Clinical and Experimental Health Sciences

Comparison of the cVEMP and oVEMP Responses with Different Stimuli in Healthy Individuals

Nilüfer Bal[1,2], Hilal Husam[2], Ziya Aydin [2,3],Büşra Demirci Cebeci[2], Niyazi Ömer Arslan[2,4] Özge Gedik Toker[2]

[1] Marmara University, School of Medicine, Department of Audiology, İstanbul, Türkiye.
[2] Bezmialem Vakif University, Faculty of Health Sciences, Department of Audiology, İstanbul, Türkiye.
[3] The University of Southampton, Auditory Implant Service, Southampton, UK.
[4] College of Health Solutions, Program of Speech and Hearing Science, Arizona, USA.

Correspondence Author: Nilüfer Bal
E-mail: fzt.niluferondag@gmail.com
Received: October 24, 2023 **Accepted:** March 5,2025

ABSTRACT

Objective: Vestibular evoked myogenic potentials (VEMP) are electromyographic responses induced by auditory, tactile, or electrical stimulation. Electrode placement, intensity, and the type of stimulus applied to influence the amplitude and latency of VEMP responses. The study aims to investigate the effect of differences in stimulus intensities and stimulus types on VEMP results.

Methods: Twenty participants (40 ears) between the ages of 18 and 30 (22.7±1.8) took part in the study. Results from the cervical VEMP (cVEMP) and ocular VEMP (oVEMP) tests were examined using six different characterized stimuli (click, LS CE Chirp, 500 Hz – 1000 Hz Tone Burst, and 500 Hz – 1000 Hz LS CE Chirp) at intensities of 100 dB nHL, 90 dB nHL, and 80 dB nHL.

Results: In cVEMP and oVEMP testing, there was no significant difference between the amplitudes of 500 Hz tone burst (TB) and 500 Hz LS CE chirp stimuli; however, the p1 and n1 latencies of chirp stimuli were found to be significantly shorter. There was no significant difference between p1-n1 latency and the asymmetry ratio of frequency-specific stimuli. No difference was seen between click and chirp stimuli in any of the assessments.

Conclusion: The chirp stimulus is an effective alternative for TB. It is encouraged that each clinic develops its normative data because of the differences in recording parameters.

Keyword: S CE Chirp, narrow band, vestibular evoked myogenic potentials, frequency-specific, otolith organs

1. INTRODUCTION

Vestibular-evoked myogenic potentials (VEMP) are electromyographic responses in which otolith organs are triggered by auditory, vibrotactile, or electrical stimulation[1]. Ocular vestibular evoked potential (oVEMP) is a short-latency response that reflects vestibuloocular reflex projection to the inferior oblique muscle. Cervical vestibular evoked myogenic potential (cVEMP) reveals the inhibition and excitability of the sternocleidomastoid (SCM) muscle because of the vestibulocollic reflex. The cVEMP test assesses the saccule and inferior vestibular nerve integrity, while the oVEMP test assesses the utricle and superior vestibular nerve and their central projections[2]. The VEMP test is important for the diagnosis of disorders such as Meniere's disease, endolymphatic hydrops, vestibular schwannoma, superior semicircular canal dehiscence, and vestibular neuronitis [3-6]. The VEMP tests have also gained popularity in neurology and neurosurgery patients because they provide important information about the location of pathology[7-11].

To measure VEMP responses, high-intensity audio stimuli (90–110 dB nHL) at rates between 3-6 Hz are often presented as either monoaural or binaural through headphones.

Different types of acoustic stimuli are used in VEMP response recording. Studies indicate that click and tone burst (TB) stimuli can produce VEMP responses [12] . The TB stimulus is frequently chosen in clinics because otolith neurons are particularly active at low-frequency region [13]. The chirp stimulus, in addition to the click and TB stimuli, has attracted interest since it is relatively new [14, 15]. The Level Specific Claus Elberling Chirp (LS CE Chirp) was produced after the chirp stimulus was developed considering the tonotopic feature of the cochlea. However, since low-frequency energy is sent first in the time domain, it is thought that it may also

https://doi.org/10.33808/clinexphealthsci.1367956

be effective in stimulating otolith organs. Studies in which the effects of stimuli are evaluated at a single intensity support this hypothesis [15].

