figure 1B). The width of the stapedius was then measured at the point that it emerged from the pyramidal eminence (Figure 1C).

Next, the tensor tympani muscle length and width were measured using the coronal plane. The tensor tympani muscle was located by using the cochleariform process and the malleus handle as anatomic landmarks (Figure 2A). The malleus length was then measured from its turn from the cochleariform process to its insertion into the malleus handle (Figure 2B). The tensor tympani width was measured within the tensor tympani canal by using the petrous part of the internal carotid artery as a landmark (Figure 2C,D).

The patients' demographic, audiologic, and clinical characteristics were evaluated by reviewing their clinical records. These included a

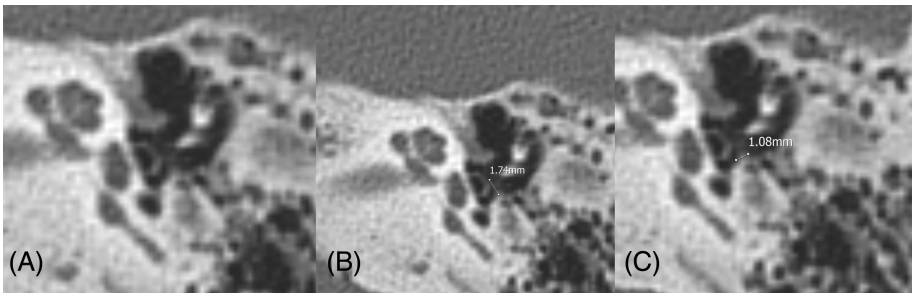

FIGURE 1 Stapedius measurement, right temporal bone CT in Axial view. (A) The stapedius muscle is located using the stapes and pyramidal eminence as landmarks. (B) Stapedius muscle length measurement. (C) Stapedius muscle width measurement.

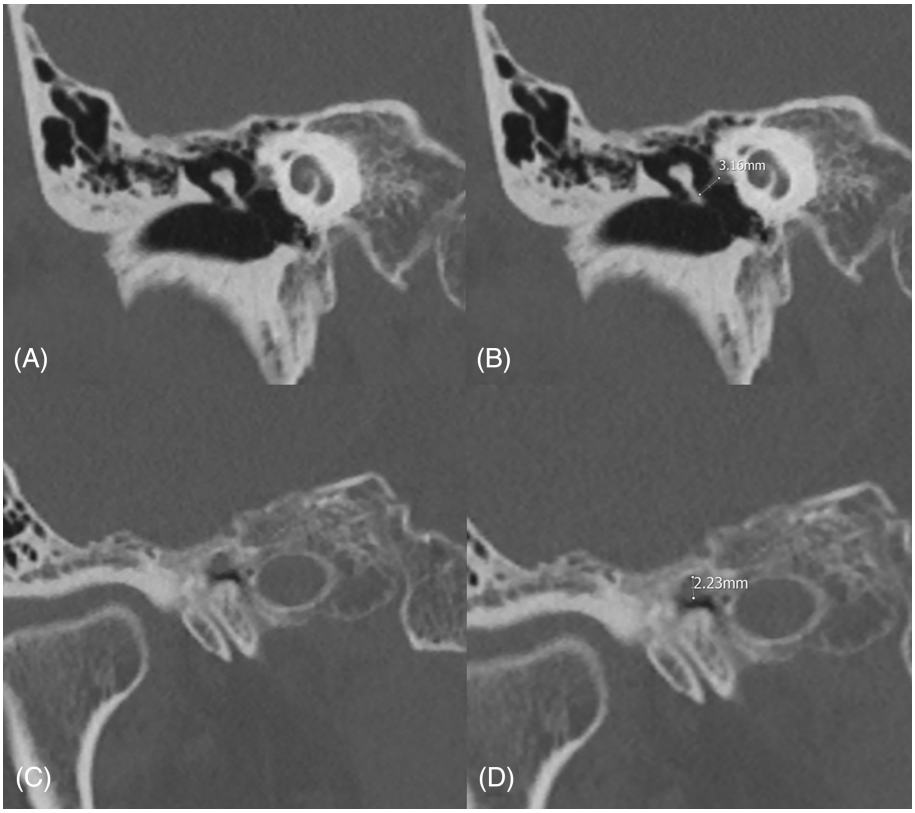

FIGURE 2 Tensor tympani measurement. Right temporal bone CT in coronal view. (A) The tensor tympani muscle was located using the cochleariform process and the malleus handle as anatomic landmarks. (B) Measurement of tensor tympani muscle length after the turn from the cochleariform process. (C) The tensor tympani muscle is located using the petrous part of the internal carotid artery as an anatomic landmark. (D) Measurement of the tensor tympani muscle width.

