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Optimisation of Head Position and Muscle Contraction Techniques for Masseter Vestibular Evoked Myogenic Potential

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Abstract

The objectives of the study were to compare mVEMP response parameters across different head positions (extension, flexion, tilt towards and away from the stimulus ear), to evaluate differences in mVEMP parameters between muscle contraction techniques (clenching vs isometric biting), and to determine the most comfortable head position and contraction method based on participant comfort ratings. Sixty healthy adults aged 20–40 years with normal auditory and vestibular function participated in the study. mVEMPs were recorded under six experimental conditions: neutral head position with clenching, neutral head position with isometric biting, and clenching with the extension, flexion, tilt towards and tilt away from the stimulus ear. Peak-to-peak amplitude, absolute latencies, asymmetry ratios (ARs), and participant comfort were analysed. Changes in head position did not produce statistically significant differences in mVEMP parameters. However, Isometric biting resulted in significantly larger mVEMP amplitude, indicating more stable and effective masseter muscle activation. Comfort ratings were higher during isometric biting and in the neutral head position. Sustained isometric biting enhances mVEMP response, while head position appears to have minimal influence on mVEMP parameters. Incorporating isometric biting in a neutral head position may improve the reliability and clinical utility of mVEMP testing in vestibular assessment.

INTRODUCTION

Vestibular evoked myogenic potentials (VEMPs) are short-latency reflexes that depend on vestibular function, elicited by short sound bursts delivered through headphones, bone vibrators, or galvanic stimulation. These stimuli primarily activate the otolith organs and are a valuable neurophysiological tool for assessing vestibular reflex pathways originating from otolithic organs [1,2]. There are three types of VEMPs: cervical VEMP (cVEMP), ocular VEMP (oVEMP), and masseter VEMP (mVEMP). The cVEMP is recorded from the sternocleidomastoid muscle ipsilateral to the stimulus ear and is used to assess the integrity of the sacullo-collic reflex pathway [3]. The oVEMP is recorded from the contralateral inferior oblique muscle of the eye and is used to assess the utriculo-ocular reflex pathway [4].

The relatively new mVEMP test is used to assess the integrity of the vestibulo-trigeminal pathway [5,6]. The vestibulo-masseteric pathway originates in the saccule and transmits signals via the inferior vestibular nerve to the medial vestibular nucleus and then to the trigeminal motor nuclei, which innervate the lower part of the masseter muscle [7,8]. As the lower masseter receives a lot of innervation, a higher amplitude is recorded when the electrode is positioned on the lower part of the masseter muscle [7,9]. Responses can be measured ipsilaterally, contralaterally, or bilaterally. However, the mVEMP amplitude is greater with bilateral sound stimulation than with unilateral stimulation [10]. The mVEMP test typically displays two prominent peaks labelled P1 and N1, with P1 occurring around 11 ms and N1 around 21 ms. Hence, they are also referred to as P11 and N21. The prominent P11 and N21 peaks reflect an overlap of vestibular (P11/N15) and cochlear (P16/N21) responses [5].

Since all VEMPs are myogenic potentials, variations in muscle activity significantly influence the recorded responses. VEMP response consistency and its parameters are influenced by multiple factors ranging from electrode montage to stimulus duration. Nagarajan and Sinha (2024) recommended a zygomatic electrode montage for higher amplitudes, a 5 Hz repetition rate, 300–500 sweeps, and amplifier gain of 5000 times, although filter settings varied [11]. Peak latency increases with longer tone burst duration, but amplitude and asymmetry remain unaffected. A 500 Hz tone burst (2-2-2 cycle) is considered optimal [6,12].

The degree of muscle activity in the target muscle is another important factor affecting VEMP recordings. Head position and contraction have a significant impact on the masseter muscle used to record mVEMP. Prior research has shown that head tilting and angular dynamics significantly affect the stiffness and activation of the masseter muscles, as measured by electromyography (EMG). Changes in head posture, such as tilting forward, backward, or laterally, alter the jaw-neck complex's alignment and impact the function of the masseter muscles [13–15]. Stable and prolonged muscle contraction is necessary to obtain accurate mVEMP responses that are consistent with cVEMP and oVEMP recordings. However, some conditions can change habitual head posture and muscle activation patterns, such as muscle weakness and specific balance disorders. [13]. Such alterations could affect mVEMP results, making it more difficult for the clinician to determine whether the effects are because of the patient's condition or because of changes in muscle activation brought on by altering head positions.

