**Research Article**

# Evaluation of Band-Pass Filter Settings in Recording 500 Hz Tone Burst–Evoked Masseter Vestibular Evoked Myogenic Potentials

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**Short running title:** Evaluation of Band-Pass Filter Settings in…

**Highlights:**

- Band-pass filtering significantly influenced mVEMP latency and amplitude measures
- Latency and amplitude showed non-monotonic changes across filter settings
- The 3.3–1500 Hz filter produced the largest amplitude with clear waveform

## ABSTRACT

**Background and Aim:** The masseter Vestibular Evoked Myogenic Potentials (mVEMPs) have gained increasing attention as a potential clinical tool for evaluating the vestibulo-trigeminal reflex pathway. However, considerable variability remains in the filter settings used for mVEMP acquisition, which can affect waveform characteristics and clinical interpretation. This study investigated the influence of varying band-pass filter settings on 500 Hz tone burst-induced mVEMP responses in healthy adults.

**Methods:** Thirty-three normal-hearing adults were included in the study. mVEMP recordings were obtained using 500 Hz tone burst stimulation under five band-pass filter configurations: 0.5–1500 Hz, 1–1500 Hz, 3.3–1500 Hz, 10–1500 Hz, and 33–1500 Hz. P11 latency, N21 latency, peak-to-peak amplitude, and Interaural Amplitude Asymmetry Ratio (IAAR) were compared across the different filter conditions.

**Results:** Clear and reproducible biphasic P11–N21 waveforms were obtained across all filter settings. P11 latency, N21 latency, and peak-to-peak amplitude differed significantly across filter settings and demonstrated non-monotonic patterns. The shortest P11 and N21 latencies and the smallest amplitude were observed at 33–1500 Hz, whereas the largest amplitude was observed at 3.3–1500 Hz. IAAR values remained stable across filter conditions.

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**Conclusion:** The findings suggest that high-pass filter settings substantially influence mVEMP response characteristics. Among the evaluated configurations, the 3.3–1500 Hz setting produced the largest peak-to-peak amplitude while maintaining clearly identifiable waveform morphology.
**Keywords:** Evoked potentials; vestibular function tests; electrophysiology; masseter muscle; acoustic stimulation

## Introduction

Vestibular Evoked Myogenic Potentials (VEMPs) are brief-latency electrophysiological responses used for evaluating the functional status of vestibular pathways and otolithic organs. Among the commonly utilized VEMP techniques, cervical VEMP (cVEMP) and ocular VEMP (oVEMP) are employed to assess vestibulo-collic and vestibulo-ocular reflex function, respectively [1]. In addition to these conventional recordings, vestibular mediated responses have also been identified from other skeletal muscles, including the masseter muscle [2]. Masseter vestibular evoked myogenic potentials (mVEMPs) are acoustically evoked electromyographic responses recorded from a tonically contracted masseter muscle and are considered to reflect the functional integrity of the vestibulo-trigeminal reflex pathway, particularly saccular function [3, 4]. The response typically appears as a biphasic P11–N21 waveform that can be recorded bilaterally in healthy individuals [2].

With growing research interest, mVEMP has gained increasing attention because of its potential clinical utility in the assessment of both peripheral and central vestibular disorders. Abnormal mVEMP findings have been reported in conditions including vestibular migraine [5, 6], Vestibular neuritis [7], Ménière's disease [8], Parkinson's disease [9], Wallenberg Syndrome [10] and multiple sclerosis [11]. Several acquisition parameters are known to influence the mVEMP recordings such as stimulus characteristics, repetition rate, level of muscle contraction, electrode placement, and filter settings [4, 12, 13].