The amplitude and latency of VEMP responses are influenced by factors that depend on the individual and recording parameters, such as electrode location, the intensity and type of stimulus used, and the individual's age [12]. For this reason, each clinic should establish its guidelines and determine its normative data. Disclosing the differences in findings based on the stimuli applied can assist clinicians in the diagnosis by helping them in choosing the appropriate parameters for the test and evaluating the results. Our study aims to investigate the amplitude and latency difference between click, TB, and LS CE Chirp stimuli at various frequencies and intensities in cVEMP and oVEMP tests.

2. METHODS

The study was conducted in the Audiology Skills and Practice Laboratory of the Bezm-i Alem Vakıf University and was approved by the decision numbered 71306642-050.01.04 of the Bezm-i Alem Vakıf University Non-Invasive Ethics Committee. In the study, 20 participants between the ages of 18 and 30 were involved. Each participant underwent cVEMP and oVEMP testing who has bilateral Type A tympanograms, hearing thresholds of 20 dB HL or better between 0.25 and 8 kHz in a conventional pure-tone audiometry test, no neurological or metabolic diseases, and no complaints or history of dizziness or vertigo. Additionally, to rule out subclinical peripheral or central vestibular pathology, spontaneous nystagmus and gaze-evoked nystagmus were evaluated using videonystagmography (VNG module; Interacoustics A/S, Denmark). The VNG, Fukuda, and Romberg tests were within normal limits.

The Interacoustics Eclipse EP25 (Interacoustics A/S, Denmark) was used to record VEMPs after the patients' skin had been cleaned with Nuprep gel. For the cVEMP test, a ground electrode was placed on the forehead, active electrodes were placed on the middle of the SCM muscle, and the reference electrode was positioned at the sternal notch. The participants were positioned in a sitting position, and when the stimulus was given, the ipsilateral SCM muscle was contracted by turning their heads to the contralateral direction of the stimulus. In the oVEMP test, the active electrodes were placed on the inferior oblique muscles, the reference electrodes were placed under the active electrodes, and the ground electrode was placed on the forehead. Participants were asked to look 30° upwards in a sitting position, and stimuli were given monaurally to the right and left ears and recorded from the contralateral electrodes. Table 1 displays the variables used in cVEMP and oVEMP recordings. The response's repeatability was examined using a double-trace recording. By integrating two traces into one wave component, the analyses of the p1-n1 amplitude, p1 latency, n1 latency, p1-n1 latency, and asymmetry ratio were carried out by experienced audiologists.

Click, LS CE Chirp, NB CE Chirps (500 Hz and 1000 Hz), and TB (500 Hz and 1000 Hz) were used to elicit cVEMP with different intensities (100 dBnHL, 90 dBnHL, and 80 dBnHL) and oVEMPs with 100dBnHL intensity. In the case of stimulus and left-right ear tests, the tests were interrupted for 15 minutes to prevent muscle fatigue. Test parameters for oVEMP and cVEMP had been shown in Table 1.

Table 1. *cVEMP and oVEMP test recording parameters. µV: Microvolt, CE: Claus Elberling, dB: Decibel, EMG: Electromyography, Hz: Hertz, LS: Level specific, ms: Millisecond, nHL: normal hearing level, TB: Tone burst*

	cVEMP				oVEMP			
	Click	LS CE Chirp	TB 500-1000 Hz	LS CE Chirp 500-1000 Hz	Click	LS Chirp	TB 500-1000 Hz	LS CE Chirp 500-1000 Hz
Rate	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
EMG Activity	49.9-150.6 µV	49.9-150.6 µV	49.9-150.6 µV	49.9-150.6 µV	25.6-70.0 µV	25.6-70.0 µV	25.6-70.0 µV	25.6-70.0 µV
Polarity	Rarefaction	Rarefaction	Rarefaction	Rarefaction	Rarefaction	Rarefaction	Rarefaction	Rarefaction
Intensity	100-90-80 dB nHL	100-90-80 dB nHL	100-90-80 dB nHL	100-90-80 dB nHL	100 dB nHL	100 dB nHL	100 dB nHL	100 dB nHL
Time Window	80 ms	80 ms	80 ms	80 ms	80 ms	80 ms	80 ms	80 ms
Sweep	150-200	150-200	150-200	150-200	150-200	150-200	150-200	150-200

The data were analyzed using the IBM SPSS 25.0 software (IBM, Ehningen, Germany) and reported as mean ± standard deviation (SD). The Kolmogorov-Smirnov test and the Q-Q plots were used to assess normality. The Wilcoxon signed-rank test was used to compare right and left ears. The nonparametric Kruskal-Wallis test and post hoc analysis with Bonferroni correction were used to compare the variables. All analyses were carried out using a 95% confidence interval, and a result of $p<0.05$ was accepted as statistically significant.