While extensive research has been conducted on cVEMP and oVEMP, mVEMP has recently garnered increased attention. Identifying and adopting an optimal muscle contraction technique for mVEMP is crucial to obtain accurate and reliable responses while ensuring patient comfort during testing. Likewise, head position plays an important role in influencing masseter muscle activity and, consequently, the recorded mVEMP responses. However, the effects of both head position and contraction technique on mVEMP parameters remain unclear. The aim of the present study was to identify the optimal head position and masseter muscle contraction technique for recording mVEMP. The objectives of the study were to compare mVEMP response parameters across different head positions (extension, flexion, tilt towards and away from the stimulus ear), to evaluate differences in mVEMP parameters between muscle contraction techniques (clenching vs isometric biting), and to determine the most comfortable head position and contraction method based on participant comfort ratings.

METHODOLOGY

The study was conducted as an analytical cross-sectional investigation in the Department of Audiology and Speech-Language Pathology at a tertiary care hospital in South India, after obtaining approval from the institutional ethics committee (IECKMCMLR02/2025/44 dated 19/02/2025). All procedures performed in this study involving human participants were conducted in accordance with the ethical standards of the institutional etgucs committee and with the 1964 Declaration of Helsinki. Each participant was given a comprehensive information sheet prior to enrolment, and written informed consent was acquired.

Participants

Convenience sampling was used to select 60 healthy young adults aged 20 to 40 based on the results of these evaluations. Inclusion criteria included normal otoscopic findings, normal middle ear status, and normal hearing sensitivity. Individuals with a history of vestibular disorders, such as vestibular neuritis, vestibular migraine, benign paroxysmal positional vertigo (BPPV), or similar conditions, were excluded. Neuromuscular disorders, conditions affecting the neck, jaw, or dentition (such as temporomandibular joint disorders, osteoarthritis, muscle strain, or pain), and the use of any dental prosthesis were additional exclusion criteria.

Each potential participant underwent a thorough screening procedure first. A comprehensive audiological and vestibular case history was obtained from each participant. Following this, otoscopic examination, immittance testing, and pure-tone audiometry were also conducted to confirm normal external and middle ear status and hearing sensitivity. Hearing thresholds ≤ 25 dB HL at frequencies between 250 Hz and 8 kHz, a Type "A" tympanogram with the presence of both ipsilateral and contralateral acoustic reflexes, were considered indicative of normal hearing and middle ear status. To establish normal vestibular function, subjective vestibular screening tests were employed, including the tandem gait test, the sharpened Romberg test, and the Fukuda stepping test. Participants further underwent objective vestibular assessments, including the video head impulse test (vHIT) and videonystagmography (VNG).

Recording of mVEMP

An IHS Smart EP version 3.92 (Intelligent Hearing Systems, Florida, USA) evoked potential system was used for the acquisition and analysis of mVEMP amplitude and latency. The stimulus was delivered via an ER-3C insert earphone.

The participants were required to sit comfortably in a soundproof, quiet room in a reclining chair. The recording of mVEMP was performed using a zygomatic electrode montage: the non-inverting electrode was placed on the lower third of the masseter muscle, the inverting electrode at the medial point of the zygomatic arch, and the ground electrode on the lower forehead [11]. Before placing the electrodes, the skin was prepared using NuPrep cleaning gel to achieve an impedance of less than 5KΩ. Gold-plated cup electrodes with ten-20 conduction paste were used to increase conductivity, and adhesive tape was used to place the electrodes securely. The recording parameters included an analysis time of 70 milliseconds, a filter setting of 0.1 Hz to 3000 Hz, amplification of 5000, and a stimulus comprising a 500 Hz tone burst of 4 milliseconds duration, presented at a rate of 5.1 per second in rarefaction polarity at 125 dB pSPL. A total of 300 sweeps were recorded, with a contraction range of 50–150 µV [11,12].

To find the optimal head position, mVEMP is recorded in five positions: neutral (looking straight), 30° in extension, and 30° in flexion, with the head tilted 30° toward and 30° away from the stimulus ear. In all these head positions, the participants are asked to keep their posterior teeth clenched. Additionally, two

muscle contraction techniques were compared in the neutral head position. First, is the clenching, i.e. firmly pressing the upper and lower posterior teeth together at a comfortable, self-maintained force to activate the masseter muscle. Second is isometric biting, where masseter muscle contraction is maintained by biting a disposable tongue depressor.