Although the literature on mVEMP has expanded in recent years, considerable methodological variability remains across studies, particularly with respect to band-pass filter settings. Previous mVEMP studies have used widely varying band-pass filter configurations, including 0.3–2000 Hz in early vestibulo-masseteric reflex studies [2, 14], 5–5000 Hz in subsequent investigations [15, 16], 10–1000 Hz [17], and 0.3–1500 Hz in more recent stimulus-comparison studies [18]. This methodological variability demonstrates the absence of a consistently adopted filter configuration for mVEMP recording and may limit direct comparison of response parameters and normative values across studies. Standardization of filter settings is particularly important as mVEMP is increasingly being investigated for identifying abnormalities involving peripheral vestibular and central vestibulo-trigeminal pathways. Clinical interpretation commonly relies on response characteristics such as peak latency, amplitude, waveform morphology, and interaural asymmetry. Because filter settings themselves can alter these parameters, methodological variability may complicate the distinction between recording-related changes and genuine physiological abnormalities, particularly when subtle alterations in brainstem function are being evaluated. Establishing appropriate recording parameters is therefore important for improving the reliability and comparability of mVEMP findings across clinical and research settings.

Variations in filter configuration may influence waveform morphology, latency, amplitude, and overall response interpretation. High-pass filters primarily attenuate slow-wave activity and low-frequency components, while low-pass filters reduce unwanted high-frequency noise. Consequently, variability in filter settings may affect electrophysiological recordings and reduce comparability across studies. Studies evaluating optimal filter settings have been reported for other VEMP modalities. Wang et al. [19] suggested that a 1–1000 Hz band-pass filter was suitable for ocular VEMP recordings, whereas Singh et al. [20] observed larger amplitudes and improved response detection with lower high-pass cut-off settings. In contrast, systematic evaluation of filter settings in mVEMP recordings remains limited. Most available mVEMP studies have selected filter parameters empirically without clear justification for the selected configuration. As a result, there is currently no standardized recommendation regarding the most appropriate filter setting for recording tone burst evoked mVEMPs.

The current investigation evaluated the influence of varying high-pass filter settings on mVEMP responses elicited by 500 Hz tone burst stimulation in healthy adults. Parameters including P11 latency, N21 latency, peak-to-peak amplitude, waveform morphology, and interaural amplitude asymmetry ratio were assessed across different filter conditions to determine configurations that yield reliable and clinically meaningful mVEMP recordings.

## Methods

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Across-sectional study design was applied in the current study, and the data were collected using purposive sampling.

**Participants**

Thirty-three adults (66 ears) aged between 18 and 35 years were enrolled in the study. The sample size was estimated using a mean ± standard deviation of 10.08±7.34, with a precision of ±2.5, a 95% confidence interval ($\alpha$=0.05), and a statistical power of 80% (1−$\beta$). The calculated sample size was 33 participants. All participants exhibited normal hearing sensitivity, with air-conduction thresholds of ≤15 dB HL at octave frequencies ranging from 500 Hz to 4 kHz. Type A tympanograms along with the presence of acoustic reflexes were confirmed bilaterally. Vestibular screening procedures included the Romberg, Fukuda stepping, and past-pointing tests, and only participants demonstrating normal findings were considered for inclusion. Individuals with a history of otological, neurological, vestibular, or oro-mandibular conditions were excluded.

**Instrumentation**

Hearing assessment was carried out using a calibrated diagnostic audiometer (Piano Inventis) equipped with Telephonics TDH-39 headphones and a Radioear B-71 bone vibrator. Immittance measurements were obtained using the Interacoustics AT-235 immittance system. mVEMP acquisition was performed using the Interacoustics Eclipse EP25 platform (Version 4.4). All assessments were conducted in well-lit rooms maintained at optimal temperature and within permissible background noise levels, in compliance with ANSI S3.1 (1999) standards.