3. RESULTS

Twenty participants (40 ears), 10 males and 10 females, between the ages of 18 and 30 (22.7 ± 1.8), took part in the study. The results of cVEMPs were studied using stimulus intensities of 100 dB nHL, 90 dB nHL, and 80 dB nHL through 6 different stimuli, and oVEMPs were studied at 100 dBnHL intensity with 6 different stimuli. Data from 40 ears were pooled because there was no significant difference between ears.

3.1. cVEMP

The p1-n1 amplitude, p1 latency, n1 latency, p1-n1 latency, and asymmetry rate values with different stimuli at 100 dB nHL were listed in Table 2. and Figure 1 shows statistically different values of the p1-n1 amplitude, p1 latency, n1 latency for different stimuli. The P1-N1 amplitude was not statistically different between click and chirp stimuli (p>.05). These stimuli were compared to frequency-specific stimuli, amplitudes were significantly higher in both TB and NB LS CE Chirp stimuli only at 500 Hz (p<.001).

The p1 latency of the 500 Hz TB stimulus at 100 dB nHL intensity was the longest and only 1000 Hz TB stimuli latencies did not show a significant difference. When the n1 latencies were examined, the longest TB latency was obtained at 500 Hz The absolute p1 and n1 wave latencies of the click and LS CE Chirp stimuli did not differ significantly (p>.05).

The response rates of different stimuli, p1-n1 amplitude values, p1 latency, n1 latency, p1-n1 latency, and asymmetry rates of the cVEMP test at 90 dB nHL are shown in Table 3. The largest amplitude value was obtained at 500 Hz LS CE Chirp when the p1-n1 amplitude of the cVEMP responses at 90 dB nHL was compared, although the difference was significant only at 1000 Hz LS CE Chirp (p=.001), 1000 Hz TB (p<.001), click (p=.012), and LS CE Chirp (p<.001). No difference was observed between click and LS CE Chirp stimuli (p>.05). There were significant differences in p1 latencies between 500 Hz LS CE Chirp and 500 Hz TB (p<0.001), 500 Hz LS CE Chirp and 1000 Hz TB (p=.003), 1000 Hz LS CE Chirp and 1000 Hz TB (p=0.021), 1000 Hz LS CE Chirp and 500 Hz TB (p<.001), click and 500 Hz TB (p=.006), LS CE Chirp and 500 Hz TB (p=.009). N1 latencies significantly differ between 500 Hz LS CE Chirp and 500 Hz TB (p<.001), 500 Hz LS CE Chirp and 1000 Hz TB (p=.003), 1000 Hz LS CE Chirp and 1000 Hz TB (p=.007), 1000 Hz LS CE Chirp and 500 Hz TB (p<.001), click and 500 Hz TB (p=.004), LS CE Chirp and 500 Hz TB (p<.001).