The outcome measures included mVEMP response rate, P1 and N1 latencies, peak-to-peak amplitude and Asymmetry ratio (AR). The AR is calculated by using Formula 1 [16]

$$\mathrm{AR} = \frac{(larger\ VEMP\ amplitude - smaller\ VEMP\ amplitude)}{(larger\ VEMP\ amplitude + smaller\ VEMP\ amplitude)} \times 100$$

1

mVEMP peak identification was carried out independently by three experienced audiologists to reduce observer-related bias. Each audiologist had prior clinical and research experience in VEMP interpretation and was familiar with standard mVEMP waveform morphology. The audiologists were blinded to the test conditions, including head position and muscle contraction technique, to prevent expectation bias during peak marking

Participant-reported comfort level

A five-point Likert scale, developed by Hwang (2018), was used to assess participants' comfort during each head position and muscle contraction methods [17] .The scale ranged from "Very uncomfortable" (1) to "Uncomfortable" (2), "Neutral" (3), "Comfortable" (4), and "Very comfortable" (5). Participants were asked to rate their perceived comfort level for each specific condition immediately after completion of the recording. This immediate post-recording assessment was employed to minimize recall bias.

DATA ANALYSIS

The Shapiro-Wilk test and the test of normality were used to determine whether the data were normally distributed. Due to the non-normal distribution of the data, non-parametric tests were employed. The mVEMP response rates across different test conditions were evaluated, and Cochran's Q test was applied for different head positions and the McNemar test for the muscle contraction technique. The Friedman test was used to compare the mVEMP parameters (peak-to-peak amplitude, latency, AR, comfort rating) across head positions in the clenching condition, and the Wilcoxon signed-rank test was used to compare the clenching and isometric biting conditions.

RESULTS

Of the 60 participants recruited for the study, 8 were male, and 52 were female, with a mean age of 22.4 ± 1.66 years. Cochran's Q test performed to determine if the mVEMP response rate differed significantly across five head positions: neutral, extension, flexion, tilt away from the stimulus ear, and tilt towards the

stimulus ear indicated no statistically significant difference in response rates across these conditions ($\chi^2(4) = 3.71$, $p = .446$). Additionally, the McNemar test was used to compare the mVEMP response rate across the muscle contraction technique. The analysis revealed no significant difference in response rates between the two techniques ($p = 1.00$).

The descriptive data for latency, peak-to-peak amplitude, and asymmetry ratio, obtained from different head positions and muscle contraction techniques, are provided in Table 1.

Table 1
Median (IQR) of different head positions and muscle contraction techniques

Conditions	Amplitude	P1 latency	N1 latency	AR	Comfort rating
Neutral + Clenching	40.2 (20.0)	13.9 (1.45)	20.8 (2.90)	8.93 (12.6)	3.43 (1.00)
Neutral + Isometric biting	52.3 (19.4)	14.0 (1.55)	20.8 (1.45)	5.52 (11.3)	4.18 (1.00)
Extension + Clenching	38.0 (19.1)	14.0 (1.80)	20.2 (3.00)	14.1 (12.1)	2.80 (1.00)
Flexion + Clenching	40.3 (22.4)	13.8 (1.85)	20.8 (3.43)	14.6 (11.7)	3.08 (1.00)
Tilt away from the stimulus ear + Clenching	42.7 (14.8)	14.0 (1.80)	20.6 (3.20)	5.68 (11.9)	3.32 (1.00)
Tilt towards the stimulus ear + Clenching	42.7 (24.9)	14.0 (1.40)	21.0 93.20)	10.6 (12.5)	3.28 (1.00)

Regarding the influence of head position, the Friedman test demonstrated no statistically significant effect of head tilt, flexion, or extension on mVEMP amplitude values (χ^2 (4) = 7.17, $p = .127$), P1 latency (χ^2 (4) = 3.72, $p = .445$) or N1 latency (χ^2 (4) = 6.65, $p = .155$). However, the asymmetry ratio showed a statistically significant difference across head positions (χ^2 (4) = 10.3, $p = .036$). Post-hoc pairwise comparisons were performed using Wilcoxon signed-rank tests with Bonferroni correction for multiple comparisons (adjusted $\alpha = 0.005$) which showed no statistically significant differences between any of the condition pairs.

In contrast, the type of muscle contraction showed a marked effect on amplitude outcomes. A statistically significant increase in amplitude was observed during isometric biting compared to clenching, as confirmed by the Wilcoxon test ($p < .001$). Additionally stronger effect size was seen in terms of rank biserial correlation (r_{rb} = -0.808). There was a statistically significant difference in N1 latency ($p= .009$) (longer latency noted for isometric biting), however the effect size was small (r_{rb} = -0.326). The muscle contraction technique type did not significantly influence P1 latency ($p = .236$) or the Asymmetry ratio ($p= .140$). For graphical illustration, waveforms from 10 randomly selected participants

were averaged to generate a representative group waveform for clenching and isometric biting, highlighting the amplitude difference shown in Fig. 1.