**Procedure**

Prior to mVEMP acquisition, all participants underwent otoscopic inspection, pure-tone audiometry, and immittance assessment. During testing, participants remained seated in an upright posture and were instructed to maintain masseter muscle contraction by clenching their teeth. Ongoing Electromyography (EMG) activity was monitored using the built-in VEMP EMG monitor, with an acceptable contraction range of approximately 50–150 µV RMS. Stimulus presentation and response acquisition were controlled according to this predefined EMG range. In addition, EMG scaling was enabled, whereby the recorded responses were scaled based on the pre-stimulus EMG activity to compensate for variations in muscle contraction across recordings. Abrasive gel was used for skin preparation to maintain electrode impedance below 5 kΩ and inter-electrode impedance below 2 kΩ. A zygomatic electrode configuration was adopted for mVEMP recording. The active (non-inverting) electrode was positioned on the lower border of mandible, while the reference (inverting) electrode was placed at the lower third of masseter muscle, on the midpoint of the zygomatic arch. The ground electrode was positioned at the lower forehead (Fpz). The zygomatic montage was selected over the mandibular montage based on previous comparative evidence demonstrating favorable response characteristics for 500-Hz tone burst–evoked mVEMPs with this electrode configuration [21]. The use of this montage also facilitates methodological comparability with previous mVEMP investigations employing a similar electrode configuration [16, 18]. Further, the mVEMP recordings were obtained ipsilaterally using ER-3C insert earphones. The order of presentation of the five filter conditions was randomized across participants to minimize potential order effects.

**Recording parameters**

mVEMP responses were elicited using 500 Hz air-conducted tone-burst stimuli with a 2–2–2 cycle rise–plateau–fall envelope (4 ms rise, 4 ms plateau, and 4 ms fall; total duration: 12 ms). A 500 Hz tone burst was selected because it consistently elicits robust and reproducible mVEMP responses with well-defined P11–N21 waveforms, larger amplitudes, and good test–retest reliability, making it the most widely recommended stimulus for clinical and research applications [12,18, 22]. The stimulus was presented monaurally at 95 dB nHL with rarefaction polarity. A repetition rate of 5.1/s and 200 stimulus sweeps were used. Responses were acquired within a 60 ms analysis window, and the artifact rejection level was set at ±800 µV. Recordings were obtained under five different band-pass filter conditions: 0.5–1500 Hz, 1–1500 Hz, 3.3–1500 Hz, 10–1500 Hz, and 33–1500 Hz. For each filter condition, two separate recording runs were obtained to confirm waveform reproducibility. The replicated traces were compared for the presence of identifiable P11 and N21 peaks at comparable latencies and with consistent waveform morphology. Peak identification was based on latency correspondence between the two runs together with the clarity and morphology of the respective peaks. Analysis of the recorded mVEMP responses included P11 latency, N21 latency, peak-to-peak amplitude, and Interaural Amplitude Asymmetry Ratio (IAAR). The IAAR values were calculated using the Jongkees formula i.e. IAAR (%)=[(Right-ear P11–N21 amplitude − Left-ear P11–N21 amplitude) / (Right-ear P11–N21 amplitude + Left-ear P11–N21 amplitude)]×100.

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### Statistical analysis

All statistical procedures were carried out using International Business Machines SPSS Version 27. Since the Shapiro–Wilk test indicated a non-normal distribution of the data, non-parametric methods were adopted for further analysis. Comparisons between ears were performed using the Wilcoxon signed-rank test, whereas gender-related differences were assessed with the Mann–Whitney U test. Variations across the different filter conditions were analyzed using the Friedman test, followed by post hoc Wilcoxon signed-rank comparisons where required. Statistical significance was established at $p<0.05$.

## Results

A total of 33 adults (66 ears) participated in the study. Clear and reproducible biphasic P11–N21 waveforms were obtained from all participants under each filter condition, resulting in a 100% response rate. Representative mVEMP waveforms recorded across the five band-pass filter settings are shown in Figure 1.

Although overall waveform morphology remained largely preserved across recording conditions, noticeable changes in latency and peak-to-peak amplitude were observed with increasing high-pass filter cut-off values. Descriptive statistics for P11 latency, N21 latency, and peak-to-peak amplitude are presented in Table 1.

