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Normalızatıon of masseter VEMP and comparıson wıth cervıcal VEMP ın normal ındıvıduals

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Abstract

Objectıve The objective of this study is to obtain normative data of the masseter vestibular-evoked myogenic potential (mVEMP) test in healthy individuals without hearing loss and dizziness and to compare the responses with the cVEMP test.

Methods Twenty healthy individuals (10 males and 10 females) aged 20–30 years without auditory and vestibular disorders participated in the study. First, mVEMP and then cVEMP tests were applied to the individuals who voluntarily participated in the study.

Results Latency values of the air-conducted mVEMP were 15.90 ± 1.68 ms for P1 and 25.86 ± 1.48 ms for N1 and 9.96 ± 1.50 ms for interpeak latencies. P1N1 amplitude value was 97.89 ± 37.34 μV and asymmetry ratio (AR) was 0.13 ± 0.07. The normative data for the mVEMP threshold was found 84 dB nHL. According to the gender difference in mVEMP measurement parameters, the P1 latency of women was found shorter than the P1 latency of men at all stimulus intensities except 90 dB nHL. There was no statistically significant difference between mVEMP and cVEMP test results in all other severity and all parameters except P1 latency at 100 dB and interpeak latency at 100 dB ($p > 0.05$).

Conclusıon In conclusion, it was the study findings suggest that obtaining normative data on mVEMP could be used as an auxiliary test in the evaluation of the vestibular and trigeminal pathway and the evaluation of patients with various peripheral and central vestibular disorders.

Keywords Masseter VEMP, Air-conducted cVEMPs, Vestibular system, Vestibular-evoked myogenic potentials

Background

Vestibular-evoked myogenic potential (VEMP) is a reflex arc response that occurs in certain muscles when peripheral vestibular organs are stimulated by sound, vibration, or galvanic stimulation. The VEMP test method evaluating the vestibular system is named according to the muscle in which the reflex arc response is measured [1, 2]. The reflex responses obtained from the sternocleidomastoid (SCM) muscle are recorded as the cervical vestibular-evoked myogenic potentials (cVEMP) and obtained from the inferior oblique muscles are regarded as the ocular vestibular-evoked myogenic potential (oVEMP). Muscles in which VEMP is obtained are not only limited to SCM and oblique muscles. In many studies conducted for a long time, it has been shown that similar responses are obtained over different muscles as a result of high-intensity click and tone-burst sound stimuli. These responses were also obtained from other

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muscles such as the masseter [3], trapezius [4], splenius capitis [5], triceps [6], soles [7], and frontalis.

Vestibulo-maseteric reflex arc responses can be obtained when the electrode attached to the masseter muscle and presents acoustic stimulus. These responses are associated with the pathway between the vestibular complex and trigeminal nerve nuclei [8]. Vestibular, auditory, visual, and somatosensory inputs also affect the innervation of trigeminal motor neurons [9]. Studies in the literature show that trigeminal motoneuron innervation in animals and humans is linked to the vestibular inputs from the masseter muscle. Accordingly, it has been shown that vestibular myogenic responses can be obtained over the masseter muscle [10].

In the literature, it is thought that the combined use of cVEMP, oVEMP, and masseter VEMP (mVEMP) will be useful in the evaluation of brainstem physiology. The mVEMP test assists in the evaluation of brainstem dysfunctions in patients with multiple sclerosis, Parkinson's, and idiopathic REM-sleeping behavior disorder, as an adjunct to clinical and radiological imaging. In diagnosing patients with peripheral vestibular disorders, cVEMP was compatible with oVEMP tests [8, 11, 12].

Since cVEMP and oVEMP tests cannot be applied in patients who cannot hold their neck, who have undergone a surgical operation in the neck region, who have congenital SCM anomaly, and who have an anomaly in the eye muscles, mVEMP can be used as an alternative test method. Thus, it is necessary to obtain normative mVEMP data. Furthermore, it is also important to compare normative mVEMP data with those of cVEMP, which is frequently preferred today.

