# Tone Burst Masseter Vestibular Evoked Myogenic Potentials: Normative Values and Test–Retest Reliability

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Abstract	<b>Background</b> Masseter vestibular evoked myogenic potential (mVEMP) is a recent tool for the assessment of vestibular and trigeminal pathways. Though a few studies have recorded mVEMP using click stimuli, there are no reports of these potentials using the more conventional VEMP eliciting stimuli, the tone bursts.				
	retest reliability of tone burst evoked mVEMP.				
	<b>Research Design</b> The research design type is normative study design.				
	<b>Study Sample</b> Forty-four healthy participants without hearing and vestibular deficits				
	In the age range of 18 to 50 years participated in the study.				
	500 Hz tone-burst stimuli at 125 dB peSPI. Ten participants underwent second mVEMP				
	testing within 1 month of the initial testing to estimate the test–retest reliability.				
	<b>Results</b> Tone burst mVEMP showed robust responses in all participants. There were				
	no significant ear and sex differences on any mVEMP parameter ( $p > 0.05$ ); however males had significantly higher EMG normalized peak-to-peak amplitude than female				
	Intraclass correlation coefficient (ICC) values of tone burst mVEMP showed excellent				
Konwords	test-retest reliability (ICC $>$ 0.75) for ipsilateral and contralateral p I I latency, ipsilat-				
<ul> <li>vestibulomasseteric reflex</li> <li>evoked potentials</li> </ul>	Fair and good test–retest reliability ( $0.4 < ICC > 0.75$ ) was observed for ipsilateral and contralateral n21 latency, contralateral EMG normalized peak-to-peak amplitude, and amplitude asymmetry ratio.				
<ul><li>otolith responses</li><li>trigeminal nerve</li></ul>	<b>Conclusion</b> Tone burst mVEMP is a robust and reliable test for evaluating the functional integrity of the vestibulomasseteric reflex pathway.				

Vestibular evoked myogenic potentials (VEMPs) are otolithic responses induced by sound, vibration, or galvanic stimulation.<sup>1</sup> Two clinical variants are popularly used, one recorded from the sternocleidomastoid muscle, known as cervical VEMP (cVEMP), and the other from the inferior oblique extraocular muscle, called ocular VEMP (oVEMP). Practically, VEMP

received September 18, 2020 accepted after revision November 30, 2020 published online June 1, 2021 can also be recorded from other muscles of the body including the gastrocnemius muscle,<sup>2</sup> the triceps muscle,<sup>3</sup> the trapezius muscles,<sup>4</sup> and the masseter muscle.<sup>5</sup> The responses from the masseter muscle are called the masseter vestibular evoked myogenic potential (mVEMP)<sup>6</sup> represented as bilaterally symmetrical biphasic p11-n21 responses.<sup>5</sup>

© 2021. American Academy of Audiology. All rights reserved. Thieme Medical Publishers, Inc., 333 Seventh Avenue, 18th Floor, New York, NY 10001, USA DOI https://doi.org/ 10.1055/s-0041-1728718. ISSN 1050-0545. mVEMP was originally studied by Deriu and colleagues<sup>5,7–9</sup> and it consists of two components.<sup>5</sup> They are: (1) vestibular origin—short-latency, higher threshold (90–100 dBnHL) p11-n15 wave and, (2) auditory origin—longer latency, low threshold (<80/90 dBnHL) p16-n21 wave. In healthy humans, n15 response is reported to appear as a small deflection in the biphasic response and is often undetectable. Though the vestibular end organ for the generation of mVEMP is possibly saccule as in cVEMP,<sup>5,8</sup> it lacks experimental evidence. mVEMP is reported to be useful in central vestibular disorders, especially multiple sclerosis<sup>10,11</sup> and Parkinson's disease.<sup>6,12</sup>