### Ear-wise comparisons

The effect of ear on recorded mVEMP parameters was analyzed across the evaluated filter settings in both male and female participants. No statistically significant differences were observed between the right and left ears for P11 latency, N21 latency, peak-to-peak amplitude, or interaural amplitude asymmetry ratio ($p>0.05$) as shown in Table 2. Therefore, responses from both ears were pooled for subsequent analyses.

### Gender-wise comparisons

The effect of gender on P11 latency, N21 latency, peak-to-peak amplitude, and interaural amplitude asymmetry ratio was analyzed across the evaluated filter settings. No statistically significant differences were observed between male and female participants for any of the recorded mVEMP parameters ($p>0.05$) as shown in Table 3. These findings indicate that gender did not significantly influence the recorded mVEMP responses in the study population.

### Effect of filter settings on P11 latency

The effect of different high-pass filter settings on P11 latency was analysed using the Friedman test. A statistically significant difference in P11 latency was observed across the five filter settings, $\chi^2$ (4)=18.46, p=0.001, Kendall's W=0.14. P11 latency differed significantly across filter settings, demonstrating a non-monotonic pattern. The longest P11 latency was observed at 3.3–1500 Hz (12.84 ms), whereas the shortest latency was observed at 33–1500 Hz. Post-hoc pairwise comparisons using the Wilcoxon signed-rank test with Bonferroni correction revealed significant differences between 0.5–1500 and 33–1500 Hz (p=0.002) and between 1–1500 and 33–1500 Hz (p=0.004). No other pairwise comparisons were statistically significant. The distribution of P11 latency across the different filter settings is illustrated in Figure 2.

### Effect of filter settings on N21 latency

The effect of different high-pass filter settings on N21 latency was analysed using the Friedman test. A statistically significant difference in N21 latency was observed across the five filter settings, $\chi^2$ (4)=30.40, $p<0.001$, Kendall's W=0.23. N21 latency differed significantly across filter settings, demonstrating a non-monotonic pattern. The longest N21 latency was observed at 10–1500 Hz (21.84 ms), whereas the shortest latency was observed at 33–1500 Hz. Post-hoc pairwise comparisons revealed that the 33–1500 Hz condition differed significantly from all other filter conditions (all $p<0.001$), whereas no significant differences were observed among the remaining filter settings. The distribution of N21 latency across the different filter settings is illustrated in Figure 3.

### Effect of filter settings on peak-to-peak amplitude

The effect of different high-pass filter settings on peak-to-peak amplitude was analyzed using the Friedman test. A statistically significant difference in peak-to-peak amplitude was observed across the five filter settings, $\chi^2$ (4)=14.84, p=0.01, Kendall's W=0.11. Peak-to-peak amplitude differed significantly across filter settings and demonstrated a non-monotonic pattern. The largest amplitude was observed at 3.3–1500 Hz (0.80 µV), whereas

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the smallest amplitude was observed at 33–1500 Hz. Post-hoc pairwise comparisons revealed a significant difference only between the 3.3–1500 and 33–1500 Hz conditions (p=0.01), while all other pairwise comparisons were non-significant. These findings suggest that a moderate high-pass filter cut-off may optimize response amplitude compared with both lower and higher cut-off settings. The distribution of peak-to-peak amplitude across the evaluated filter settings is illustrated in Figure 4.

#### Effect of filter settings on interaural amplitude asymmetry ratio

The effect of different high-pass filter settings on interaural amplitude asymmetry ratio was analyzed using the Friedman test. No statistically significant differences in IAAR values were observed across the five filter settings, $\chi^2(4)=1.48$, p=0.83, Kendall's W=0.01. These findings indicate stable interaural symmetry despite variations in filter configuration.

## Discussion

The present study evaluated the effect of different high-pass filter settings on 500 Hz tone burst evoked masseter vestibular evoked myogenic potentials in healthy young adults. Well-defined biphasic P11–N21 responses were consistently recorded under all filter conditions, with responses obtained from every participant. P11 and N21 latencies and peak-to-peak amplitudes varied significantly across filter settings, although these changes did not follow a strictly progressive pattern. The shortest P11 and N21 latencies and the smallest peak-to-peak amplitude were observed at 33–1500 Hz. In contrast, waveform morphology and interaural amplitude asymmetry ratio remained largely preserved across the tested filter settings. No significant ear-wise or gender-related differences were identified for any of the analysed mVEMP parameters.

