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Test-Retest Reliability of Vestibular Evoked Myogenic Potential across Different Age Groups

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Abstract

Background: VEMPs are used to evaluate the function of otolith system. cVEMP evaluate the function of saccule and oVEMP evaluate the function of utricle. There are equivocal findings in the test-retest reliability of cVEMP and oVEMP response among the young adult's groups. Therefore, the present study was taken up to see test-retest reliability the test-retest reliability of cVEMPs (with and without integrated visual feedback system) and oVEMP parameters across different age groups.

Method: A total of 60 participants were included among the three groups (young adult, middle adult and old adult) with an equal number of in each group. cVEMP and oVEMP were performed thrice for all the participants to see the test-retest reliability.

Results: Present study results showed test-retest reliability was fair to good and above for all the parameters for cVEMP as well as oVEMP response. cVEMP peak to peak amplitude retest reliability with integrated visual feedback showed more reliability than without integrated visual feedback system in middle and old adults.

Conclusion: It can be concluded from the current study that cVEMP and oVEMP testing procedures are reliable in the young, middle and old adult groups during and between test recordings.

Keywords: test-retest, reliability, otolith system, VEMP, adult.

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INTRODUCTION

VEMP test is a relatively new diagnostic advancement that investigates functions of the otolith structures, inferior and superior branch of the vestibular nerve[1-3]. There are two types of VEMP testing, cervical VEMP (cVEMP) and ocular VEMP (oVEMP). cVEMP responses involve a reflex pathway having its origin in the vestibular saccule, carried by the inferior vestibular nerve, synapsing at the SCM muscle. The response waveform is biphasic, having an early positive peak (p13) followed by a negative peak (n23)[4]. The oVEMP pathway thought to travel from the utricle, going through the superior vestibular nerve, vestibular nucleus, then crossing over to contralateral oculomotor nuclei *via* the medial longitudinal fasciculus and finally innervating the extraocular muscles. The oVEMP waveform is considered as normal if the initial negative peak is at 10-12 ms (N10 or N1) and the following positive peak is at 15-20 ms (P15 or P1)[5].

Although the literature reports a wide range of studies on test-retest reliability of cVEMPs and oVEMP testing methods, there is no consensus in their findings. While some report greater reliability for latency measures, others have found amplitude measures to be more reliable. Excellent reliability showed for P1, N1 latencies and interpeak amplitudes with the use of feedback method[6,7]. The study reported poor to good reliability for P13 and N23 latencies, but excellent reliability for peak to peak amplitudes[8,9]. Therefore, the reliability of cVEMP test is still not clearly understood. Furthermore, due to the variations found in the amplitude measures even within normal hearing individuals as a result of the varied level of SCM muscle contraction, the results might also show variations across test conditions. Generally, cVEMPs are performed with the conventional evoked potential system, without monitoring the electromyographic level, which can lead to large variations in VEMP responses. Therefore, monitoring the muscle contraction during cVEMP testing would prove beneficial while interpreting the responses obtained. Thus, the objective of the present research was to explore the test-retest reliability of cVEMP testing while controlling the muscle tone activity with and without integrated visual feedback software.

Furthermore, research findings on the test-retest reliability of oVEMP demonstrate variable results. oVEMP latencies (N1 and P1) reported fair to good reliability[10], and poor reliability for latency measures was indicated9. However, amplitude measures of oVEMP responses have consistently shown excellent reliability across studies. Therefore, there is a need to clearly understand the reliability of these response characteristics for accurate clinical evaluations. So the current study aims to check the test-retest reliability of cVEMPs (with and without integrated visual feedback system) and oVEMP parameters across different age groups.

METHODOLOGY

The study started with ethical clearance after the institutional ethics board permission. The cross-sectional study design was adopted for the research using a convenient sampling method to select the participants for this study. The participants in this study were divided into three groups based on their age; young adult group (20-40 years), middle adult group (41-60 years), and old adult group (60 years and above) with 20 (40 ears) participants in each group was considered. The participants were young adults with a mean age of 25.5 ± 8.4 years, middle adults with a mean age of 50.6 ± 6.9 years and old adults with a mean age 67.2 ± 6.7 years. Before conducting the test procedures, participant consent was obtained. In the older adult group, participants were either diagnosed as having a normal hearing sensitivity or sensory neural hearing loss with an air-bone gap of 10 dB with 'A' type tympanogram. None of the participants had any conductive hearing component (like ear discharge, earache, etc.), exposure to high-intensity noise for a longer duration, symptomatic neurological symptoms like vertigo or giddiness, vomiting or nausea and seizures.