mVEMP is a relatively new tool and the normative data are available for only click stimuli.<sup>13,14</sup> However, the literature on cVEMP and oVEMP has shown that they are more robust when elicited by 500 Hz tone bursts than the clicks.<sup>15–18</sup> Also study on frequency tuning of cVEMP and oVEMP<sup>19</sup> shows that the lowest VEMP threshold is obtained at 500 Hz. Further, as mVEMP eventually becomes widely recognized test for saccular function, it is likely that it would be used for the assessment of saccular function and the functional integrity of the vestibulotrigeminal neural pathways. However, test–retest reliability is the most important aspect of any test, the data on which is missing from the literature, especially for the 500-Hz tone burst-induced mVEMP. Therefore, the present study aimed to establish the normative values for tone burst mVEMP and determine its test–retest reliability.

# Methods

#### Participants

Forty-four healthy individuals (12 males and 32 females) with a mean age of 31.49 years (range 18–50 years) were included in the study. None of the participants had a history of auditory disorders, vestibular disorders, and systemic diseases. Otoscopic examination showed normal external ear and tympanic membrane. Pure tone audiometry showed hearing threshold within normal limits (pure-tone average  $\leq$  15 dBHL). They all had normal oromandibular structure. Ten participants (three males and seven females) from the abovementioned healthy individuals underwent a second testing session within 1 month of the initial testing. Ethical committee approval was obtained from the ethical committee for biobehavioral research of the institute (DOR.9.1/ph.d/PBJ/1071/2015–16). All the participants gave written informed consent for the mVEMP testing.

#### Recording of mVEMP

mVEMP testing was performed using a commercial dualchannel diagnostic evoked potential instrument (Neurosoft, Russia) in a sound-treated room. The participants were seated in a comfortable chair with an upright posture. mVEMP was elicited by tone bursts of 500 Hz (2–0-2 cycle) delivered at 125 dB peSPL in compliance with the safety recommendations by Singh et al.<sup>20</sup> Stimuli were presented monaurally at the rate of 5.1 Hz into the ear canal through the etymotic ER3A insert earphones. The surface electromyographic (EMG) activity of masseter muscle was picked-up using the belly tendon configuration with an active electrode placed on the lower third of



**Fig. 1** Electrode placement for recording masseter VEMP. The active electrode is positioned on the lower third of the masseter muscle, the reference electrode on the zygomatic arch, and ground on the forehead. VEMP, vestibular evoked myogenic potential.

the masseter muscle, reference electrode over the zygomatic arch (2 cm above the active electrode), and ground over the forehead<sup>5</sup> as seen in  $\succ$  Fig. 1. Absolute and interelectrode impedance was maintained below 5 and 2 k $\Omega$ , respectively. The two-channel recording was used to record ipsilateral and contralateral responses from both masseter muscles and each response was recorded twice to ensure the reproducibility. The in-built visual display of the EMG needle deflection was used to give visual feedback on the computer screen. Maximum voluntary contraction of the masseter muscle was calculated by measuring the maximum EMG needle deflection during the forceful bite of the jaw before initiation of recordings. From the maximum voluntary contraction values, the target level to maintain masseter muscle tension was set between 30 and 50% and the participants were asked to maintain muscle tension within these target levels during recording. The mean and standard deviation values for maximum voluntary contraction were 180.18 and 50.94 µV, respectively. A rest period of approximately 2 minutes was given after each recording to avoid fatigue. The mVEMP responses were band-pass filtered from 0.3 to 2,000 Hz, amplified by a factor of 5,000 and averaged for 300 stimuli. Each response was recorded with a time window of 150 milliseconds (50 ms before and 100 ms after stimulus delivery). After recording, EMG normalization was used to counter the differential effects of muscle tension over the mVEMP amplitude within and across the participants.