Well-defined biphasic waveforms were obtained in all participants across each filter condition, indicating that 500 Hz tone burst stimulation reliably elicited mVEMP responses. Previous studies have similarly shown that 500 Hz tone bursts generate larger amplitudes and clearer waveforms than click or chirp stimuli, possibly due to more effective activation of vestibular afferents and otolithic organs [12, 13]. Although the filter settings varied, the characteristic P11–N21 morphology remained identifiable throughout, suggesting that the vestibulo-trigeminal reflex pathway can be recorded reliably under varying acquisition conditions.

P11 and N21 latencies differed significantly across the evaluated filter settings, although the changes were non-monotonic. P11 latency was longest at 3.3–1500 Hz and shortest at 33–1500 Hz, whereas N21 latency was longest at 10–1500 Hz and shortest at 33–1500 Hz. This pattern may be attributed to attenuation of slow waveform components and low-frequency baseline activity at higher cut-off settings. By reducing slow fluctuations within the recording, higher high-pass filters may sharpen waveform onset characteristics and facilitate earlier identification of response peaks during waveform analysis. Similar effects of filter manipulation on latency measures have previously been reported for cVEMP and oVEMP recordings [19, 23]. Physiologically, suppression of low-frequency activity may enhance the transient components of the vestibular response, thereby improving waveform definition.

Peak-to-peak amplitude differed significantly across filter settings and demonstrated a non-monotonic pattern. The largest amplitude was observed at 3.3–1500 Hz, whereas the smallest amplitude was observed at 33–1500 Hz. This reduction may reflect the substantial contribution of low-frequency components to the overall energy of vestibular evoked potentials. As the high-pass cut-off increases, portions of the physiological response may be attenuated along with unwanted low-frequency noise. Similar observations have been reported in previous VEMP optimization studies, where broader filter ranges were associated with larger amplitudes and improved response detectability [19, 20]. Although higher cut-off settings may enhance waveform sharpness and shorten latency measures, excessive filtering may compromise response amplitude, particularly in individuals with weaker vestibular responses. The present findings are broadly consistent with previous oVEMP filter optimization studies demonstrating that filter selection influences VEMP response characteristics. Wang et al. [21] identified a 1–1000 Hz band-pass filter as suitable for recording acoustically evoked oVEMPs. Singh et al. [20] further reported that a 0.1–1000 Hz filter produced larger amplitudes, comparable signal-to-noise ratios, and higher response detection than a 1–1000 Hz filter. Similarly, the present study demonstrated significant differences in mVEMP latency and peak-to-peak amplitude across filter settings. However, the changes observed in the present study were non-monotonic, with the largest amplitude occurring at 3.3–1500 Hz and the shortest P11 and N21 latencies occurring at 33–1500 Hz. These findings suggest that although both oVEMP and mVEMP responses are influenced by filter

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selection, the optimal filter configuration identified for oVEMP may not be directly applicable to mVEMP recordings, supporting the need for response-specific optimization of recording parameters.

Among the evaluated filter configurations, the 3.3–1500 Hz setting produced the largest peak-to-peak amplitude while maintaining clearly identifiable P11–N21 waveform morphology. Although this setting also produced the longest P11 latency, the latency remained within the expected range for an identifiable mVEMP response. In contrast, the 33–1500 Hz setting produced the smallest amplitude and significantly shorter latency values, indicating a greater influence of high-pass filtering on the recorded response characteristics. Therefore, the 3.3–1500 Hz setting appears advantageous primarily for preserving response amplitude and clear waveform morphology rather than representing a uniform balance across all response parameters. However, as the present study included only healthy young adults, the suitability of this filter setting for clinical populations requires further investigation.