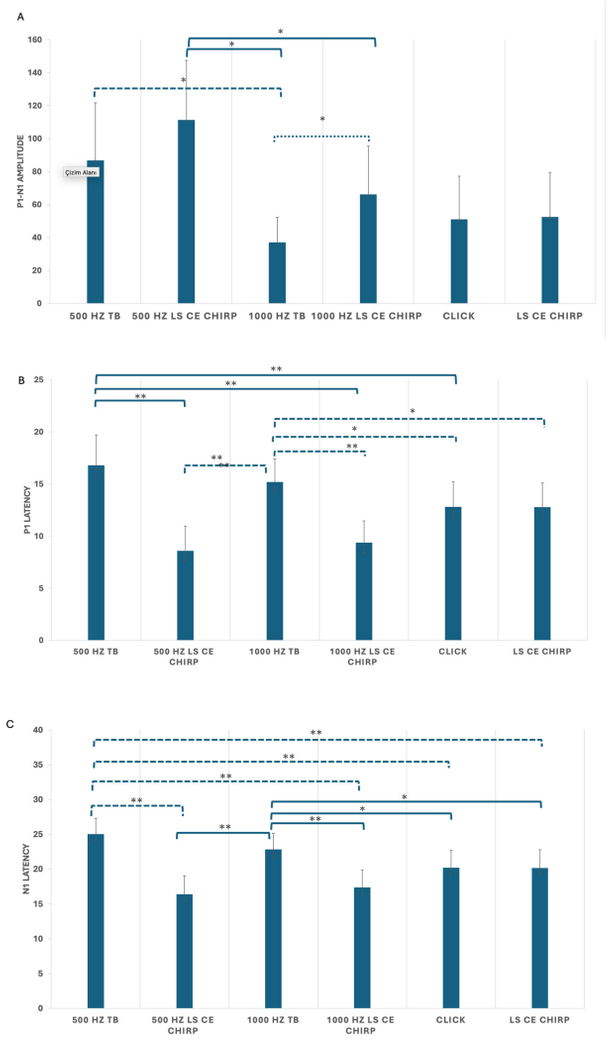

Figure 1. *cVEMP 100 dB nHL responses comparisons for different types of stimuli. A. P1-N1 Amplitudes. B P1 latencies. C. N1 Latencies. **: p<0.001, *: p<0.001µV: Mikrovolt, CE: Claus Elberling, Hz: Hertz, LS: Level specific, ms: Millisecond, nHL: normal hearing level, TB: Tone burst.*

Table 2 *100 dB nHL responses for the cVEMP. µV: Mikrovolt, CE: Claus Elberling, Hz: Hertz, LS: Level specific, ms: Millisecond, nHL: normal hearing level, TB: Tone burst*

	Vemp Responses(%)	P1-N1 Amplitude (µV)	P1 Latency (ms)	N1 Latency (ms)	P1-N1 Latency (ms)	Asymmetry Ratio (%)
500 Hz TB	40(100%)	86,77 ± 34,91	16,80±2,09	25,03±2,29	8,30±1,35	18±09
500 Hz LS CE Chirp	40(100%)	111,26 ± 36,08	8,60±2,36	16,38±2,70	8,17±1,76	15±10
1000 Hz TB	40(100%)	37,08 ± 15,26	15,20±2,21	22,84±2,32	7,65±1,81	16±11
1000 Hz LS CE Chirp	40(100%)	66,17 ±29,26	9,37±2,10	17,39±2,52	7,95±1,70	17±12
Click	40(100%)	50,96 ±26,27	12,80±2,42	20,21±2,47	7,42±1,88	17±11
LS CE Chirp	40(100%)	52,47 ± 26,91	12,78±2,31	20,16±2,64	7,36±2,09	19±13

Table 3. *90 dB nHL responses for the cVEMP. µV: Microvolt, CE: Claus Elberling, Hz: Hertz, LS: Level specific, ms: Millisecond, nHL: normal hearing level, TB: Tone burst*

	Vemp Response (%)	P1-N1 Amplitude (µV)	P1 Latency (ms)	N1 Latency (ms)	P1-N1 Latency (ms)	Asymmetry Ratio (%)
500 Hz TB	39(97,5%)	39,82 ± 22,79	18,02±2,52	25,53±2,48	7,82±2,58	19±11
500 Hz LS CE Chirp	40(100%)	49,55 ±30,80	13,61±2,43	20,88±3,63	7,59±2,21	19±10
1000 Hz TB	34(85%)	14,28 ± 6,69	16,15±4,06	23,61±5,02	7,46±2,94	16±15
1000 Hz LS CE Chirp	33(82,5%)	24,24 ± 12,65	13,84±2,77	21,02±3,08	7,17±2,21	19±17
Click	26(65%)	25,89 ±12,56	15,25±3,09	22,76±4,02	7,51±2,50	18±12
LS CE Chirp	28(70%)	19,57 ± 9,11	15,02±4,49	21,27±5,32	6,33±2,82	13±13

When p1-n1 latency values were compared, no significant difference was found for stimuli at 90 dB nHL and 100 dB nHL intensity levels (p>.05). There was no significant difference between the asymmetry ratios (p>.05).

Due to statistically insufficient data, responses to all stimuli with the intensity of 80 dB nHL in the cVEMP test could not be analyzed. However, the stimulus with the highest response at 80 dB nHL intensity was a 500 Hz narrow band (NB) LS CE Chirp observed in 16 ears (40%).