#### **Response Analyses**

Each waveform of mVEMP was analyzed by two experienced audiologists independently to identify peaks. Peak latencies of p11 and n21, EMG normalized peak-to-peak amplitude (from p11 to n21), and mean EMG were obtained for each waveform. EMG normalized amplitudes are expressed as the ratio between the absolute peak-to-peak amplitude of the response in the post-stimulus time frame and the mean root mean square of EMG activity in the prestimulus time period.<sup>5</sup> Amplitude asymmetry ratio was obtained using the Jongkee's formula (shown in the equation below) which is also used for calculating the amplitude asymmetry ratio of cVEMP and oVEMP.<sup>21</sup> Amplitude asymmetries were calculated for ipsilateral and contralateral waveforms separately.

Amplitude asymmetry ratio =

Right ear EMG normalized amplitude–Left ear EMG normalized amplitude ×100 Right ear EMG normalized amplitude+Left ear EMG normalized amplitude

## **Statistical Analysis**

Statistical analyses were performed using the statistical package for the social sciences (SPSS) software version 20. The Shapiro-Wilk's test of normality showed that the data followed non-normal distribution (p < 0.05) for all parameters of the tone burst mVEMP. Therefore, nonparametric statistical tests were used throughout. The Wilcoxon signed ranks test was used for between the ear comparisons. The Mann-Whitney *U* test was used for between-groups comparisons for evaluating the sex differences. The test–retest reliability was assessed by the intraclass correlation coefficient (ICC). ICC values were categorized in the way Versino et al<sup>22</sup> categorized them for labeling the test–retest reliability of cVEMP. The ICC values above 0.75 represent excellent reliability, values between 0.4 and 0.75 represent fair-to-good reliability, and values below 0.4 represent poor test–retest reliability.

# Results

#### **Normative Values of Tone Burst mVEMP**

The mean, median values, and standard deviation of p11 latency, n21 latency, EMG normalized peak-to-peak amplitude, and mean rectified EMG of ipsilateral and contralateral tone burst mVEMP responses recorded from right and left ears are shown in - Table 1. All 44 healthy participants had p11 and n21 peaks in both the ears. Both these peaks were consistently present and clear among all individuals. The right and left ear comparison was performed using the Wilcoxon signed-rank test. The Wilcoxson signed-rank test showed no significant difference between the ears on ipsilateral mVEMP parameters including ipsilateral p11 latency (Z = 4.08, p = 0.683), n21 latency (Z = 1.070, p = 0.285), EMG normalized peak-to-peak amplitude (Z = 0.613, p = 0.540), and mean rectified EMG (Z=1.419, p=0.156). The results also showed no significant ear differences in the contralateral mVEMP's p11 latency (Z=0.074, p=0.941), n21 latency (Z=1.068, p=0.285),EMG normalized peak-to-peak amplitude (Z = 0.069, p = 0.945), and mean rectified EMG (Z = 1.794, p = 0.073).

## Effect of Sex on mVEMP Parameters

Mean, median, and standard deviation of p11 latency, n21 latency, EMG normalized peak-to-peak amplitude, mean rectified EMG, and interaural amplitude ratio of ipsilateral and contralateral tone burst mVEMP responses recorded from 12 males and 32 females are shown in **- Table 1**. Latency

