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Efficacy of subjective and objective test for assessing vestibular disorder

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Abstract
Dizziness is an unpleasant and debilitating symptom which affects daily activities and participation of individual with dizziness. Assessment of individual with dizziness includes, taking a detailed case history and administering some formal and informal test. The informal test is extensively used since many years at bedside and vestibular clinics such as; Fukuda test, Romberg test. However, VEMP is a recent advancement in assessment, which include both cVEMP and oVEMP. Despite the fact that clinician are using these test enormously, there is a dearth of literature available regarding the combined effect and its usefulness of Fukuda, Romberg and VEMP. Therefore, the current study was designed to investigate the usefulness of Fukuda and Romberg test in investing the person with vestibular dysfunction.
Need of the study: To check the accuracy of subjective and objective test for vestibular disorder.
Aim: To see the usefulness of Fukuda and Romberg test in evaluating vestibular pathology over cVEMP and oVEMP.
Methods: A comparative study was carried out. A total 40 participants ranging from 30 to 60 years were included in the study. Two groups were included, which were aging divided into two different group age range with 20 participants. Group I consisted of 20 participants with normal hearing sensitivity, without any symptom of vestibular disorder and no significant medical history. Group II consisted of 20 participants with a complaint of dizziness. Initial, a detailed audio vestibular evaluation was carried out having a detailed case history, pure tone audiometry to interpret the type and degree of hearing loss and Immittance evaluation along with reflexometery to rule out if any middle ear pathology and retro cochlear pathology respectively. Selected participants had undergone Fukuda test, Romberg test, Cervical vestibular evoked myogenic potentials and Ocular vestibular evoked myogenic potentials.
Results and Conclusion: Results of the present study affirmed that, there was significant deviation seen on the Fukuda test between the group I and group II as per the norms available. In the cVEMP, latency p13 & n23 and the amplitude was calculated and compared between Group I and group II. The results revealed that statistically no significance for latency and for amplitude there was statistically significance difference was observed. Similarly, in oVEMP latency n10, p16 and amplitude was calculated. It showed statistically difference for the latency but not for the amplitude. Moreover, in the Romberg test the positive sway and negative sway was calculated for the both the groups. The group I was revealed that the negative Romberg and for the group II it was positive Romberg. Which means if the sway was absent than it was considered as a normal Romberg or negative Romberg & if the sway was present than it was observed as an abnormal Romberg or positive Romberg.
Therefore, it can be concluded from the above study that the Fukuda test and Romberg test are useful in test battery for the audio-vestibular evaluation. It should be used along with the formal test like the VEMP. Both subjective and objective test has their own pros & cons, and both are equally important in clinical setup.

Keywords: Dizziness, Romberg test, Fukuda test, cVEMP, oVEMP, p13 & n23, n10, p16

Introduction

The vestibular system is one of the most important organs to detect and control motion in any environment. In humans the labyrinths consist of the cochlea, otolith organs, and semicircular canal. The otolith organs and three semicircular canals (lateral semicircular, anterior semicircular canal, and posterior semicircular canal) forms the vestibular system which reports magnitude and direction of linear and angular motion of the head respectively (Moore, et al., 2001) [38].

The vestibular system is responsible for sensing of the head to maintain postural control and stability of images in the fovea of the retina during that motion. Within the petrous portion of each temporal bone lies the membranous vestibular labyrinth. Each labyrinth contains five neural structures that detect head acceleration: three semi-circular canal and two otolith organs. Three semi-circular canals (horizontal, anterior and posterior) respond to angular acceleration and are orthogonal with respect to each other. The SCCs enlarge at one end to form the ampulla. Within the ampulla, a gelatinous goblet shaped structure called the Capula serve as a barrier separating the semi-circular canal from the vestibule. The saccule and utricle make up the otolith organs of the membranous labyrinth. Sensory hair cells project into gelatinous materials that have calcium carbonate crystals (otoconia) embedded in it, which provide the otolith organs with an inertial mass. The presence of otoconia increases the specific gravity above that of the endolymph.

Dizziness is an unpleasant disturbance of spatial orientation or erroneous perception of movement. It is a broad term which includes light headedness, unsteadiness, ataxia, syncope, giddiness, wooziness and vertigo. Hall and Muller (1997) have summarized the inner ear disorder that causes vertigo. It includes Meniere’s disease (MD), infective labyrinthitis, autoimmune labyrinthitis, otosclerosis, benign paroxysmal position vertigo (BPPV), ototoxic perilymph fistula.