3.2. oVEMP

The response values of the oVEMP test at different stimuli at 100 dB nHL are given in Table 4 and Figure 2 shows the statiscally significant dişfferences of P1-N1 amplitudes, p1 an n1 latencies. The highest p1 amplitude was recorded at 500 Hz LS CE Chirp. The longest p1 and n1 latencies were recorded at 500 Hz TB; There was no significant difference between the click and LS CE Chirp stimuli (p>.05).

No significant difference was observed between p1-n1 latency values and the asymmetry ratio between stimuli results (p>.05).

Table 4. *100 dB nHL responses for the oVEMP. µV: Microvolt, CE: Claus Elberling, Hz: Hertz, LS: Level specific, ms: Millisecond, nHL: normal hearing level, TB: Tone burst*

	Vemp Responses (%)	P1-N1 Amplitude (µV)	P1 Latency (ms)	N1 Latency (ms)	N1-P1 Latency (ms)	Asymmetry Ratio (%)
500 Hz TB	40(100%)	6,76 ± 5,72	17,28 ±1,53	11,99 ± 1,34	5,59 ± 1,10	13 ± 11
500 Hz LS CE Chirp	40(100%)	10,77 ±8,23	9,26 ± 2,43	4,10 ± 2,32	5,40 ± 1,20	14 ± 10
1000 Hz TB	40(100%)	5,89 ± 3,62	16,02 ± 0,84	10,71 ± 0,88	5,30 ± 1,00	18 ± 12
1000 Hz LS CE Chirp	40(100%)	6,17 ± 4,88	10,51 ± 0,80	5,25 ± 1,25	4,59 ± 2,57	20 ± 14
Click	40(100%)	4,15 ± 3,58	13,64 ± 1,43	8,00 ± 1,26	5,58 ± 1,09	21 ± 16
LS CE Chirp	40(100%)	3,75 ± 2,91	13,54 ±1,40	8,37 ± 1,31	5,19 ± 1,32	21 ± 19

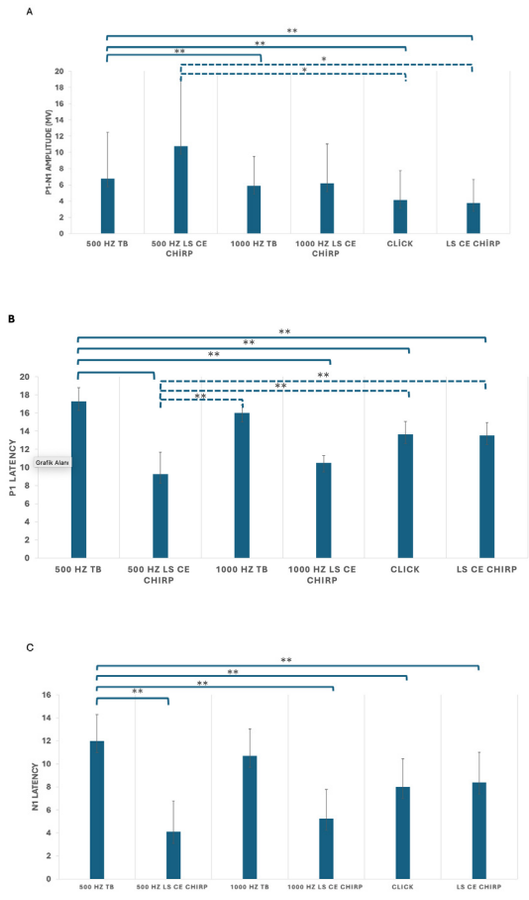

Figure 2. *oVEMP 100 dB nHL responses comparisons for different types of stimuli. A. P1-N1 Amplitudes. B P1 latencies. C. N1 Latencies. **: p<0.001, *: p<0.001µV: Mikrovolt, CE: Claus Elberling, Hz: Hertz, LS: Level specific, ms: Millisecond, nHL: normal hearing level, TB: Tone burst.*

4. DISCUSSION

Results of VEMPs are influenced by recording parameters such as electrode location, stimulus type, intensity level, polarity, and frequency, as well as patient-related features including age and gender. Selection of the stimulus is an essential component of the VEMP test since it affects the response's latency and amplitude values [14]. Although studies have been conducted to investigate the differences between the stimuli utilized in the literature, there is no consensus on the chirp stimulus type and normative values [15].