IHS Smart EP version: 3.92 (Intelligent hearing systems, Florida, USA) was used to record and analyze cVEMPs (with and without integrated visual feedback system) and oVEMP responses. cVEMP testing was carried out using two methods with following electrode placement: Non-inverting electrode-the midpoint of the SCM muscle on the side of the test ear, inverting electrode-Sternoclavicular junction and the ground electrode on the forehead. In the first method, the participants were instructed to turn their heads 45 degrees to the contralateral side of the test ear to maintain constant tonic muscle activity of the ipsilateral SCM muscle throughout the recording. There was no feedback provided to monitor the tonic muscle contraction of the SCM muscle. Throughout the 200 sweeps, participants had to maintain the same level of tonic muscle contraction of the SCM muscle. After each recording session, one minute relaxation time was given. In the second method, the tonic muscle contraction was monitored from 50 μV to 150 μV throughout the recording using integrated visual feedback software. By providing visual feedback to the participant, the software ensured that sufficient muscle contraction was achieved throughout the testing. The biphasic wave with a positive (P13) and a subsequent negative (N23) peaks were recorded to determine the latency and amplitude in both ears.

oVEMP was recorded from the extraocular muscle with electrode configuration involved placement of the non-inverting electrode beneath the eye, contralateral to the ear being tested. The inverting electrode was positioned 1-2 cm below the non-inverting electrode over the cheek, and the ground electrode was placed on the forehead. The participants were instructed to look upward at a visual angle of 30-35 degree vertically above the horizontal at a fixed target which was approximately at >2 m distance from the eyes. Also, they were instructed to avoid extraneous movements of the head, neck, and jaw while recording the oVEMP. The eyes remained fixed on the target throughout the 200 sweeps. After each recording, a one minute break was given to the participants to relax, and then the test was continued. The recording was initiated, and the initial biphasic wave with a negative (N10) peak followed by a positive peak (P15) was used to determine the latency and peak to peak amplitude for bilateral responses. The protocol used to record cVEMPs and oVEMP is given in Table 1.

The first two consecutive recording sessions with a gap of 5 minutes was considered as intrasession retest and the third recording after a gap of 3-5 days as intersession retest recording. Intra Class correlation test was carried out to see the test-retest reliability for latencies and amplitudes of cVEMPs (with and without integrated visual feedback system) and oVEMP in different age groups. In the present study, the reliability coefficient was considered as preferred reliability with ICC=1.00, excellent reliability with ICC>0.75, fair-good reliability with 0.04>ICC<0.75 and poor reliability with ICC<0.04[9].

Table 1. Parameters used to record cVEMPs and oVEMP response.

Parameter	oVEMP	cVEMP
Analysis time	Pre-stimulus: 10 ms Post-stimulus: 50 ms	Pre-stimulus: 10 ms Post-stimulus: 50 ms
Filter setting	High pass: 1 Hz Low pass: 1000 Hz	High pass: 30Hz Low pass: 1500Hz
Amplification	50000	5000
Type of stimulus	500 Hz tone burst with 8 ms duration	500 Hz tone burst with 8 ms duration
Rate	5.1/sec	5.1/sec
Polarity	Rarefaction	Rarefaction
Total number of stimulus	200	200
Intensity	100 dBnHL	100 dBnHL

RESULTS

The mean and standard deviation of latencies (P13, N23 P13-N23 interval), peak to peak amplitude and amplitude ratio of cVEMP obtained with and without integrated visual feedback for the three test recordings are shown in Table 2.