Response	Parameter	Males ( $n = 12$ )						Females $(n=3)$	3)				
		Right ear $(n = 1)$	2)	Left ear ( $n = 12$	(	Ears combined	(n = 24)	Right ear ( $n=3$	12)	Left ear ( $n = 32$	()	Ears combined	(n = 64)
		Mean (SD)	Median	Mean (SD)	Median	Mean (SD)	Median	Mean (SD)	Median	Mean (SD)	Median	Mean (SD)	Median
Ipsilateral	p11 latency	12.85 (1.54)	13.3	12.91 (1.45)	12.65	12.88 (1.47)	12.90	13.32 (1.18)	13.05	13.32 (1.13)	13.45	13.32 (1.15)	13.10
	n21 latency	21.25 (1.36)	21.15	21.12 (1.28)	20.90	21.18 (1.30)	20.95	21.32 (1.36)	21.20	21.63 (1.16)	21.80	21.47 (1.26)	21.50
	Peak to peak amplitude	1.11 (0.46)	0.98	1.05 (0.48)	0.97	1.08 (0.46)	96.0	0.76 (0.27)	0.80	0.79 (0.34)	0.72	0.78 (0.31)	0.77
	Average EMG	89.78 (26.86)	88.70	91.35 (31.10)	85.40	90.57 (28.43)	85.85	75.08 (19.46)	76.20	78.04 (20.98)	79.70)	76.56 (20.13)	77.70
	Amplitude asymmetry ratio	NA	NA	NA	NA	12.47 (8.94)	12.10	NA	NA	NA	NA	16.04 (12.17)	13.10
Contralateral	p11 latency	13.38 (1.64)	13.55	13.13 (1.69)	13.15	13.25 (1.63)	13.50	13.54 (1.24)	13.30	13.59 (1.24)	13.45	13.57 (1.23)	13.40
	n21 latency	21.37 (1.25)	21.45	20.95 (1.14)	21.00	21.16 (1.19)	21.10	21.45 (21.81)	21.70	21.58 (1.09)	21.35	21.70 (1.35)	21.60
	Peak to peak amplitude	0.94 (0.48)	0.71	1.03 (0.25)	1.10	0.98 (0.38)	1.00	0.71 (0.79)	0.74	0.75 (0.26)	0.80	0.77 (0.26)	0.75
	Average EMG	87.80 (26.11)	84.40	91.02 (28.32)	89.10	89.41 (26.69)	85.50	75.46 (18.80)	74.00	78.14 (21.45)	78.55	76.80 (20.06)	77.05
	Amplitude asymmetry ratio	NA	NA	NA	NA	15.21 (10.47)	15.20	NA	NA	NA	NA	15.58 (9.75)	13.80

parameters in 44 healthy participants

burst mVEMP

tone

Mean, median, and standard deviation of

Table 1

parameters (mean latencies of p11 and n21) of ipsilateral and ears) in the first contralateral tone burst mVEMP responses were similar in both the sex. Mann-Whitney U test showed no significant difference between males and females in ipsilateral p11 latency (Z = 1.093, p = 0.245), ipsilateral n21 latency (Z=0.839, p=0.401), contralateral p11 latency (Z=0.338, p=0.401)participants (20 p = 0.736), contralateral n21 latency (Z = 1.566, p = 0.117), ipsilateral amplitude asymmetry ratio (Z = 0.485, p = 0.490), and contralateral amplitude asymmetry ratio (Z = 0.947, p = 0.948). However, males had significantly larger ipsilateral EMG normalized peak-to-peak amplitude of (Z=3.015,ן 10 ר p = 0.003), contralateral EMG normalized peak-to-peak amplitude (Z = 2.410, p = 0.016), a fied EMG (Z = 1.977, p = 0.048), a Although the mean rectified EMC

# The Test-Retest Reliability of

# Discussion

## Normative Values of Tone Bur

This study was performed to esta tone burst mVEMP and determine Normative values of unilateral to responses showed a bilateral and click-evoked mVEMP<sup>5</sup> that can be all participants. Comparison of tor between the ears showed that the similar between both the ears wit ence. From the review of literatu knowledge this is the first study on tone burst evoked mVEMP responses. Hence, the comparison was made with click-evoked mVEMP that were extensively studied by Deriu and colleagues.<sup>5,7,8,13,14</sup>