The 500 Hz TB stimulus is often used in clinics since it activates the otoliths [13] and produces the biggest amplitude VEMP amplitudes [16]. However, the shortest latencies and the largest amplitudes were obtained in the 500 Hz LS CE Chirp stimulus compared with others. Similar results were obtained in different studies using NB Chirp stimuli [14, 15, 17]. It has been hypothesized that the use of chirp stimuli results in more efficient activation of the macula with enhanced synchronization, which accounts for the short delay [15]. Another hypothesis is that since the developers of the NB CE Chirp stimulus set its onset time earlier than in TB, shorter wave latencies are obtained in chirp [18]. In our study, the reason that the p1 and n1 wave latencies in the cVEMP and oVEMP tests were shorter than all other stimuli in the 500 Hz and 1000 Hz LS CE Chirp stimuli is assumed to be linked to the difference in the onset time of the stimuli.

The NB LS CE Chirp stimulus had a larger p1-n1 amplitude at 500 Hz than the TB stimulus in the cVEMP and oVEMP tests, but this difference was not statistically significant (p>.05). Although there is research in the literature that claims there is no difference [19], contrary to our finding, there are studies that claim the TB stimulus amplitude [20]

or NB CE Chirp stimulus amplitude is higher [14, 15, 17]. The chirp stimulus was developed by modeling the tonotopic structure of the cochlea to provide a more synchronized firing by simultaneously delivering the auditory stimulus to low and high frequencies [21]. However, unlike the cochlea, otolith organs do not have a tonotopic organization, thus stimulation influences differently. Although the stimulus used in the VEMP test is auditory, the irregular afferent neurons of the utricle and/or saccule are stimulated [13]. These factors would be the reason for the absence of a statistically significant difference between the NB LS CE Chirp and TB stimuli. It was determined that there was no difference between LS CE Chirp and Click stimuli for the same reason. The findings support the idea that the NB LS CE Chirp stimulus could have a similar impact on eliciting a response as the TB stimulus.

The asymmetry ratio did not differ between stimuli, similar to other studies in the literature [15, 19]. The interaural asymmetry ratio is an important parameter in the presence of unilateral peripheral vestibular pathology [22]. The asymmetry ratio did not differ because individuals without dizziness complaints were included in our study. As a result, the sensitivity and specificity of the various stimuli used to evaluate the asymmetry ratio could not be investigated. In future studies, studying the stimulus differences within the pathologic group will help physicians decide which stimulus to use in the assessment.

In our study, the cVEMP and oVEMP tests both generated 100% response rates for all stimuli at 100 dB nHL intensity. The 500 Hz LS CE Chirp had the highest response rate (100%) at 90 dB nHL intensity. Adult VEMP response rates range from 80% to 100% [23]) and they decline with aging[14, 24]. Although our results are in line with previous research, the difference in 90 dB nHL could be due to some of the energy from the 500 Hz LS CE Chirp stimulus being scattered towards 1000 Hz, increasing the rate of excitation [14]. On the other hand, it should be noted that in our study, the difference between the number of responses observed in recordings with 500 Hz TB and 500 Hz LS CE Chirp stimulus was only one ear. In our study, the lowest response was obtained in the click stimulus (65%), in accordance with the literature [23, 24]. This was attributed to the fact that the VEMP response is most effectively produced at 500 Hz[13], and wideband stimulus is insufficient to stimulate the otolith organs.

The data obtained in our study is expected to be helpful for physicians in terms of stimulus selection and normalization values. Our findings provide clinicians with valuable insights for stimulus selection and establishing normative values . The small sample size is considered one of the limitations of the study. In addition, it is believed that it would be beneficial to investigate the difference between stimuli in the population with unilateral vestibular hypofunction and/or central disease in future studies.

5. CONCLUSIONS

We compared the wave amplitudes, P1 and N1 latencies, and P1-N1 latencies of the cVEMP and oVEMP at different frequency and intensity levels. The results showed that while P1 and N1 latencies were significantly shorter with LS CE Chirp stimuli, which had the highest response rate, there was no significant difference in response amplitude between the commonly used 500 Hz TB stimulus and the novel 500 Hz LS CE Chirp stimulus.