For cVEMP parameters, the ICC value of P13 indicated fair to good reliability (ICC<0.75), whereas N23 showed excellent reliability (ICC>0.75) across the different age groups except in the old adult groups without integrated visual feedback system (ICC=0.70). The P13-N23 interval also showed fair to good reliability across the different age groups with and without an integrated visual feedback system. Peak to peak amplitude across all age groups showed ICC value near excellent/excellent test-retest reliability with an integrated visual feedback system but showed only fair to good reliability without integrated visual feedback. Amplitude ratio showed a fair to good reliability across different age groups. Table 3 shows ICC co-efficient of latencies, peak to peak amplitude, and amplitude ratio for cVEMP with and without integrated visual feedback system across the different age groups.

oVEMP was recorded using a single procedure without the integrated visual feedback system. Latencies (N10, P15 and N10-P15 interval), peak to peak amplitude, and amplitude ratio of oVEMP response were measured. Table 4 shows the mean and standard deviation of oVEMP parameters across the different age groups during three sessions of recording.

For oVEMP parameters, the ICC values of N10 and P15 indicated a fair to good and excellent reliability, respectively across the different age groups. From Table 5, it can be observed that in the young adult group N10-P15 interval showed excellent reliability. However,

Table 2. The mean and standard deviation of cVEMP parameters with and without integrated visual feedback system across different sessions.

cVEMP parameter	Age group	Session 1 Mean (SD)		Session 2 Mean (SD)		Session 3 Mean (SD)	
		With integrated visual feedback	Without integrated visual feedback	With integrated visual feedback	Without integrated visual feedback	With integrated visual feedback	Without integrated visual feedback
P13 Latency (ms)	Young	16 (0.97)	15.96 (0.89)	16.14 (1)	16.15 (0.98)	16.19 (1.35)	16.21 (1.37)
	Middle	16.20 (1.14)	16.30 (1.33)	16.35 (1.55)	16.55 (1.79)	16.1 (1.86)	16.29 (1.94)
	Old	17.22 (1.36)	17.30 (1.43)	17.12 (1.51)	17.19 (1.57)	17.02 (1.88)	17.07 (1.92)
N23 Latency (ms)	Young	21.86 (1.56)	22.27 (1.63)	21.86 (1.57)	22.16 (1.62)	21.74 (1.63)	22.5 (1.86)
	Middle	22.34 (1.46)	22.05 (1.56)	22.2 (2.02)	21.95 (1.59)	22.35 (1.56)	22.2 (2.04)
	Old	23.24 (0.84)	23.28 (0.87)	23.09 (1.12)	23.15 (1.13)	23.05 (1.29)	23.12 (1.32)
P13-N23 interval (ms)	Young	5.93 (1.61)	6.31 (1.66)	5.72 (1.58)	6.01 (1.57)	5.55 (2)	6.29 (1.95)
	Middle	6.14 (1.72)	5.75 (1.65)	6.26 (1.95)	5.4 (1.61)	5.84 (1.69)	5.91 (1.85)
	Old	6.02 (1.63)	5.98 (1.76)	6.03 (1.66)	5.96 (1.61)	5.98 (1.59)	6.05 (1.81)
Peak to peak amplitude (µv)	Young	41.93 (22.61)	36.38 (22.04)	43.85 (26.20)	35.95 (26.94)	39.48 (20.54)	32.19 (19.52)
	Middle	27.23 (16.84)	21.55 (12.70)	28.31 (13.53)	25.12 (13.56)	30.05 (16.26)	26.21 (12.33)
	Old	20.9 (9.74)	18.58 (8.97)	22.58 (11.47)	19.15 (9.03)	24.12 (10.23)	21.39 (8.34)
Amplitude ratio (%)	Young	13.02 (9.23)	15.32 (10.17)	13.65 (9.95)	14.17 (10.31)	14.4 (9.74)	17.10 (10.68)
	Middle	14.04 (9.43)	14.54 (9.40)	14.8 (9.17)	15.30 (9.53)	15.76 (10.18)	16.26 (10.35)
	Old	13.41 (7.74)	14.76 (8.75)	14.79 (8.54)	15.62 (8.66)	13.79 (8.82)	14.27 (9.12)

Table 3. The Intraclass correlation coefficient of cVEMP parameters, with and without integrated visual feedback across different age groups.