series of questionnaires including the tinnitus handicap inventory (THI), Beck's depression inventory (BDI), the Korean version of brief encounter psychosocial instrument (BEPSI-K), and visual analog scales assessing various tinnitus characteristics (loudness, awareness, annoyance, and effect on life).

2.1 | Statistical analysis

The intergroup comparison of baseline characteristics was performed using the Mann–Whitney and Fisher's exact tests. The analysis of the stapedius and tensor tympani muscles was evaluated using the Mann–Whitney test. Audiologic characteristics were also evaluated using the Mann–Whitney. The correlation evaluation of the patient demographic and clinical characteristics was done by using Spearman's correlation coefficient. Statistical analysis was performed using IBM Statistical Package for Social Science (SPSS) for Windows, version 24.0 (IBM Corp., Armonk, NY, USA). Statistical significance was set when the *p*-value was lower than .05.

3 | RESULTS

3.1 | Clinical characteristics

A total of 38 patients with chronic intractable MEMT ($n = 24$, 63.2% men, $n = 14$, 36.8% women) who underwent METR, and 39 patients with VT ($n = 8$, 20.5% men, $n = 31$, 79.5% women) were included in the study. More males were in the MEMT group when compared to the VT group (MEMT: $n = 24$, 63.2%, VT: $n = 8$, 20.5% $p = .001$), and more females were in the VT group when compared to the MEMT group (MEMT: $n = 14$, 36.8%, VT: $n = 31$, 79.5% $p = .001$). The mean age of the MEMT group was 35 ± 12 years (ranges from 16 to 63) whereas the mean age of the VT group was 44 ± 14.3 years (ranges

TABLE 1 Baseline characteristics.

Characteristics	MEMT group ($n = 38$)	VT group ($n = 39$)	p-value
Age (years)	35 ± 12	44 ± 14.3	.005‡
Sex			
Male	24 (63.2%)	8 (20.5%)	<.001†
Female	14 (36.8%)	31 (79.5%)	
BMI	22.3 ± 2.5	24.8 ± 4.36	.010†
Laterality			
Right	21 (55.3%)	30 (76.9%)	.056†
Left	17 (44.7%)	9 (23.1%)	
Duration of symptoms (months)	27.8 ± 29.4	23.0 ± 33.3	.399‡

Note: All values are presented by mean standard deviation or n and percentage, as appropriate. p-value is based on †Fisher-exact or ‡Mann–Whitney test.

TABLE 2 Baseline questionnaire results and pure tone audiometry and speech discrimination scores.

Questionnaire	MEMT group	VT group	p-value
Tinnitus handicap index	50.1 ± 24.5	43.4 ± 26.1	.277
VAS loudness	5.5 ± 2.3	5.2 ± 1.8	.551
VAS awareness	6.4 ± 2.7	6.3 ± 2.8	.963
VAS annoyance	6.6 ± 2.6	6.3 ± 1.8	.578
VAS effect on quality of life	6.7 ± 2.1	5.8 ± 2.2	.152
Beck's depression inventory	7.2 ± 6.9	10.3 ± 8.4	.081
Brief encounter psychological instrument	10.2 ± 3.4	10.2 ± 4.3	.660
Pure tone audiometry	11.9 ± 9.1	10.3 ± 6.5	.543
Speech discrimination score	98.2 ± 4.2	98.4 ± 5.3	.673

Note: All values are presented by mean standard deviation. p-value is based on the Mann–Whitney test.

from 18 to 75). The MEMT group was younger when compared to the VT group (MEMT: 35 ± 12, VT: 44 ± 14.3 $p = .005$). The mean BMI for the MEMT group was 22.3 ± 2.5 whereas the mean BMI for the VT group was 24.8 ± 4.36. The BMI for the MEMT group was less than the VT group (MEMT: 22.3 ± 2.5, VT: 24.8 ± 4.36 $p = .010$). The duration of symptoms before the first consult for the MEMT and VT groups were 27.8 ± 29.4 months and 23 ± 33.3 months, respectively ($p = .399$). Detailed baseline characteristics of the two groups can be seen in Table 1.