A normalization study of the mVEMP test has been performed in the literature (11). However, mVEMP test studies with 500-Hz tone-burst stimulus are limited. mVEMP normative values were found in studies, but mVEMP threshold values were not found.

This study was conducted to obtain the normative data and threshold value of the mVEMP test and compare it with cVEMP in healthy individuals without a history of hearing loss and dizziness.

Methods

Participants

Twenty healthy individuals (10 males and 10 females) aged 20–30 years without auditory and vestibular disorders participated in the study. The approval for the research was obtained from the Ethics Committee of Istanbul Medipol University on December 24, 2020 (approval number: 959). This study was carried out in compliance with the principles of the Helsinki Declaration. An informed consent form was obtained from the participants.

Inclusion criteria

Inclusion criteria of the study were as follows:

- A chronological age ranging from 20 to 30 years
- Normal otoscopic examination
- Obtaining type A tympanogram and obtaining bilateral acoustic reflexes in immitansmetric evaluation
- In the pure tone audiometry test, hearing threshold within normal limits (pure tone average <15 dB HL)
- Speech discrimination score within normal limits (88% and above)
- No current or past history of any vestibular or systemic disease

Exclusion criteria

Exclusion criteria of the study were as follows:

- The presence of neurological or psychiatric disease
- Having a history of otological disease and/or ear surgery
- Any history and diagnosis of hearing loss
- Lack of airway cVEMP responses
- The presence of pathology in the cervical region

VEMP testing

In the study, the Interacoustics® brand Eclipse Smart EP25 device was used to record cervical and masseter vestibular myogenic-evoked potential responses. Unilateral stimulation was applied. First, mVEMP and then cVEMP tests were applied to the individuals. Before starting the test, information such as the name, age, and gender of the individuals was recorded in the OtoAccess® program, and then, the individuals were prepared for the test. Before the individuals were prepared for the test, the places where the electrodes would be placed were cleaned with NuPrep® brand skin cleansing gel. Four disposable, Ambu® brand Neuroline 720 self-adhesive electrodes were used for each individual on the cleaned areas. Two different tests were applied to individuals.

mVEMP recording

In electrode placement for mVEMP, active electrodes were placed in the lower third of the masseter muscle, the reference electrode was placed in the middle of the vertex, and the ground electrode was placed on the forehead. Attention was paid to ensuring that the

Table 1 Descriptive statistical data of mVEMP measurements

Stimulus intensity	Data count (ear)	Parameter				
		P1 latency (ms)	N1 latency (ms)	Interpeak latency (ms)	P1N1 amplitude (μV)	Asymmetry ratio
100 dB nHL	40	15.9 0 ± 1.68	25.86 ± 1.48	9.96 ± 1.50	97.89 ± 37.34	0.13 ± 0.07
95 dB nHL	40	16.76 ± 2.02	25.69 ± 2.22	8.93 ± 1.97	83.02 ± 36.57	0.16 ± 0.08
90 dB nHL	33	17.12 ± 1.38	24.69 ± 2.07	7.57 ± 1.90	74.28 ± 33.14	0.16 ± 0.08
85 dB nHL	24	17.83 ± 1.55	24.75 ± 1.43	6.89 ± 1.17	63.61 ± 21.63	0.16 ± 0.13
80 dB nHL	16	18.69 ± 1.96	24.23 ± 1.37	5.54 ± 1.48	65.30 ± 28.74	0.14 ± 0.06
75 dB nHL	10	18.40 ± 1.40	24.53 ± 1.31	5.90 ± 1.02	58.68 ± 16.73	0.21 ± 0.07

impedances of the electrodes were below 5 kΩ and the impedance values between the electrodes were below 3 kΩ. During the recording, the participants were asked to keep their posterior teeth contracted as if they were chewing something. In VEMP monitoring, the appropriate contraction range was set as "70–120 μV RMS." Thus, a more symmetrical contraction of the masseter muscles was achieved. Patients who could not achieve sufficient contraction were asked to tighten their back teeth by placing a sterile cloth in their mouths. Thus, the difference in contraction between patients was minimized.