Dizziness may also occur to disease of VII cranial nerve including vestibular neuritis (VN) and acoustic neuroma. Similarly, Desmond (2004) reported that the causes of dizziness can range from benign self-limiting conditions to potentially life-threatening conditions. The causes may be otologic, neurologic, cardiovascular, psychiatric, orthopedic, ophthalmologic, or side effect of medicine and diet. Moreover, there are many central neurological disorders such as multiple sclerosis, post meningitis and post encephalitis neurological disorder, cerebrovascular disorder, migraine which may also cause giddiness other causes are head injury, syphilis, tuberculosis, Ramsay Hunt syndrome, anemia, hyperviscocity, heart failure, hypoglycemia, hyperventilation, degenerative neurological disorder, skull base abnormality, Paget’s disease, medication, toxin, fistula, stroke, cholesteatoma.

Thus, these persons with vestibular disorder need a detailed audio-vestibular evaluation. The test battery that can be used for diagnosis of vestibular disorder include a detailed history, clinical test such as Otoscopic evaluation, cranial nerve examination, standing test, walking test, Fukuda’s stepping test, past pointing test, Fukuda’s writing test, Romberg’s test, Vergence test, test for coordination, Head impulse test, Head shaking nystagmus test and Babinski-waill test etc. Whereas, some formal investigation such as Electro-nystagmogrphy (ENG), videonystagmogrphy (VNG), Craniocorogrphy (CCG), Computerized dynamics posturography (CDP), and vestibular evoked myogenic potentials (VEMP) should also be used in the diagnosis of vestibular disorder. The neuroimaging studies can also help to differentiate and make proper diagnosis in most individual with dizziness. However, sensitivity and specificity of the entire mentioned test needs to be considered while choosing the test battery for in today clinic.

Need of the study

To check the accuracy of subjective and objective test for vestibular disorder.

Aim

To see the usefulness of Fukuda and Romberg test in evaluating vestibular pathology over cVEMP and oVEMP.

Objectives

- To investigate angle of deviation on Fukuda test on person with normal and abnormal in vestibular functioning.
- To assess Romberg test on person with normal and abnormal in vestibular functioning.
- To compare and investigate if Fukuda and Romberg are interdependent related to assess normal and abnormal.
- To compare the latency with amplitude of cVEMP on person with normal and abnormal vestibular function.
- To compare the latency with amplitude of oVEMP on person with normal and abnormal vestibular function.

Methodology

Participants

The 40 participants age ranging between 30 to 50 years included in this study, of with 20 participants are control/normal group (group-1) and second group of 20 participants were with the complaint of dizziness (group-2). The mean age was 37.12 years.

Participant’s selection criteria for the both the groups were as follows

Inclusion criteria: Normal

Group I

- Age range 30-50 years
- Individual with hearing loss i.e. pure tone average (500Hz, 1000 KHz, 2000 KHz) less then equal to 25.
- Individual with no history or complaints of vertigo or dizziness in 1 year.

Exclusion criteria: Normal

Group I

- Individual undergoing treatment for dizziness since last 1year
- Any known history of cognitive and language problem
- Any known history of any otological or neurological problems
- Any known history of retrocochlear pathology

Inclusion criteria: Abnormal

Group II

- Age range 30-50 years.
- Individual with normal hearing sensitivity or any degree of sensorineural hearing loss.
- Individual with the complaints of dizziness.

Exclusion criteria: Abnormal

- Person diagnosed as diplopia.
- Person who has undergone cardiac surgery.
- Individual with history of cognitive and language problem.

Instrumentation

- Calibrated 2 channel Madson OB9-22 Diagnostic audiometer with TDH 39 head phones, B71 bone vibrator.

- Calibrated Amplaid A756 Immittance meter.
- Calibrated Labat Epic- Plus vestibular evoked myogenic potentials system, software version 1.0.0.478 with matched TDH 39 headphones.
- Fukuda Mat
- Video Camera
- Stopwatch
- Compass

Ethical consideration

Participants were explained about the study in details both verbally and by using a printed participant's information sheet. A written consent was taken from each participant in the study.

Test environment

All the tests were carried out in acoustically treated room with adequate lighting. The ambient noise level was within the permissible limits as recommended by ANSI (S3.1. 1991).

Test procedure

Firstly, on the selected participants following audiological test battery was performed.

- Otoscopic will be done for all the participants.
- Pure tone threshold will be assessed using the modified Hughson Westlake method (Carhart and Jerger, 1959) [39] for air conduction stimuli from 250 Hz-8000 Hz and for bone conduction stimuli from 250 Hz-4000 Hz.
- Tympanometry for 226 Hz probe tone was done for all subjects, ipsilateral and contralateral acoustic reflex threshold were obtained for 500Hz, 1 KHz, 2 KHz, and 4 KHz for all the participants.