Comfort ratings across different head positions were analysed using the Friedman test. The analysis revealed a statistically significant difference in comfort ratings across head positions ($\chi^2(4) = 25.3$, $p < .001$). Consequently, post hoc pairwise comparisons using the Wilcoxon signed-rank test confirmed that the neutral head position had significantly higher comfort ratings than extension ($p < .001$) and flexion ($p < .001$). In contrast, comparison of muscle contraction techniques using the Wilcoxon signed-rank test showed a statistically significant difference, with isometric biting receiving higher comfort ratings than clenching ($p < .001$) with a stronger effect size ($r_{rb} = -0.958$).

DISCUSSION

The rationale for this investigation is based on several studies demonstrating that the strength and consistency of muscle contraction (tonic EMG levels) significantly influence the amplitude of VEMP responses [18]. In addition, some debate still lingers in research about the importance of head position affecting VEMP results, particularly in recordings of both cervical and masseter muscles [7,14,19].

The masseter muscle, selected for mVEMP recording, receives vestibular inputs during abrupt head movements and contributes to the stabilization of head orientation and coordination of jaw position. The vestibular system also plays an important role in regulating the opening and closing phases of mastication, reflecting a close functional coupling between vestibular and masticatory systems. Consequently, alterations in head posture have the potential to influence masseter muscle activity. Previous electromyographic studies have demonstrated that angular head movements and tilting can modify masseter activity and stiffness by altering baseline muscle activation and inducing side-to-side asymmetry [13,14,20]. Furthermore, tonic EMG activity of the target muscle has been shown to exhibit a linear relationship with the amplitude of vestibular-evoked responses, while latency measures remain largely unaffected, underscoring the importance of maintaining a constant level of contraction for reliable recordings [18,21]. Supporting this vestibulo-trigeminal interaction, Deriu et al. (2000) demonstrated that static body tilts modulate trigeminal motor excitability, producing asymmetric masseter activation during ipsilateral and contralateral tilts [22]. Similarly, using cathodal vestibular stimulation, Deriu et al. (2003) reported that tilting the body toward the side of stimulation resulted in a marked increase in P1–N1 amplitude (up to 143% relative to the upright position), whereas tilting away from the stimulation side led to a reduction in response amplitude, highlighting the sensitivity of masseter responses to vestibular inputs and postural orientation [7].

The findings of the present study indicate that mVEMP response rates and response parameters remain unaffected by the different head positions evaluated. However, significant differences in participant comfort ratings were observed across head positions. The neutral head position was consistently rated as the most comfortable, suggesting that while head orientation may not compromise response integrity, it can influence test tolerability. From a clinical view, adopting a neutral head position may

therefore enhance patient compliance and reduce fatigue without adversely affecting mVEMP outcomes.

In contrast to head position, the muscle contraction technique showed a significant influence on mVEMP amplitude. The present findings demonstrate that isometric biting produced higher and more consistent mVEMP amplitudes than clenching. These results are consistent with previous VEMP studies emphasizing the strong positive relationship between tonic EMG levels and VEMP amplitude, with little to no effect on.

The enhanced responses observed with isometric biting are likely attributable to sustained and stable motor unit recruitment within the masseter muscle, providing a more reliable baseline for the recording of vestibular-evoked responses. In contrast, clenching may be associated with brief or inconsistent variations in muscle tension, resulting in less consistent EMG activation and reduced response amplitudes. Participant comfort ratings also favoured isometric biting, which was perceived as easier to maintain and less fatiguing during prolonged recordings. This finding is clinically relevant, as excessive effort during clenching may introduce variability in EMG levels and compromise recording consistency. Taken together, these results indicate that isometric biting represents a superior contraction method for mVEMP acquisition, yielding robust and symmetrical responses while simultaneously improving participant comfort.

CONCLUSION

This study demonstrates that mVEMP responses are not significantly affected by head position, however, the neutral position is preferred due to greater participant comfort. Isometric biting produced more consistent masseter activation, resulting in larger mVEMP amplitudes without affecting latency. Therefore, a neutral head position combined with isometric biting is optimal and comfortable method for obtaining reliable mVEMP recordings.