cVEMP recording

In electrode placement for cVEMP, active electrodes were placed on the upper third of the sternocleidomastoid muscle, the referance electrode was placed on the sternum of the sternocleidomastoid muscle, and the ground electrode was placed on the forehead. The impedances of the electrodes were kept below 5 kΩ, and the impedance values between the electrodes were kept below 3 kΩ. VEMPs were recorded, while subjects were seated on a revolving chair and rotated to face the contralateral side to provide adequate tension of the SCM muscle.

VEMP stimulus parameter

Air-conducted sound stimuli were monaurally presented to the ear canal via Etymotic® brand ER-3A insert earphones. Both tests were recorded at a sampling rate of 5.1 Hz and averaged over 200 individual trials using OtoAccess® software. The band-pass filter was 10–1 kHz. The initial intensity was 100 dB nHL for air-conducted stimulation adjusted by 5 dB nHL per step to elicit the threshold. P1 and N1 latency (ms), P1–N1 interpeak latency (ms), P1–N1 interpeak amplitude (μV), and VEMPs asymmetry ratio of VEMPs waves were determined at each stimulus intensity.

Statistical analysis

Statistical analyses were performed using the Statistical Package for Social Sciences version 25.0 (SPSS v.25.0, IBM®, Chicago, IL, USA). Descriptive statistical information was given as mean and standard deviation (mean ± SD). When comparing measurement values, nonparametric tests were used because the distributions were not normally distributed. Wilcoxon test was used for the comparison of mVEMP and cVEMP threshold values and measurement values. Mann–Whitney *U*-test was used in the comparison of mVEMP and cVEMP measurement values according to gender and ear side. $p < 0.05$ was considered to indicate statistically significant differences.

Results

Descriptive statistical data of mVEMP measurement at all stimulus intensities are shown in Table 1. For mVEMP of 100 dB nHL, mean P1 latency 15.90 ± 1.68 ms, N1 latency 25.86 ± 1.48 ms, interpeak latency 9.96 ± 1.50 ms, P1N1 amplitude 97.89 ± 37.34 μV, and asymmetry ratio were found to be 0.13 ± 0.07. As stimulus intensity decreased, P1 and N1 latencies were prolonged, and P1N1 amplitude decreased (Figs. 1 and 2).

The comparison of mVEMP parameter values by gender is shown in Table 2. In the evaluation of mVEMP measurements according to gender, there is a statistically significant difference ($p < 0.05$) in P1 and N1 latencies at 100-dB nHL, 95-dB nHL, and 85-dB nHL intensities. There is a statistically significant difference ($p < 0.05$) in P1 latency, interpeak latency, and asymmetry rate at 80-dB nHL intensity and P1 latency and asymmetry rates at 75-dB nHL intensity. In female participants, P1 and N1 latencies were obtained shorter than in male participants.

The comparison of mVEMP and cVEMP measurement parameters is shown in Table 3. There is a statistically significant difference ($p < 0.05$) in P1 latency and interpeak latency at 100-dB nHL intensity.