Although latency and amplitude measures varied across filter settings, IAAR values remained consistent throughout the recordings. This indicates that alterations in filter configuration affect bilateral responses in a comparable manner without substantially disturbing interaural symmetry. Clinically, this observation is relevant because IAAR is widely used in the identification of unilateral vestibular involvement. The comparable IAAR values obtained across conditions suggest that interaural comparisons remain reliable despite variations in acquisition filtering. Therefore, while filter settings may influence absolute waveform parameters such as latency and amplitude, their impact on bilateral symmetry appears minimal.

The present findings underscore the importance of standardization in mVEMP recording protocols. Considerable variation still exists across studies with respect to acquisition filter settings, and many investigations use different band-pass configurations without clear justification for the selected configuration. Such methodological differences may contribute to inconsistencies in normative values, latency measures, waveform morphology, and amplitude characteristics reported across laboratories. The present findings demonstrate that even controlled changes in high-pass filter settings can alter key mVEMP parameters. Establishing standardized acquisition settings, particularly for filtering, could therefore improve recording reliability and enhance comparability between studies. Further validation in clinical populations is required before specific filter settings can be recommended for clinical application.

Certain limitations should be considered while interpreting the findings of the present study. The study included only healthy young adults; therefore, the results may not be directly generalizable to older individuals or patients with vestibular pathology. In addition, the study evaluated only a single low-pass filter cut-off and one stimulus intensity level. Future investigations should examine the combined influence of different high-pass and low-pass filter settings and evaluate these recording parameters in clinical vestibular populations. Overall, the findings demonstrate that high-pass filter settings significantly influence mVEMP latency and amplitude characteristics while largely preserving waveform morphology and interaural symmetry. These observations support the need for standardized acquisition protocols for reliable mVEMP recordings, while further studies in clinical populations are required to establish the clinical applicability of the present findings.

## Conclusion

The present study demonstrated that high-pass filter settings significantly influence the latency and amplitude of 500 Hz tone burst–evoked masseter Vestibular Evoked Myogenic Potentials (mVEMPs), with non-monotonic changes across filter conditions. The 3.3–1500 Hz filter setting generated the largest amplitude with clear waveform morphology, whereas 33–1500 Hz yielded the smallest amplitude and altered latency characteristics. These findings highlight the need for standardized filter settings in mVEMP acquisition. The 3.3–1500 Hz configuration may be suitable for healthy young adults; however, validation in clinical populations and across different stimulus and filter configurations is warranted before routine clinical application.

## Ethical Considerations

### Compliance with ethical guidelines

All the procedures were carried out as per the ethical guidelines of the Institutional Ethics Committee, Bharati Vidyapeeth (Deemed to be University) Medical College, Pune (Ref: BVDUMC/IEC/341/25-26), dated 24/07/2025. Informed written consent was obtained from all the participants to participate in the study.

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**Authors' contributions**
HV: Acquisition of data, statistical analysis, interpretation of the results, and drafting the manuscript; AKN: Study design and supervision, interpretation of the results, and critical revision of the manuscript.

**Data availability**
All the data generated during the study are contained in this article. Any additional data can be retrieved from the corresponding author, upon reasonable request.