As with click mVEMP, tone burst mVEMP shows robust and clear positive peak (p11) responses followed by later variable negative peak (n21) responses. The tone burst mVEMP responses were prolonged in latency and increased amplitude when compared with click-evoked mVEMP responses.<sup>13</sup> The mean values of ipsilateralp11, n21 latency and contralateral p11, n21 latency of tone burst mVEMP

amplitude ( $Z = 2.410$ , $p = 0.016$ ), and ipsilateral mean recti- fied EMG ( $Z = 1.977$ , $p = 0.048$ ), as can be seen in <b>- Table 1</b> . Although the mean rectified EMGs of contralateral mVEMP	orded from	atistics		Upper bou	C 10 0
responses were higher in males than females, they were not significantly different ( $Z = 1.874$ , $p = 0.061$ ).	leters reco	efficient sta	CI	er bound	
The Test–Retest Reliability of mVEMP	Tam	Ö	95%	NO-	
Ten participants underwent mVEMP testing a second time	ра	atior	•	_	F
within a month of being tested the first time. Mean, standard deviation, median, and ICC of various parameters of mVEMP of	nVEMP	s correla	ICC		
excellent test–retest reliability (ICC $> 0.75$ ) for ipsilateral p11 latency, contralateral p11 latency, ipsilateral EMG normalized	e burst i	Intraclas	α		
peak-to-peak amplitude, and ipsilateral amplitude asymmetry ratio. Fair-to-good test-retest reliability (ICC values between 0.4 and 0.75) was observed for ipsilateral n21 latency, contra-	tics of ton		Median		1 7 7
lateral n21 latency, contralateral EMG normalized peak-to- peak amplitude, and contralateral amplitude asymmetry ratio, as seen in <b>&gt; Table 2. &gt; Fig. 2</b> shows grand averaged waveforms	ent statis	2	SD		000
of ipsilateral and contralateral tone burst mVEMP responses from 10 healthy individuals recorded during the first and second session.	ı coefficie	Session	Mean		
Discussion	correlation		Median		L C
<b>Normative Values of Tone Burst mVEMP</b> This study was performed to establish normative values for	raclass (		SD		L
tone burst mVEMP and determine its test-retest reliability. Normative values of unilateral tone burst evoked mVEMP responses showed a bilateral and symmetrical response like	s, and inti	Session 1	Mean		L 7
click-evoked mVEMP <sup>5</sup> that can be consistently recorded on all participants. Comparison of tone burst mVEMP responses between the ears showed that these VEMP parameters are similar between both the ears without any significant differ- ence. From the review of literature and to the best of our	median value:				

p-Value <0.001 <0.001 <0.001 <0.001 <0.001 average mean rectified electromyography recorded during the pre-stimulus interval of 50ms, AAR, interaural amplitude asymmetry ratio, lpha, Cronbach's alpha; ICC, interclass 0.003 0.005 0.001 0.002 0.27 df2 19 19 19 19 19 19 б б б σ ۱fb 19 19 19 19 19 19 б б б σ 10.735 F-value 32.621 3.849 7.975 4.049 8.237 23.6 3.411 3.945 11.7 0.897 0.966 0.955 0.989 0.884 0.902 0.985 0.937 0.952 0.95 0.455 0.829 0.259 0.376 0.780 0.344 0.683 -0.02 0.784 0.693 0.915 0.958 0.875 0.753 0.830 0.707 0.879 0.941 0.747 0.74 0.915 0.907 0.875 0.707 0.753 0.969 0.747 0.958 0.879 0.74 12.75 16.45 77.50 12.75 21.25 84.35 1.05 20.6 1.08 21 14.34 11.08 14.61 0.90 1.10 1.12 0.34 7.31 0.87 0.4 16.72 21.02 81.34 12.71 21.05 78.17 16.84 12.62 1.11 1.04 79.30 16.85 12.70 16.15 20.95 84.35 21.5 1.05 12.5 1.00 19.70 14.34 1.05 1.00 7.37 1.11 1.32 0.37 9.43 1.07 17.38 12.82 21.34 21.19 78.84 13.30 81.34 1.00 1.12 12.5 amplitude (µV) amplitude (µV) peak p11-n21 peak to peak parameters Average EMG (µV) Average EMG (µV) peak to p p11 latency (ms) n21 latency (ms) p11 latency (ms) n21 latency (ms) Abbreviations: Average EMG, Response p11-n21 p AAR (%) AAR (%) Contralateral Response Ipsilateral