3.2 | Questionnaire scores and hearing test results

The THI scores for the MEMT and VT groups were 50.1 ± 24.5 and 43.4 ± 26.1, respectively. The BEPSI-K scores for the MEMT and VT groups were 10.2 ± 3.4 and 10.2 ± 4.3, respectively. The BDI scores for the MEMT and VT groups were 7.2 ± 6.9 and 10.3 ± 8.4, respectively. The VAS scores for loudness, awareness, annoyance, and effect on quality of life showed similar scores for both groups. No statistical significance for all these tinnitus questionnaire scores was noted between the two groups.

The mean speech frequency hearing levels of pure tone audiogram for the MEMT and VT groups were 11.9 ± 9.1 and 10.3 ± 6.5 decibels, respectively. The speech discrimination scores for the MEMT and VT groups were 98.2 ± 4.4 and 98.4 ± 5.3 percent, respectively. No statistical significance was noted. A summary of the baseline questionnaire and hearing results of the two groups are shown in Table 2.

3.3 | Comparison of stapedius and tensor tympani muscle measurements

The MEMT group revealed significantly longer and wider stapedius and tensor tympani muscles than the VT group. For the stapedius measurements, the MEMT group had significantly longer mean stapedius length (1.47 mm, 95% CI 1.27–1.67) than the VT group (0.98 mm, 95% CI 0.91–1.06), $p = .001$. The MEMT group also had significantly wider mean stapedius width (0.89 mm, 95% CI 0.78–0.99) than the VT group (0.72 mm, 95% CI 0.65–0.77), $p = .009$. For the tensor tympani measurements, the MEMT group had significantly longer mean tensor tympani length (3.10 mm, 95% CI 2.94–3.27) than the VT group (2.27 mm, 95% CI 2.14–2.40), $p = .001$. The MEMT group had significantly wider mean tensor tympani width (2.02 mm, 95% CI 1.90–2.14) than the VT group (1.75 mm, 95% CI 1.67–1.83), $p = .001$. A detailed summary of the comparison of muscle measurements of the two groups is shown in Table 3 and Figure 3.

TABLE 3 Comparison of muscle measurements.

Measurements	MEMT group	VT group	*p*-value
Stapedius tendon length (mm)	1.47 ± 0.60	0.98 ± 0.24	.001
Stapedius tendon width (mm)	0.89 ± 0.32	0.72 ± 0.19	.009
Tensor tympani tendon length (mm)	3.10 ± 0.50	2.27 ± 0.42	.001
Tensor tympani tendon width (mm)	2.02 ± 0.36	1.75 ± 0.26	.001

Note: Values mean ± SD. *p*-value is based on the Mann–Whitney test.