**Conflict of interest**
The authors declare no conflicts of interest.

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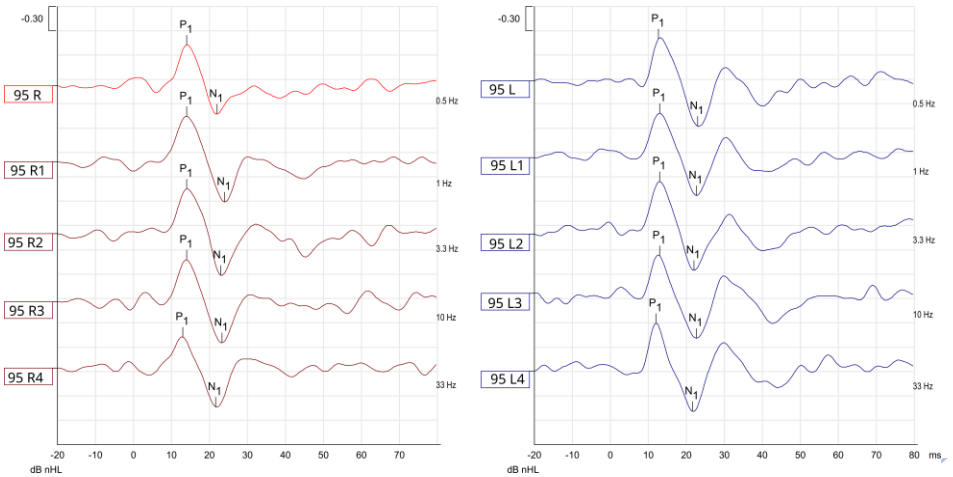


Figure 1. Representative 500 Hz tone burst evoked masseter vestibular evoked myogenic potential responses across five different filter settings in a normal hearing participant

Table 1. Median and interquartile range values of P11 latency, N21 latency, and peak-to-peak amplitude across different high-pass filter settings

| Filter setting (Hz) | P11 latency (ms) | N21 latency (ms) | Peak-to-peak amplitude (μV) |
|---|---|---|---|
| **0.5–1500** | 12.67 (11.84–13.42) | 21.59 (20.54–22.34) | 0.76 (0.63–1.01) |
| **1–1500** | 12.83 (12.50–13.59) | 21.58 (20.88–22.33) | 0.79 (0.64–1.11) |
| **3.3–1500** | 12.84 (11.92–13.50) | 21.42 (20.67–22.29) | 0.80 (0.67–1.05) |
| **10–1500** | 12.50 (11.92–13.08) | 21.84 (20.54–22.34) | 0.76 (0.62–1.01) |
| **33–1500** | 12.17 (11.67–12.75) | 20.50 (20.04–21.00) | 0.71 (0.61–0.98) |

Values are expressed as median (Q1–Q3).

Table 2. Wilcoxon signed-rank test statistics for ear-wise comparison of masseter vestibular evoked myogenic potential parameters across the evaluated filter settings in male and female participants

| | Male participants | | | Female participants | | |
|---|---|---|---|---|---|---|
| **Filter setting (Hz)** | **P11 z (p)** | **N21 z (p)** | **Amplitude z (p)** | **P11 z (p)** | **N21 z (p)** | **Amplitude z (p)** |
| **0.5–1500** | 0.45 (0.66) | 0.53 (0.59) | 0.31 (0.75) | 0.33 (0.74) | 0.58 (0.56) | 0.47 (0.64) |
| **1–1500** | 1.54 (0.12) | 1.54 (0.12) | 0.08 (0.94) | 0.80 (0.42) | 0.80 (0.42) | 0.40 (0.69) |
| **3.3–1500** | 1.02 (0.31) | 1.02 (0.31) | 0.94 (0.35) | 1.88 (0.06) | 1.88 (0.06) | 0.57 (0.57) |
| **10–1500** | 1.29 (0.20) | 1.29 (0.20) | 0.63 (0.53) | 0.55 (0.58) | 0.55 (0.58) | 0.09 (0.93) |
| **33–1500** | 0.53 (0.59) | 0.53 (0.59) | 0.24 (0.81) | 0.58 (0.56) | 0.58 (0.56) | 1.23 (0.22) |

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Table 3. Mann–Whitney U test statistics for gender-wise comparison of masseter vestibular evoked myogenic potential parameters across the evaluated filter settings

| Filter setting (Hz) | P11 latency z (p) | N21 latency z (p) | Peak-to-peak amplitude z (p) | IAAR z (p) |
|---|---|---|---|---|
| **0.5–1500** | 0.60 (0.55) | 1.44 (0.15) | 0.36 (0.72) | 0.82 (0.41) |
| **1–1500** | 1.88 (0.06) | 0.30 (0.76) | 1.31 (0.19) | 1.02 (0.30) |
| **3.3–1500** | 0.26 (0.79) | 1.01 (0.31) | 0.15 (0.88) | 0.64 (0.52) |
| **10–1500** | 1.30 (0.20) | 1.55 (0.12) | 0.37 (0.71) | 0.59 (0.55) |
| **33–1500** | 1.11 (0.27) | 0.02 (0.99) | 0.64 (0.53) | 0.48 (0.63) |