Table 2 Mean, standard deviation

and second session



**Fig. 2** Grand averaged waveforms of ipsilateral and contralateral tone burst mVEMP responses from 10 healthy participants during the first and second session of testing. mVEMP, masseter vestibular evoked myogenic potential.

were prolonged in the present study when compared with corresponding values of the click mVEMP responses reported by De Natale et al.<sup>13</sup> Similarly, the mean EMG normalized peak-to-peak amplitudes of ipsilateral and contralateral tone burst mVEMP responses were higher in tone burst mVEMP responses when compared with click-evoked mVEMP responses as evidenced in **- Table 3**. These EMG normalized peak-to-peak amplitudes of tone burst mVEMP were higher even with the lower intensity level of stimulation (125 peSPL) when compared with click-evoked mVEMP<sup>13</sup> at 138 dB peSPL. The amplitude asymmetry ratio of ipsilateral and contralateral responses was similar to the corrected ampli-

tude asymmetry ratio of click-evoked responses reported by De Natale et al.<sup>13</sup> These observations are similar to the findings in the cervical<sup>15,23–25</sup> and oVEMP<sup>16</sup> that report increased latency and higher amplitude for tone burst stimuli than click stimuli.

# Effect of Sex on mVEMP Parameters

Normative studies on click-evoked mVEMP responses<sup>13,14</sup> have reported significant differences inp11 and n21 latencies between males and females. Females were reported to show shorter latencies of click-evoked mVEMP responses than males. These differences were attributed to the difference

Response	Parameter	Tone burst evoked mVEMP Present study	Click evoked mVEMP De Natale et al <sup>13</sup>
		Total (n = 44)	Total ( <i>n</i> = 62)
		Mean (SD)	Mean (SD)
Ipsilateral	p11 latency	13.20 (1.25)	11.17 (0.98)
	n21 latency	21.40 (1.27)	19.68 (1.81)
	Peak to peak amplitude	0.86 (0.38)	0.72 (0.31)
	Average EMG	80.38 (23.38)	104.31 (41.66)
	Amplitude asymmetry ratio	15.07 (11.40)	14.56 (11.8)
Contralateral	p11 latency	13.48 (1.35)	11.38 (0.9)
	n21 latency	21.55 (1.32)	19.53 (1.9)
	Peak to peak amplitude	0.83 (0.31)	0.74 (0.31)
	Average EMG	80.24 (22.62)	102 (40.96)
	Amplitude asymmetry ratio	15.48 (9.83)	Not measured

**Table 3** Comparison of tone burst mVEMP findings in this study with the click evoked mVEMP findings published earlier

Abbreviations: EMG, electromyography; mVEMP, Masseter vestibular evoked myogenic potentials; SD, standard deviation. Note: The latency values are in ms, amplitude asymmetry ratio in %, and amplitude and EMG in  $\mu$ V.

in the cochlear average length, which is lower in females.<sup>13</sup> Though the sex differences are not observed in the cervical<sup>26</sup> and oVEMP,<sup>27</sup> the sex difference in mVEMP due to cochlear anatomy is questionable.<sup>28</sup> The present study showed no significant difference in p11 and n21 latencies between the sex, instead, we observed significant differences in EMG normalized peak-to-peak amplitude between the males and females. These sex differences in EMG normalized peak-to-peak amplitude were not reported by any other research studies using click-evoked mVEMP.