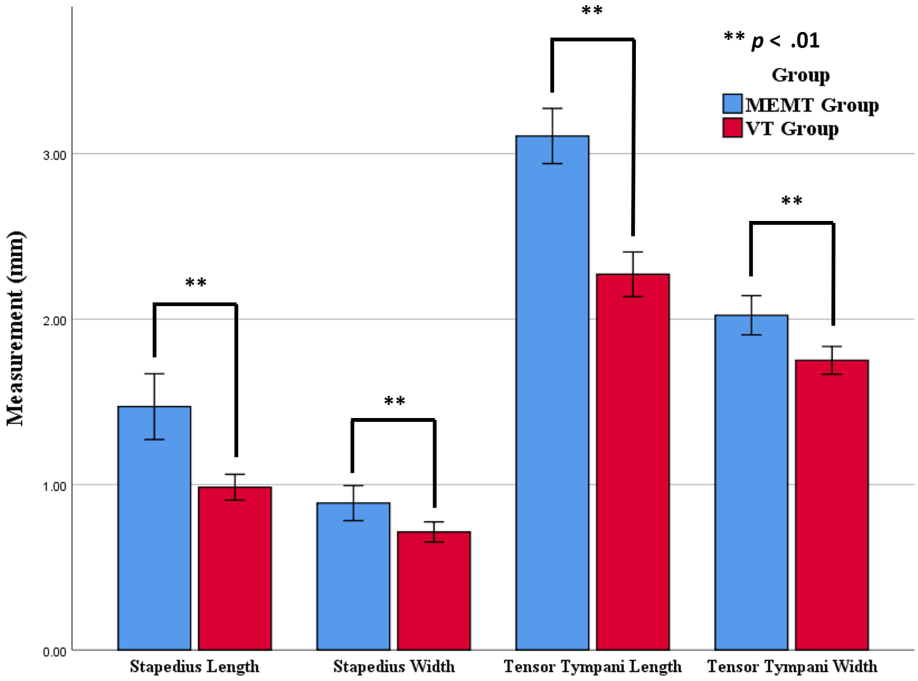

FIGURE 3 Clustered bar graphs with 95% confidence interval of stapedius and tensor tympani muscle measurements divided into MEMT and VT groups.

3.4 | Correlation study of stapedius and tensor tympani muscle measurements with clinical characteristics of the tinnitus

For Spearman's correlation study of the various clinical characteristics, Beck's depression inventory and the brief encounter psychosocial instrument results also showed a moderate correlation ($r = .584$, $p = .001$). There was a correlation noted between the pure tone audiometry decibel of hearing loss and the patient's VAS score for annoyance and effect on quality of life (VAS – annoyance: $r = .364$ $p < .001$, VAS effect on QOL: $r = .348$, $p < .001$). A moderate correlation was noted between the stapedius width and the symptom duration of tinnitus ($r = .314$, $p = .005$). Lastly, there was a positive correlation between the measured lengths and widths for both stapedius ($r = .729$, $p < .001$) and tensor tympani muscles ($r = .347$, $p < .001$).

4 | DISCUSSION

This study was conducted to investigate the sizes of the stapedius and tensor tympani muscles measured in TBCT in patients with MEMT. We hypothesized that these middle ear muscles in patients with chronic intractable MEMT could be hypertrophied and elongated due to the repeated tonic–clonic motion of the muscles. To prove our hypothesis, we performed a comparison analysis of the sizes of these middle ear muscles between two different groups of MEMT and VT.

The baseline characteristics revealed that the MEMT group was significantly younger than the VT group (MEMT: 34 ± 11.9, VT: 46 ± 13.8, $p = .005$). This finding is consistent with the findings of Park et al. on 58 MEMT patients who had a young mean age of 29.8 years in this rare type of tinnitus[6] as well as with the findings of Bae et al. on 57 VT patients who had an older mean age of 48.9 years.[7] In terms of the gender for the VT group, there was a notable female predominance ($n = 31$, 79.5%) which is also consistent with the study of Bae et al. ($n = 47$, 82.5%). The results also revealed that the BMI for the VT group was significantly higher when compared to the MEMT group (MEMT: 22.3 ± 2.5, VT: 24.8 ± 4.36, $p = .010$). A possible explanation for this significance is that vascular tinnitus has etiologies from hypertension and atherosclerotic carotid disease both of which are correlated with a higher BMI.