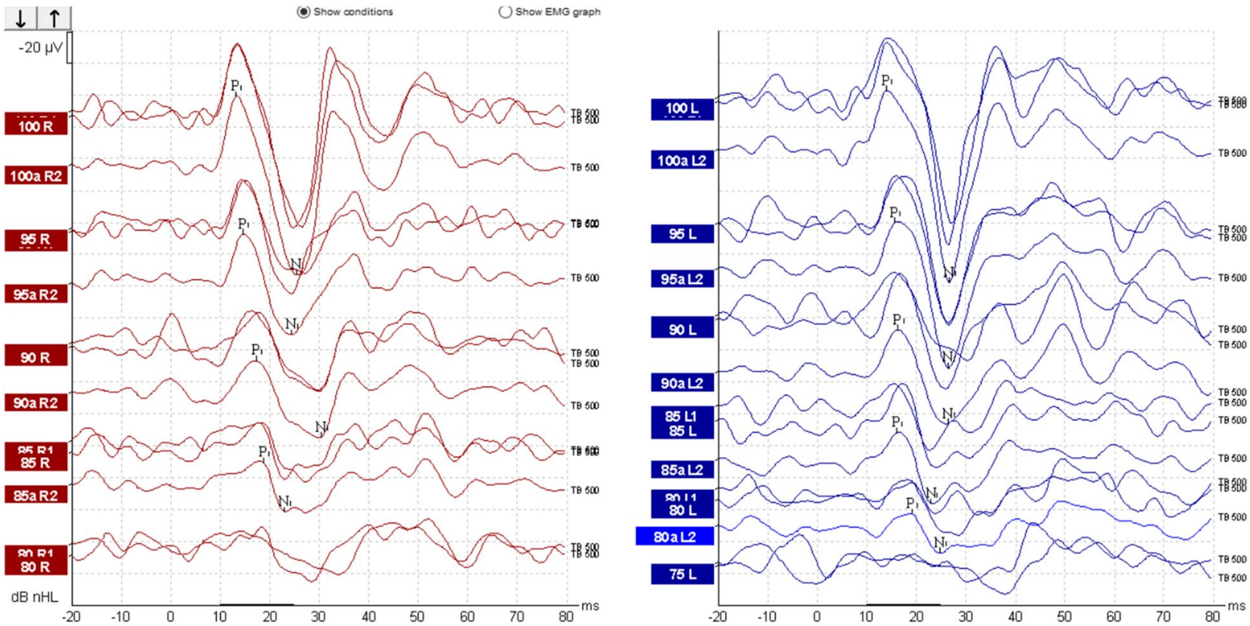

Fig. 1 Record of mVEMP mVEMPs responses were obtained from a female individual. (mVEMPs responses, right ear VEMPs threshold 85 dB nHL, left ear VEMPs threshold 80 dB nHL)