After the completion of basic audiological test battery, Fukuda test, Romberg test/ sharpened Romberg test and the vestibular evoked myogenic potential [VEMP] were carried out.

Fukuda / Unterbuerger's Test

In the stepping test, described by Fukuda (1958) [40], which was modification of the Tretversuch test, originally described by Unterberger (1938) [41] will use. In this test the participants will asked to extend his arms, close eyes and step on same spot (grid) alternately with each foot for 100 times. The clinician remained at the sides to protect the participants from falling. through the participants will instructed to step on same spot, yet due to the walking reflex, the participants usually moved forward and backward for 1-2 meters while stepping. The starting and the end point will mark on the floor and the amount of rotation, deviation and sway are assessed.

Test will be terminated if the participants fall down, and the direction of fall is recorded. Fukuda (1958) [40], recommended that Moffat stepping mat should be used which is made up of a thin smooth rubber the proprioception inputs. Thus, for the present a foam-based mat will prepare for Fukuda testing which will be concentric round in shape and have a diameter of 100cms, and 4.5 inches of thickness. It was made such a way that the proprioception was reduced or had no effect. The concentric circle were divided into degree i.e. 0º, 30º, 45º, and 90º on both sides, to mark the degree of deviation. A small circle was made in between to refer as a starting point where the patient was instructed to perform the test Based on the deviation (left or right side) and degree of rotation, diagnosis was given.

Romberg Test

The Romberg test quantifies the ratio of sway with the eyes closed to sway with eyes open.

Romberg Ratio= (Sway closed/Sway open)

A ratio of greater than 1 indicates that sway increase with the eye closed, whereas a ratio of less than 1, indicates a decrease in sway with the eye closed. The test is performed by instructing the patient to stand with eyes open, the feet together (to narrow the base of support), and arms crossed across the chest with the palm of each hand placed on the opposite side of shoulder. Postural stability should be assessed by examiner while the patient's eyes are open. Direction and amplitude of sway should be recorded. The patient should than be instructed to closed the eyes and maintain the current posture. It is important to assure the patient that they will support by examiner when the eyes are closed. Changes in postural stability, direction of sway, and/or direction of fall are then noted by the examiner when the eyes are closed.

Interpretation

- **Normal:** The patient should be able to maintain a standing position with eyes closed for approximately 30 seconds without falling to either side and without marked in sway.
- **Abnormal:** When the eyes are closed the patient will exhibit a marked increase in sway, and may stagger or fall. The patient should also consider abnormal if the patient moves their feet from the original standing position or moves their hands from the shoulder. These results are consistent with a loss of proprioceptive input from the lower limbs.

Vestibular evoked myogenic potentials

Recording of Cervical vestibular evoked myogenic potential (cVEMP)

Procedure

Participants were asked to sit erect on chair. The electrode sites were first cleaned using skin preparing gel to get good impedance. Then the electrodes were secured in place using disposable electrode. The non-inverting electrode will place on the middle third of anterior neck muscle {sternocleidomastoid}. Inverting electrode on the sternum and ground on the forehead.

Further, the insert ear phones will be placed in the ears of the participants. Finally, participants were asked to turn their neck to the right or left side, one side at a time so as to tense the sternocleidomastoid (SCM) muscle and pointer will placed on the participants shoulder as a reference.

Later the impedance will be monitored once the low impedance will achieved, acoustically evoked VEMPs will be recorded using the protocol given in table 2. Two trials were taken to check the reliability and were stored in the computer. Rest time about 1 minute was given so as to relax the muscle tension after every trial.

Recording of the Ocular vestibular evoked myogenic potentials (oVEMP)

Ocular VEMP were recorded from both the ears of all participants. For recording oVEMP, participants were instructed to sit in upright position. A skin preparing gel was used to scrub the electrode sites band gold plated electrode were placed with the help of conduction paste and surgical plaster. The non-inverting electrode was placed 1 cm below the center of the lower eye lid, the inverting electrode 2 cm below the non-inverting electrode and the ground electrode on the lower forehead. This electrode placement is similar to those used previously (Rosengren et al, 2005; Chihara et al, 2009) [42, 10].

The absolute and inter electrode impedance were maintained below 5 KΩ and 2 KΩ respectively. The contra lateral stimulation was given with the same protocol followed as that for cVEMP. The participants were asked to maintain upward gaze during recording because response is the largest at this gaze position. The subjects were asked to relax in between the subsequent acquisition to avoid fatigue. 200 sweeps were recorded for each run. They were also asked to maintain their gaze at angle of approximately 45 degrees with the neck held straight. This angle was monitored by the clinician throughout the testing.