Interestingly, there was no statistical significance for the two group characteristics when laterality and duration of symptoms prior to consultation were analyzed. The distribution of laterality for both the MEMT and VT groups is consistent with other studies showing that there is no predisposition for specific laterality for both disease entities although the right-side predominant condition (75%) was

observed in the VT group. In terms of the questionnaires for quality of life, pure tone audiometry, and speech discrimination score, there was no statistical significance between the two groups. This lack of statistical significance might be due to the complex nature of tinnitus with it having both an objective and subjective component that varies greatly from patient to patient.[8]

The measurement of the middle ear muscles followed the muscle measurement protocol of Wojciechowski and his colleagues in their study where they used the lateral semicircular canal, stapes, and pyramidal eminence as important landmarks to identify and measure the middle ear muscles.[9] We adopted and modified the protocol of this previous study which revealed that the length and width of the stapedius as well as tensor tympani in the MEMT group were significantly larger and longer than those of the VT group, indicating that the hypertrophied and elongated middle ear muscles measured in TBCT could be a biomarker for supporting a diagnosis of intractable chronic MEMT. Moreover, our hypothesis of hypertrophied and elongated muscles probably caused by repeated myoclonic movement of the middle ear muscles in patients with chronic MEMT seemed to be proven through this study. In contrast to this, the muscles of the VT group were measured to be smaller possibly due to the vascular origin of the tinnitus for the disease entity, thus not affecting the size of the muscles.

The correlation study of stapedius and tensor tympani muscle measurements with clinical characteristics of tinnitus also revealed various valuable findings in this study. Like other studies about tinnitus, we could find strong correlations among the parameters of the tinnitus questionnaire in patients with MEMT, indicating the discomfort of patients caused by tinnitus always affects the emotional condition of the patients with tinnitus.[10]

We also found that there was a positive correlation between the duration of tinnitus and the size of the stapedius muscles. Moreover, the sizes of the stapedius and tensor tympani muscles also showed a positive correlation in this study. Therefore, hypertrophied, and elongated middle ear muscles seem to be the results of repeated myoclonic motion of the muscles in MEMT patients, although its causal effect needs to be further elucidated.

The presence of statistically significant differences in the sex and age for the two groups (MEMT and VT) is a possible contributing factor to the derived results. To account for this potential influence, a sub-analysis using Mann–Whitney test was performed separating the cohort based on sex (male $n = 32$ vs. female $n = 45$) and age groups (≤40 years $n = 45$ vs. >40 years $n = 32$). The age groups are based on the evidence proposing that age-related muscle decline occurs as early as the 4th decade of life with up to 50% of mass being lost at the 8th decade.[11] For the sub-analysis comparing sex (male vs. female), results showed no statistically significant difference for stapedius length ($p = .299$), stapedius width ($p = .899$), tensor tympani length ($p = .076$), and tensor tympani width ($p = .414$). For the sub-analysis comparing age groups (≤40 years vs. >40 years) results showed no statistically significant difference for stapedius length ($p = .609$), stapedius width ($p = .269$), tensor tympani length ($p = .091$), and tensor tympani width ($p = .311$). Despite no significant difference for the cohort sub-analyses, it is noteworthy that the tensor tympani length sub-analysis p-value for sex ($p = .076$) and age group ($p = .091$) was low.

Several potential limitations can be observed in this study. First, the presence of statistically significant differences in the sex and age for the two groups (MEMT and VT) is still a possible influence for the results. Despite no significance seen in the cohort sub-analyses performed, it cannot be ruled out completely. Therefore, we recommend that future studies be performed with a larger sample size and separation of groups based on sex and age stratification. Furthermore, subsequent studies can be done comparing normative data from cases without tinnitus and cases with tinnitus, also stratified by sex and age. The previous study done by Wojciechowski and his colleagues used a TBCT scan with 0.07 mm thin cuts. Thinner cuts of ≤0.1 mm would be more informative and valuable for supporting the diagnosis of MEMT. A study with thinner cuts of TBCT scan may give more information not only for the diagnosis but also for a probable prognostic value of other studies related to middle ear myoclonic tinnitus.[12] Lastly, the measurements of this study were performed by a single investigator, we recommend that future studies use a blind design with multiple raters.

5 | CONCLUSION

The mean length and width of the stapedius and tensor tympani muscles measured in TBCT scan in the MEMT group were significantly longer and wider than those of the VT group, which suggests the possible value of TBCT scan as a diagnostic tool for chronic MEMT when used in conjunction with other clinical findings. Further studies with thinner cuts of TBCT scans in a larger study group will be needed to validate the results of this study as well as to investigate its more practical clinical value for the diagnosis and management of MEMT.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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