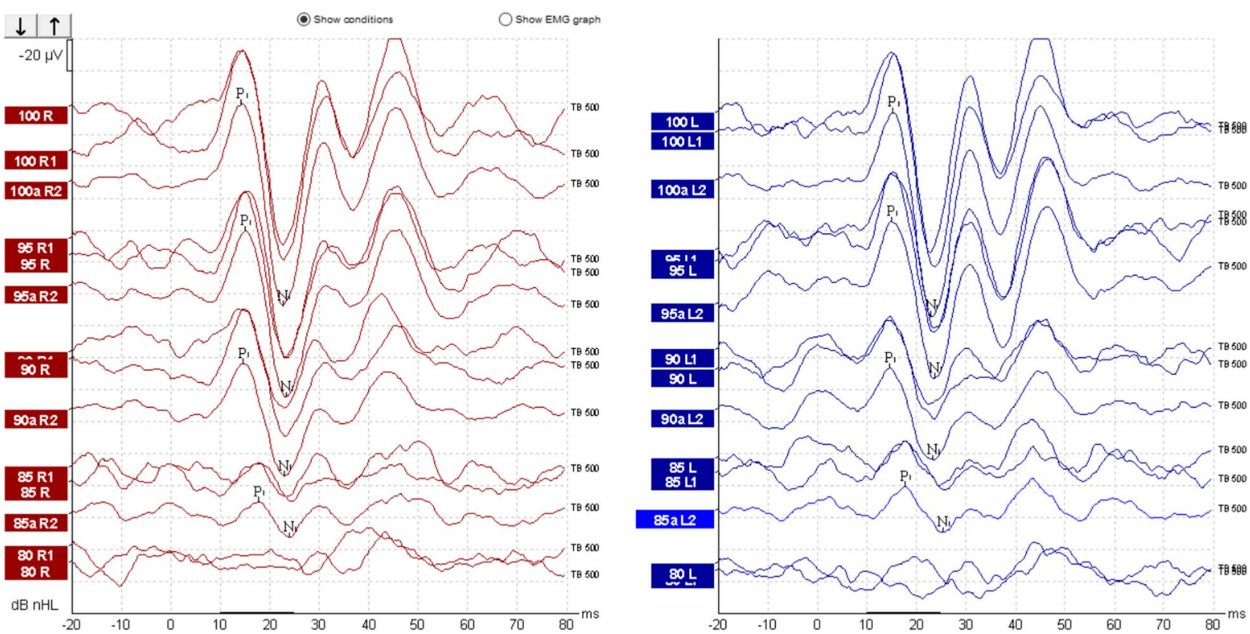

Fig. 2 It is the cVEMP response of the same individual cVEMPs responses were obtained from the same female individual. (cVEMPs responses, right and left ear VEMPs threshold 85 dB nHL)

Discussion

This study was conducted to establish the normative values of 500-Hz tone-burst mVEMP measurement parameters in individuals aged 20–30 years. The study also examined the comparison of the cVEMP test with the mVEMP test.

VEMP tests are interpreted by looking at many parameters. Evaluation parameters consist of P1 latency, N1 latency, interpeak latency, P1N1 amplitude, and VEMP

Table 2 Comparison of mVEMP measurement parameters by gender

Stimulus intensity	Parameter	Gender		
		Male	Female	*P*
100 dB nHL	P1 latency (ms)	16.63 ± 1.65	15.17 ± 1.40	0.005**
	N1 latency (ms)	26.40 ± 1.36	25.32 ± 1.42	0.014*
	Interpeak latency (ms)	9.77 ± 1.58	10.15 ± 1.44	0.473
	P1N1 amplitude (µV)	100.50 ± 40.15	95.29 ± 35.16	0.589
	Asymmetry ratio	0.15 ± 0.08	0.11 ± 0.06	0.142
95 dB nHL	P1 latency (ms)	17.48 ± 2.14	16.03 ± 1.64	0.022**
	N1 latency (ms)	26.18 ± 1.88	25.20 ± 2.47	0.045*
	Interpeak latency (ms)	8.70 ± 2.03	9.17 ± 1.93	0.607
	P1N1 amplitude (µV)	89.70 ± 42.22	76.34 ± 29.48	0.344
	Asymmetry ratio	0.17 ± 0.10	0.14 ± 0.06	0.587
90 dB nHL	P1 latency (ms)	17.58 ± 1.31	16.69 ± 1.34	0.058
	N1 latency (ms)	25.02 ± 1.46	24.37 ± 2.52	0.286
	Interpeak latency (ms)	7.44 ± 1.65	7.69 ± 2.16	0.678
	P1N1 amplitude (µV)	84.98 ± 35.25	64.20 ± 28.45	0.056
	Asymmetry ratio	0.13 ± 0.14	0.16 ± 0.12	0.182
85 dB nHL	P1 latency (ms)	18.78 ± 1.02	16.89 ± 1.43	0.003**
	N1 latency (ms)	25.11 ± 0.48	24.39 ± 1.94	0.036*
	Interpeak latency (ms)	6.33 ± 1.22	7.44 ± 0.85	0.041*
	P1N1 amplitude (µV)	73.51 ± 22.81	53.71 ± 15.64	0.064
	Asymmetry ratio	0.18 ± 0.14	0.15 ± 0.11	1.000
80 dB nHL	P1 latency (ms)	19.78 ± 0.99	17.29 ± 2.06	0.043*
	N1 latency (ms)	24.52 ± 0.71	23.86 ± 1.92	0.219
	Interpeak latency (ms)	4.74 ± 1.34	6.57 ± 0.94	0.008**
	P1N1 amplitude (µV)	66.31 ± 32.69	63.99 ± 25.22	0.874
	Asymmetry ratio	0.09 ± 0.01	0.20 ± 0.01	0.009**
75 dB nHL	P1 latency (ms)	19.47 ± 1.10	17.33 ± 0.62	0.014*
	N1 latency (ms)	25.20 ± 0.90	23.87 ± 1.39	0.140
	Interpeak latency (ms)	5.73 ± 1.19	6.07 ± 0.93	0.398
	P1N1 amplitude (µV)	56.98 ± 9.81	60.39 ± 22.94	0.917
	Asymmetry ratio	0.15 ± 0.04	0.27 ± 0.00	0.013*