In this present study, the mean EMG normalized peak to peak amplitudes of ipsilateral (1.08 µV) and contralateral p11n21 (0.98  $\mu$ V) were higher in males than amplitudes of ipsilateral (0.78 µV) and contralateral p11-n21 (0.77 µV) of females. Sex difference in the present study could be due to: (1) higher mean rectified EMG values in males than females observed in this study; (2) masseter muscle is thicker in males than females;<sup>29</sup>(3) volume of the trigeminal nerve is larger in males than females<sup>30</sup> and (4) difference in the number of male (n = 12) and female (n = 32) participants considered in this study. The mean maximum voluntary contraction observed in males (210.75  $\mu$ V) was higher in males than females (168.72  $\mu$ V). Since the EMG target levels for recording mVEMP were set to 30 to 50% of maximum voluntary contraction, it would have led to increased EMG target levels in males than females. Though EMG normalization was used for mVEMP, as used in cVEMPs, in this study to reduce the effects of the increase in amplitude with increased muscle tension levels,<sup>31</sup> we observed a significant difference in amplitude levels between males and females in mVEMP recordings. Hence other factors of the thicker masseter muscle and increased volume of the trigeminal nerve may play a role in increased amplitude of tone burst mVEMP in males. Similar findings of higher oVEMP amplitude in males than females are reported in oVEMP studies.<sup>27,32</sup> These differences were attributed to larger muscle bulk of inferior oblique muscles in males than females.<sup>27</sup>

#### **Test-Retest Reliability of mVEMP**

Tone burst mVEMP in the present study showed excellent testretest reliability, which is an essential indicator for any test to use in clinical practice. Though there are no studies investigating the test-retest reliability of even click-evoked mVEMP this study highlights that tone burst mVEMP has high reliability in healthy individuals. The positive p11 peak of tone burst mVEMP in this study has excellent test-retest reliability which is described as a clear and well-defined response in click-evoked mVEMP responses.<sup>8</sup> But, later negative peak n21 showed fair test-retest reliability which is described as a variable response in clickevoked mVEMP by Deriu et al.<sup>8</sup> Though several parameters showed excellent and fair test-retest reliability, there was individual variation between participants, which could be due to variation in the amount of masseter muscle activation between participants. Also, we observed variation in tone burst mVEMP responses on some participants between first and sessions of recording possible due to variations in electrode placement between the sessions.

mVEMP recording can therefore be a simple, inexpensive, fast, and reliable test that is well tolerated and can be easily

implemented in any laboratory that has cVEMP recording facilities or evoked potentials systems. Because mVEMP is a vestibular evoked potential, sharing pathway that is common with cervical and oVEMP,<sup>9</sup> it would be interesting to check its clinical application in various peripheral and central vestibular disorders. Click evoked mVEMPs have been studied in few clinical populations including conductive hearing loss,<sup>5</sup> profound sensory neural hearing loss, vestibular neuritis, complete removal of the auditory and vestibular nerve (surgical excision of acoustic schwannoma),<sup>8</sup> Parkinson's disease,<sup>6,12</sup> and multiple sclerosis.<sup>10,11</sup> Especially mVEMP abnormalities are reported to be higher than cVEMP (in multiple sclerosis), cVEMP and oVEMP (in Parkinson's disease) to identifying and monitoring brainstem dysfunction.<sup>10–12</sup> Therefore, in addition to cervical and oVEMP, mVEMP can be useful in assessing vestibulomasseteric pathways along the brainstem. Also, tone burst mVEMPs are larger in amplitude when compared with click-evoked mVEMP, hence tone burst stimuli can be of choice in recording mVEMP. Though this potential is robust and reliable it lacks investigation of studies like the origin of this potential in vestibular apparatus, normative in a large population with different age groups, and frequency tuning of mVEMP, for its clinical use. Though we provide normative data for tone burst mVEMP, the number of participants in this study is small and could be a drawback for this study. More research is needed with a larger sample size to be absolutely certain of these normative values.

## Conclusion

The present study was carried to establish normative data for tone burst mVEMP and determine its test-retest reliability. It was observed that tone burst mVEMP responses are robust and consistently observed on all participants with prolonged latencies and higher amplitude over click-evoked mVEMP responses. The latencies of tone burst mVEMP responses were similar across males and females but the amplitudes were higher in males than females. Also, this test showed excellent or fair test-retest reliability on all participants. Therefore, mVEMP can be a useful tool in evaluating vestibular and trigeminal pathway in various peripheral and central vestibular disorders.

Conflict of Interest None declared.

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