The stimulation and recording of cVEMP and oVEMP was carried out unilaterally. Test and retest reliability will be checked for both cVEMP and oVEMP by taking reruns on every subject while testing on the first occasion and on 5% of the sample by retesting them on later date.

Results and Discussion

The present study was aimed at findings the usefulness of Fukuda and Romberg test in identifying patient with vestibular dysfunction over the cVEMP and oVEMP. Two groups were included in the study. Group I consisted of 20 normal individuals (without complaint of dizziness) whereas, in group II 20 abnormal individual (with the complaint of dizziness) were included.

The degree of deviation for Fukuda test and Romberg were subjectively calculated. Whereas the value using latency and amplitude measures for p13 and N23 of cVEMP and N10 and P16 for oVEMP were determined. Data obtained were tabulated & Statistical Package for Social Sciences (SPSS) software version 20 was used to carry out the statistical analysis to attain objectively of the study.

Following Statistical measure was used

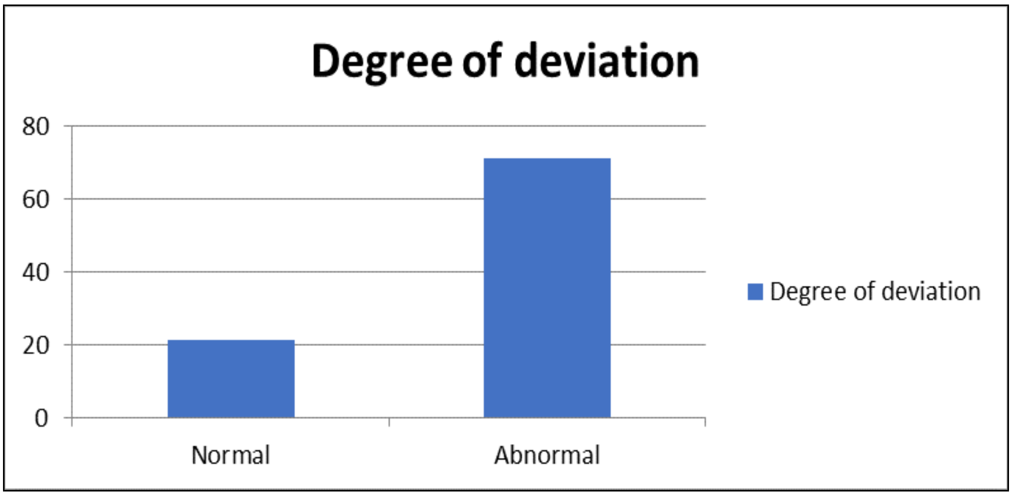
- Descriptive statistic (Mean and standard Deviation).
- Independent t-test.

The first objective of the study was to investigate and compare the angle of deviation on Fukuda test in person with dizziness. To achieve the first aim of the study descriptive statistic was used to determine the mean & standard deviation.

Table 1: Mean & standard deviation values of degree of deviation parameter of Fukuda test in Group I and Group II

Parameter	Mean		Standard Deviation	
Degree of Deviation	Group I	Group II	Group I	Group II
	21.33°	71.36°	6.935°	97.41°

Note: M-Mean, SD-Standard Deviation



It can be noted from the above that the degree of deviation in group I showed a mean value of 21.33° (SD± 6.935). Whereas, for the group II the mean value was 71.36° (SD± 97.41) as shown in table 1. Thus, it suggested that, degree of deviation for group II was higher than group I irrespective of side.

The second objective of study was to investigate the Romberg test in person with dizziness.

Table 2: Positive sway and negative sway of Romberg test in group I and group II

Parameter	Group I	Group II
Positive/Negative	Negative	Positive

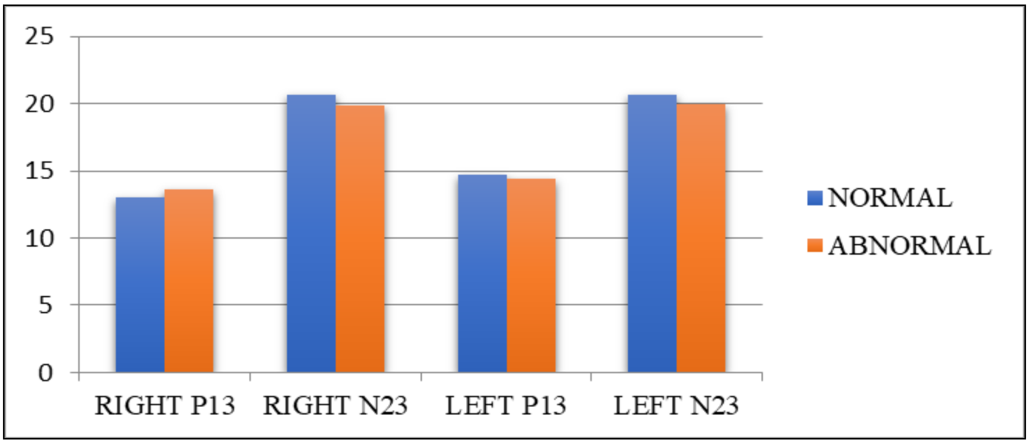
It can be noted the above that the group I showed the negative sway of Romberg which indicated that within normal Romberg. Similarly in II group it indicates that the positive sway of Romberg which means abnormal sign of Romberg.