Category	Age group	P13 latency	N23 latency	P13-N23 interval	Peak to peak amplitude	Amplitude ratio
With integrated visual feedback	Young adult	0.71	0.79	0.75	0.81	0.72
	Middle adult	0.69	0.8	0.74	0.79	0.7
	Old adult	0.62	0.77	0.69	0.73	0.66
Without integrated visual feedback	Young adult	0.7	0.8	0.67	0.7	0.67
	Middle adult	0.66	0.77	0.73	0.65	0.62
	Old adult	0.64	0.7	0.68	0.59	0.65

Table 4. The mean and standard deviation of oVEMP parameters across different age groups across three different sessions.

oVEMP parameter	Age group	Session 1	Session 2	Session 3
		Mean (SD)	Mean (SD)	Mean (SD)
N10 Latency (ms)	Young	11.15 (1.16)	11.28 (1.30)	11.22 (0.98)
	Middle	11.80 (1.24)	11.80 (1.21)	11.73 (1.05)
	Old	13.43 (1.82)	14.04 (2.20)	13.55 (1.74)
P15 Latency (ms)	Young	16.37 (1.01)	16.64 (1.13)	16.87 (1.30)
	Middle	16.76 (1.18)	16.53 (1.23)	16.54 (1.47)
	Old	18.32 (1.91)	18.56 (1.81)	18.42 (2.05)
N10-P15 Interval (ms)	Young	5.22 (1.07)	5.36 (1.18)	5.65 (1.31)
	Middle	4.96 (0.94)	4.73 (1.07)	4.81 (0.89)
	Old	4.89 (1.25)	4.52 (1.27)	4.87 (1.49)
Peak to peak Amplitude (μV)	Young	7.62 (2.68)	7.46 (2.90)	7.55 (3.14)
	Middle	6.00 (2.29)	6.17 (2.39)	6.62 (2.37)
	Old	5.14 (2.47)	4.96 (2.33)	4.92 (2.41)
Amplitude ratio (%)	Young	17.68 (6.29)	17.60 (5.96)	16.43 (6.44)
	Middle	13.88 (7.51)	12.54 (5.70)	13.53 (6.88)
	Old	13.42 (8.57)	15.13 (8.20)	14.19 (9.59)

Table 5. The intraclass correlation coefficient of oVEMP parameters across different age groups.

Age groups	N1 latency	P1 latency	N1-P1 interval	Peak to peak amplitude	Amplitude ratio
Young	0.71	0.8	0.81	0.86	0.69
Middle	0.69	0.8	0.7	0.84	0.7
Old	0.67	0.82	0.71	0.72	0.63

in the middle and old adult groups, it showed a fair to good reliability. Reliability of peak to peak amplitude was excellent in the young and middle adult groups as compared to the old adult group which showed only a fair to good reliability. Amplitude ratio showed a fair to good reliability across the different age groups. Table 5 shows ICC co-efficient of oVEMP parameters across the young, middle and old adult groups.

DISCUSSION

P13 and P13-N23 interval latencies showed a fair to good reliability with and without integrated visual feedback system in all age groups, except P13-N23 interval latency in the young adult group without an integrated visual feedback system. Similarly, N23 latency showed excellent reliability across different age groups except in the old adult group without an integrated visual feedback system. Comparable reliability measures were also demonstrated[11]. In their study, SCM muscle contraction was monitored on a computer screen as feedback, and their results indicated a fair to good reliability for P13, excellent reliability for N23 latency and P13-N23 interval latency. Another similar study reported reliability measures which varied from fair to good to excellent for P13 and N23 latencies[12]. A good to excellent reliability scores for latencies recorded monaurally from bilateral SCM muscle with the use of feedback mechanism. They also reported good reliability for P13 and N23 latencies when simultaneous recording of cVEMP was done from left and right ear together with monaural and binaural stimulation[7]. Another study with the feedback method showed excellent reliability for P13 and N23 latencies[6,13]. No significant difference in P13 and N23 latencies across three different sessions for tone burst stimuli[14]. In contrast, studies have reported poor reliability for latencies P13 and fair to good reliability for N23[8,15]. The above mentioned slightly lower reliability for latencies of cVEMP parameters may be due to small sample size and the longer testing gap between the first and the second/third testing.