asymmetry rate. The latency prolongation in these parameters, the increase in amplitudes due to the stimulus intensity and the intensity of the contraction of the evaluated muscle, the high VEMP asymmetry rate obtained, and the low VEMP threshold are helpful in differential diagnosis [13–15]. In our study, as in other studies, P1 latency, N1 latency, interpeak latency, P1N1 amplitude, and VEMP asymmetry ratio parameters were examined for the interpretation of mVEMP and cVEMP tests.

In the literature, there are studies in which the stimulus is transmitted unilaterally and bilaterally in the mVEMP test, and generally, a similar response occurs as a result of bilateral and unilateral stimulation [12, 16, 17]. There are studies in which greater responses were obtained in bilateral stimulation, but no statistically significant difference was found [3]. In our study, mVEMP was obtained with unilateral stimulation.

There are differences in the electrode placement in the mVEMP test in the literature. In the studies of Deriu et al., the active electrode was placed on the lower one-third of the masseter muscle, the reference electrode was placed on the mandible and the zygomatic bone, and the ground electrode was placed on the forehead [18]. In our study, we placed the active electrodes on the right-left one-third of the masseter muscle, the reference electrode on the vertex, and the ground electrode on the forehead. The reason for the different electrode placement is that the test device used belongs to a different brand and model.

In our study, mVEMP with 500-Hz tone-burst excitation at unilateral 100 dB NHL was obtained with P1 latency 15.90 ± 1.68 ms, N1 latency 25.86 ± 1.48 ms,

Table 3 Comparison of mVEMP and cVEMP measurement parameters

Stimulus intensity	Parameter	VEMP		
		mVEMP	cVEMP	*P*
100 dB nHL	P1 latency (ms)	15.90 ± 1.68	16.68 ± 1.67	0.027*
	N1 latency (ms)	25.86 ± 1.48	25.83 ± 2.28	0.850
	Interpeak latency (ms)	9.96 ± 1.50	9.17 ± 1.71	0.032*
	P1N1 amplitude (μV)	97.89 ± 37.34	111.02 ± 54.45	0.301
	Asymmetry ratio	0.13 ± 0.07	0.14 ± 0.12	0.925
95 dB nHL	P1 latency (ms)	16.76 ± 2.02	17.20 ± 2.07	0.314
	N1 latency (ms)	25.69 ± 2.22	25.89 ± 2.32	0.601
	Interpeak latency (ms)	8.93 ± 1.97	8.69 ± 1.98	0.321
	P1N1 amplitude (μV)	83.02 ± 36.57	84.39 ± 43.07	0.554
	Asymmetry ratio	0.16 ± 0.08	0.20 ± 0.12	0.053
90 dB nHL	P1 latency (ms)	17.04 ± 1.43	17.52 ± 2.19	0.375
	N1 latency (ms)	24.63 ± 2.15	25.28 ± 2.75	0.313
	Interpeak latency (ms)	7.59 ± 1.96	8.01 ± 1.99	0.551
	P1N1 amplitude (μV)	71.04 ± 30.08	57.21 ± 26.10	0.153
	Asymmetry ratio	0.14 ± 0.12	0.12 ± 0.15	0.427
85 dB nHL	P1 latency (ms)	17.64 ± 1.71	17.00 ± 1.67	0.410
	N1 latency (ms)	24.15 ± 0.89	24.79 ± 2.07	0.310
	Interpeak latency (ms)	6.46 ± 1.32	7.79 ± 2.17	0.184
	P1N1 amplitude (μV)	54.64 ± 15.49	45.82 ± 19.80	0.196
	Asymmetry ratio	0.13 ± 0.07	0.13 ± 0.04	1.000