These findings suggest that the NB LS CE Chirp stimulus may be a suitable alternative to the TB stimulus; however, further research is needed, particularly in patients with vestibular disorders. Additionally, since VEMP application procedures may vary across clinics, each clinic should establish its own normative data.

Acknowledgement: *We thank the study participants and control subjects for their contributions to this study. Niyazi O. Arslan and Ziya Aydin are Scholarship Holders of the Ministry of National Education of the Republic of Türkiye.*

Funding: *The author(s) received no financial support for the research.*

Conflicts of interest: *The authors declare that they have no conflict of interest.*

Ethics Committee Approval: *This study was approved by Ethics Committee of Bezmialem Vakıf University (approval date 27.01.2017. and number 71306642-050.01.04)*

Peer-review: *Externally peer-reviewed.*

Author Contributions:

Research idea: NB
Design of the study: NB
Acquisition of data for the study: ZA, BDC, NÖA
Analysis of data for the study: NB, HH, ZA, BDC, NÖA, ÖGT
Interpretation of data for the study: HH,
Drafting the manuscript: HH
Revising it critically for important intellectual content: NB, ÖGT
Final approval of the version to be published: NB

REFERENCES

[1] Murofushi T. Clinical application of vestibular evoked myogenic potential (VEMP). Auris Nasus Larynx, 2016; 43(4): 367-376. https://doi.org/10.1016/j.anl.2015.12.006

[2] Rodriguez AI, Marler E, Fitzpatrick D, Creutz T, Cannon SA, Thomas MLA, Janky KL. Optimization of cervical and ocular vestibular evoked myogenic potentialtesting using an impulse hammer in adults, adolescents, and children. Otology & Neurotology, 2020; 41(6):817-827. https://doi.org/10.1097/MAO.0000000000002632

[3] Seo YJ, Kim J, Choi JY, Lee WS. Visualization of endolymphatic hydrops and correlation with audio-vestibular functional testing in patients with definite Meniere's disease. Auris Nasus Larynx, 2013;40(2):167-172. https://doi.org/10.1016/j.anl.2012.07.009

[4] Chiarovano E, Cynthia Darlington C, Vidal PP, Lamas G, Waele C. The role of cervical and ocular vestibular evoked myogenic potentials in the assessment of patients with vestibular

schwannomas. PLoS One, 2014; 9(8):e105026 https://doi.org/10.1371/journal.pone.0105026

[5] Noij KS, SD. Rauch, Vestibular evoked myogenic potential (VEMP) testing for diagnosis of superior semicircular canal dehiscence. Frontiers in Neurology, 2020;11:695; 1-8. https://doi.org/10.3389/fneur.2020.00695

[6] Magliulo A, Iannella G, Gagliardi S, Re M. 1-year follow-up study with C-VEMPs, O-VEMPs and video head impulse testing in vestibular neuritis. European Archives of Oto-Rhino-Laryngology, 2015; 272: 3277-3281. https://doi.org/10.1007/s00405-014-3404-9

[7] Guo X, Liu X, Ye S, Liu X, Yang X, Fan D. Eye movement abnormalities in amyotrophic lateral sclerosis. Brain Sciences, 2022; 12(4): 489. https://doi.org/10.3390/brainsci12040489

[8] Eleftheriadou A, Deftereos SN, Zarikas V, Panagopoulos G, Sfetsos S, Karageorgioub CL, Ferekidou E, Kandilorosd D, Korres S. The diagnostic value of earlier and later components of vestibular evoked myogenic potentials (VEMP) in multiple sclerosis. Journal of Vestibular Research, 2009;19(1-2): 59-66. https://doi.org/10.3233/VES-2009-0342

[9] Bal N, ŞengülY, Behmen MB, Powel A, Louis ED. Vestibular reflexes in essential tremor: abnormalities of ocular and cervical vestibular-evoked myogenic potentials are associated with the cerebellum and brainstem involvement. Journal of Neural Transmission, 2023;1-7. https://doi.org/10.1007/s00702-023-02652-3

[10] Matsuzaki M, Murofushi T, Mizuno M. Vestibular evoked myogenic potentials in acoustic tumor patients with normal auditory brainstem responses. European archives of oto-rhino-laryngology, 1999; 256: 1-4. https://doi.org/10.1007/s004050050112