Declarations

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Nil

AUTHOR CONTRIBUTIONS

Sinchana Hegde (SH), Ramiz Malik M (RMM), Mayur Bhat (MB), Mohan Kumar Kalaiah (MKK), and Kaushlendra Kumar (KK) conceptualised the study. SH performed formal analysis, investigation, methodology, validation, visualisation, and writing–original draft. RMM contributed to conceptualisation, methodology, supervision, validation, writing–original draft, and investigation. MB contributed to conceptualisation, supervision, methodology, formal analysis, validation, and writing–review and editing. MKK contributed to methodology, resources, supervision, validation, and writing–review and editing. KK

contributed to conceptualisation, methodology, resources, supervision, writing–review and editing, data curation, and validation. All authors reviewed and approved the final manuscript.

DECLARATION OF CONFLICTING INTEREST

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article

DATA AVAILABILITY

The data that support the findings of this study are not publicly available due to their containing information that could compromise the privacy of research participants, but are available from the corresponding author upon reasonable request

ETHICAL CONSIDERATIONS

Ethical approval was taken from the Institutional Ethics Committee (IECKMCMLR02/2025/44)

CONSENT TO PARTICIPATE

Each person was given a comprehensive information sheet prior to enrolment, and written informed consent was acquired.

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Figures

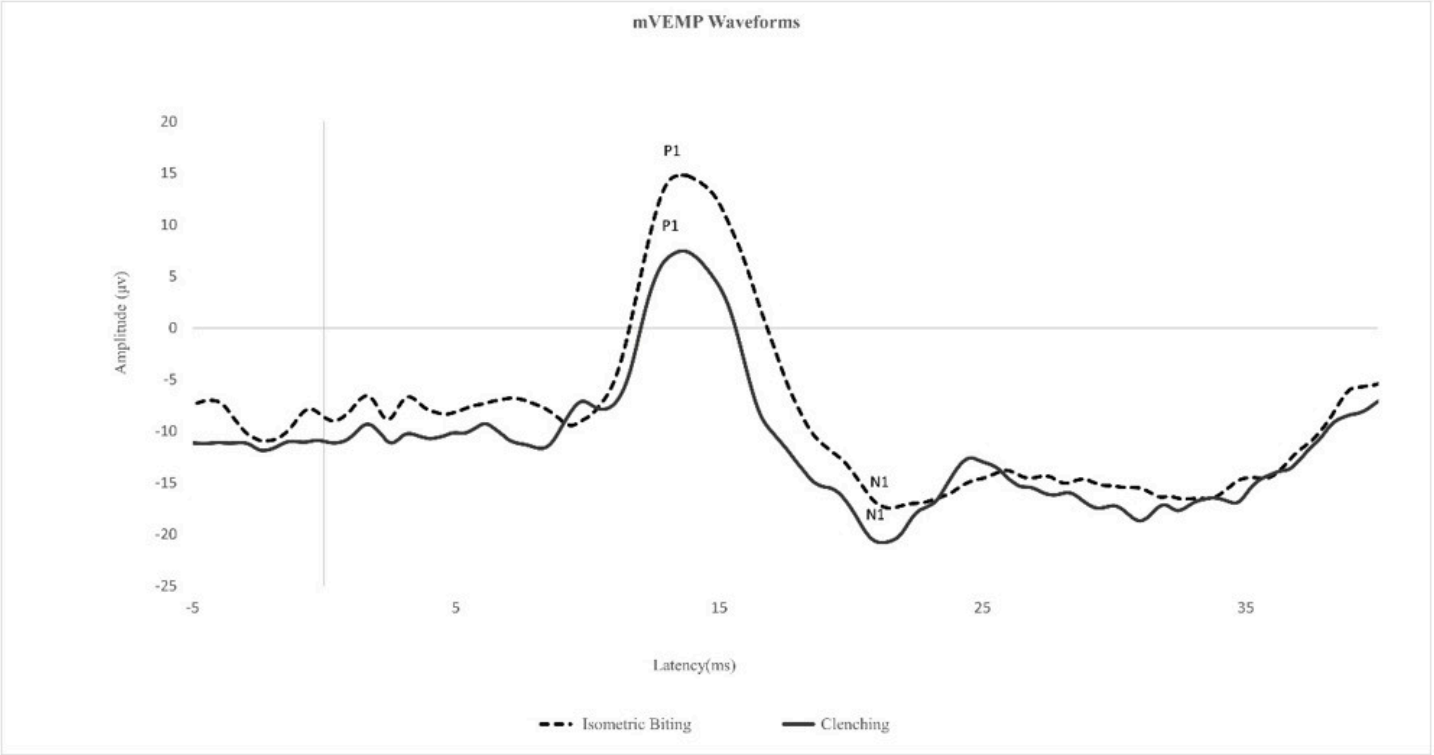


Figure 1

Representative mVEMP waveform of clenching vs isometric biting