IAAR; interaural amplitude asymmetry ratio

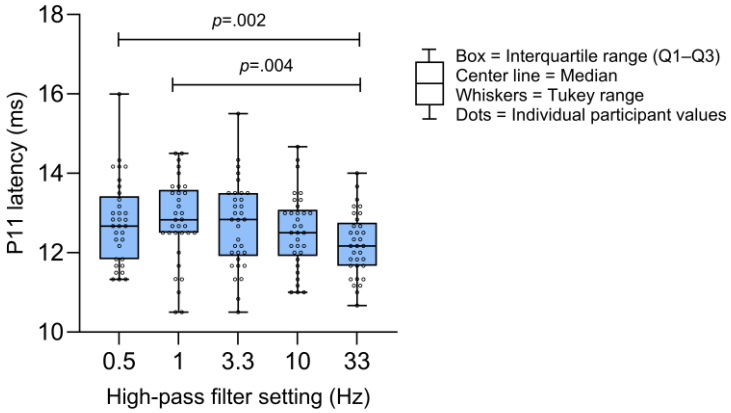


Figure 2. Distribution of P11 latency across the five filter settings

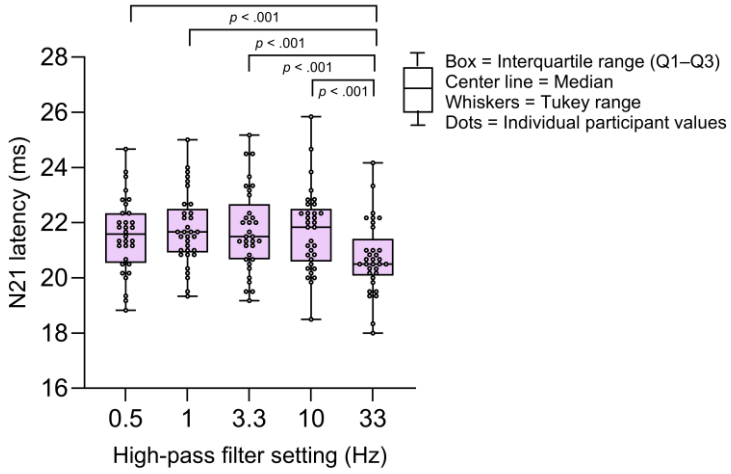


Figure 3. Distribution of N21 latency across the five filter settings

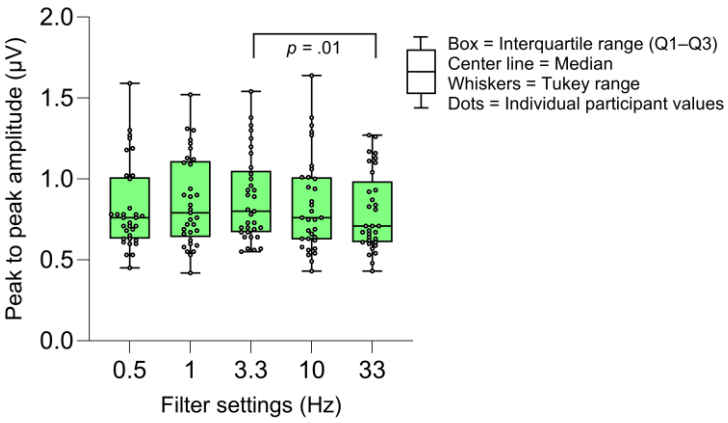


Figure 4. Distribution of peak-to-peak amplitude under the five filter settings

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