interpeak latency 9.96 ± 1.50 ms, P1N1 amplitude 97.89 ± 37.34 μV, and VEMP asymmetry ratio 0.13 ± 0.07. When we compared the mVEMP parameter results of our study with the literature, P1 latency was prolonged in our study [16, 17]. It is thought that the reason for the differences with other studies may be due to the differences in the stimulus, electrode placement, and hardware.

In our study, mVEMP measurement parameters in all stimulus intensities were compared according to gender. In the comparison of mVEMP measurement parameters by gender, females P1 latency was earlier than males P1 latency at all stimulus intensities except 90 dB nHL. Females N1 latency was shorter than males N1 latency at all stimulus intensities except 90 dB nHL, 80 dB nHL, and 75 dB nHL. In mVEMP gender comparisons in the literature, P1 and N1 latencies of female were found to be shorter than males [17, 18]. It is thought that this may be due to the short length of the cochlea in women and the lower trigeminal nerve volume in men [19, 20].

In the study, we also examined the comparison of normative values of the mVEMP and cVEMP tests. Few studies have compared mVEMP and cVEMP in the literature [3, 8, 11, 12]. There was no statistically significant difference ($p > 0.05$) in the comparison of mVEMP and cVEMP threshold values and measurement parameters. In studies in the literature, mVEMP and cVEMP were found to be compatible [3, 8, 11, 12].

Lımitatıon
In our study, the mVEMP test was applied to individuals between the ages of 20–30. By applying the mVEMP test in wider age groups, normative data can be obtained, and comparisons can be made according to age groups.

Conclusıons
There are few studies in the literature examining all parameters of the mVEMP test, and there are differences in these studies. The population in which the test is applied, the type of stimulus used in the test, its intensity, different electrode mountings, and the application of different recording parameters provide these differences. With our study, descriptive statistical values of mVEMP measurement parameters of the Turkish population between the ages of 20 and 30 were obtained. The study also examined the comparison of the cVEMP test used in the examination of vestibular functions with the mVEMP test. Since cVEMP and oVEMP tests cannot be applied in patients who cannot hold their neck, who have undergone a surgical operation in the neck region, who have congenital SCM

anomaly, and who have an anomaly in the eye muscles, mVEMP is thought to be an alternative test method. With this study, it is thought that obtaining normative data on mVEMP responses can be used as an auxiliary test in the evaluation of the vestibular and trigeminal pathway and the evaluation of patients with various peripheral and central vestibular disorders.

Abbreviations

dB	Decibel
HL	Hearing level
mVEMP	Masseter vestibular-evoked myogenic potential
cVEMP	Cervical vestibular-evoked myogenic potential
AC	Air conducted
AR	Asymmetry ratio
TB	Tone burst
SCM	Sternocleidomastoid muscle
VEMP	Vestibular-evoked myogenic potential
oVEMP	Ocular vestibular-evoked myogenic potential

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Authors' contributions
EK, data collection, article writing, investigation, methodology, and project administration. EG, conceptualization, data curation, and formal analysis. BT, data collection and editing. MBS, supervision. The authors read and approved the final manuscript.

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Availability of data and materials
The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Written informed consent was obtained from the study participants, and Ethics Committee of Istanbul Medipol University approved the study proposal.

Consent for publication
Not applicable.

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

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