With regard to peak to peak amplitude, an excellent or near excellent reliability was obtained for cVEMP response with an integrated visual feedback system in all age groups. Without integrated visual feedback system showed a fair to good reliability obtained for all the age groups. Overall peak to peak amplitude with integrated visual feedback showed higher reliability than without integrated visual feedback. In concurrence with the present research, studies have shown excellent reliability for peak to peak amplitude with an electromyographic monitoring system[7,8,11-13]. Peak to peak amplitude reliability was more with monitoring of SCM muscle contraction than without[8] . Results of the present study also show a similar trend across the age groups.

The present study showed a fair to good reliability for amplitude ratio with and without integrated visual feedback system across the age groups. Similar to the present research, a fair to good reliability for amplitude ratio was obtained with and without electromyographic monitoring using tone burst stimuli[8]. In contrast, amplitude ratio showed poor reliability with visual feedback system[12,15]. The disparity in the present and previous research may be due to the protocol used for recording, which was different in terms of the type of stimuli used (click or tone burst), type of electromyography monitoring system, stimulus duration (4-10 ms), etc.

The current study showed a fair to good reliability for N10 and excellent reliability for P15 latencies across different age groups. In addition, excellent reliability in the young adult group and fair to good reliability in the middle and old adults groups were observed. Studies had reported fair to good reliability for N10 latency and excellent reliability for P15 latency[16,17]. Piker et al. had reported fair to good reliability for N10 and P15 latencies[18]. In contrast, Nguyen et al. reported poor reliability for N10 latency and fair to good reliability for P15 latency[15]. Amidst such controversial results regarding oVEMP latencies, the present research showed fair to good or excellent reliability for oVEMP latencies. The differences in reliabilities for latencies may be due to the type of stimuli (air conduction, bone conduction, forehead taps and vibration), stimulus duration (4-10 ms), testing position (sitting or lying down), and the location of electrode placement between sessions.

The present research showed excellent reliability for peak to peak amplitude in the young and middle adult groups, and in the old adult group, it showed fair to good reliability. In concurrence with the present research, excellent reliability for peak to peak amplitude of oVEMP response has been mentioned in the literature[9,10,16,17]. The excellent reliability of peak to peak amplitude might be because the oVEMP response is an excitatory potential, rather than an inhibitory potential like the cVEMP, which is measured in the midst of comparatively minimal background noise from the extra-ocular muscles. Another reason to obtain excellent reliability of peak to peak amplitude of oVEMP may be due to the small surface area of the cheek, posing difficulty in the optimal placement of the electrode between the sessions. The old adult group showed only a fair to good reliability, probably due to the lack of consistency in the inferior oblique muscle contraction between the sessions.

Present research showed fair to good reliability for amplitude ratio across different age groups. There was variation in amplitude ratio across the age groups. There are few studies which also report fair to good reliability for amplitude ratio of oVEMP response[9,10]. A study has reported fair to good reliability for amplitude ratio with monaural oVEMP, and excellent reliability for binaural oVEMP recording. The better reliability for binaural oVEMP amplitude ratio may be due to the ease of maintaining bilateral inferior oblique muscle contraction, and in a monaural condition, it is not easy to maintain muscle contraction at a similar level between sessions[17].

Present study reported similar test-retest reliability as of previous literature of cVEMP and oVEMP. Hence, it is suggested that both cVEMP and oVEMP testing can be utilized for clinical evaluations as they show fair to good to excellent reliability across different age groups. However, due to different protocols and norms utilized at different laboratories, the latency and amplitude measures might show deviations from the standard values. Therefore norm specific evaluation for these responses can further strengthen the reliability of the tests which will aid in the identification of vestibular disorders.

CONCLUSION

The reliability of cVEMPs and oVEMP has similar findings that have been reported in literatures. Reliability was acceptable for both cVEMPs and oVEMP response parameters. Thus it can be concluded from the current research that cVEMP and oVEMP testing procedures are reliable in the young, middle and old adult groups during and between test recordings.

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