[11] Tsutsumi T, Tsunoda A, Noguchi Y, Komatsuzaki A. Prediction of the nerves of origin of vestibular schwannomas with vestibular evoked myogenic potentials. Otology & Neurotology, 2000;21(5):712-715. https://doi.org/10.1016/b878-0-323-01830-2.50022-5

[12] Eleftheriadou A, E Koudounarakis. Vestibular-evoked myogenic potentials eliciting: An overview. European archives of oto-rhino-laryngology, 2011;268(3): 331-339. https://doi.org/10.3233/VES-2009-0342

[13] Curthoys IS. A critical review of the neurophysiological evidence underlying clinical vestibular testing using sound, vibration and galvanic stimuli. Clinical Neurophysiology, 2010;121(2):132-144. https://doi.org/10.1016/j.clinph.2009.09.027

[14] Mat Q, Duterme JP, Tainmont S, Lelubre C, Manto M. Optimizing ocular vestibular evoked myogenic potentials with narrow band CE-chirps. Ear and Hearing, 2021;42(5):1373-1380. https://doi.org/10.1097/AUD.0000000000001031

[15] Reddy TM, Heinze B, Biagio-de Jager L, Maes L. Cervical and ocular vestibular evoked myogenic potential: A comparison of narrowband chirp, broadband chirp, tone burst and click stimulation. International Journal of Audiology, 2023; 62(6):579-586. https://doi.org/10.1080/14992027.2022.2064924

[16] Akin FW, Murnane OD, Proffitt TM. The effects of click and tone-burst stimulus parameters on the vestibular evoked myogenic potential (VEMP). Journal of the American Academy of Audiology, 2003;14(09); 500-509. https://doi.org/10.3766/jaaa.14.9.5

[17] Karaçaylı C, Karaçaylı C, Öçal FCA, Çoban VK, Satar B. Normative data of ocular vestibular evoked myogenic potentials in response to chirp stimulus. The Journal Of International Advanced Otology, 2020;16(3): 378. https://doi.org/10.5152/iao.2020.6354

[18] Speidel DP, BeckL. Demystifying the CE-Chirp. Hearing Review, 2016;23(2):28. https://hearingreview.com/hearing-products/accessories/components/demystifying-ce-chirp

[19] Ocal FCA, Karacayli C, Coban VK, Satar B. Can narrow band chirp stimulus shake the throne of 500 Hz tone burst stimulus for cervical vestibular myogenic potentials? Journal of Audiology & Otology, 2021;25(2): 98. https://doi.org/10.7874/jao.2020.00486

[20] Özgür A, Çelebi Erdivanlı Ö, Özergin Coşkun Z, Terzi S, Yiğit E, Demirci M, Dursun E. Comparison of tone burst, click and chirp stimulation in vestibular evoked myogenic potential testing in healthy people. International Advanced Otology, 2015;11(1): 33-35 https://doi.org/10.5152/iao.2015.927

[21] Cebulla M, Stürzebecher E, Don M, Müller-Mazzotta J. Auditory brainstem response recording to multiple interleaved broadband chirps. Ear and Hearing, 2012;33(4): 466-479. https://doi.org/10.1097/AUD.0b013e318241e85a

[22] Bas B, Keseroglu K, Er S, Ozdek A, Korkmaz MH. Is chirp more effective than click and tone-burst during oVEMP test? Annals of Medical Research, 2021; 27(3): 0819-0824. https://doi.org/10.5455/annalsmedres.2019.11.693

[23] Isaradisaikul S, Navacharoen N, Hanprasertpong C, Kangsanarak J. Cervical Vestibular-Evoked Myogenic Potentials: Norms and Protocols. International Journal of Otolaryngology, 2012; 2012(1): 913515. https://doi.org/10.1155/2012/913515

[24] Janky KL, Shepard N. Vestibular evoked myogenic potential (VEMP) testing: normative threshold response curves and effects of age. Journal of the American Academy of Audiology, 2009;20(08): 514-522. https://doi.org/10.3766/jaaa.20.8.6

How to cite this article: Bal N, Husam H, Aydın Z, Demirci Cebeci B, Arslan NÖ, Gedik Toker Ö. Comparison of the cVEMP and oVEMP Responses with Different Stimuli in Healthy Individuals. Clin Exp Health Sci 2025; 15: 42-47. DOI: 10.33808/clinexphealthsci.1367956