The third objective of the study was to investigate and compare the latency of cVEMP and oVEMP in person with Dizziness. To achieve this aim independent sample't' test for Equality of variances was applied along mean and standard deviation.

Table 3: Mean and standard deviation values of latency of cVEMP in group I and group II

	Group I		Group II	
Parameters	**Mean**	**SD**	**Mean**	**SD**
Right p13	13.00	1.170	13.60	1.314
Right n23	20.65	2.134	19.85	2.033
Left p13	14.70	2.849	14.40	2.326
Left n23	20.65	2.477	19.95	2.605

Note: M-Mean, SD-Standard Deviation



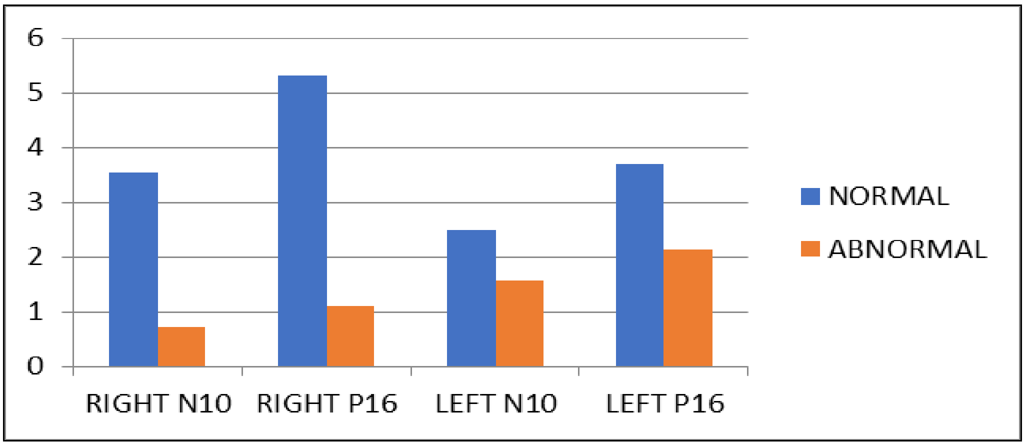
The mean values for the cVEMP latencies of p13 and n23 of right were 13.00 msec (SD ± 1.170) and 20.65 msec (SD ± 2.13) respectively for group I. whereas, it was 13.60 msec (SD ± 1.314) for p13 and 19.85 msec (SD ± 2.033) for n23 latencies of right for group II. Similarly, the mean of group I for left p13 and n23 latencies were 14.70 msec (SD±2.849) and 20.65 msec (SD± 2.477) respectively. However, for left ear it was found to be 14.40 msec (SD±2.326) and 19.95 msec (SD ± 2.605) for p13 and n23 latency as shown in table 3. Therefore, it can be observed that the mean and standard deviation of latencies of cVEMP for the group I are similar to group II.

On other hand the mean latency of n10 and p16 of the oVEMP was also calculated.

Table 4: Mean and standard deviation values of latency of oVEMP in group I and group II

	Group I		Group II	
Parameters	**Mean**	**SD**	**Mean**	**SD**
Right n10	3.53	5.09	0.73	2.8
Right p16	5.30	7.63	1.10	4.20
Left n10	2.50	4.62	1.57	4.07
Left p16	3.70	6.83	2.23	5.81

Note: M-Mean, SD-Standard Deviation



The mean of n10 & p16 latencies for right of group I was 3.53 msec (SD± 5.09) and 5.30 msec (SD ± 7.63) respectively. Whereas, it was 0.73 msec (SD ± 2.8) for n10 and 1.10 msec (SD±4.20) for p16. Similarly, the mean latency for left n10 and p16 was 2.50 msec (SD± 4.63) and 3.70 msec (SD± 6.83) respectively for group I and 2.23 msec (SD± 5.81) for group II as shown in table 4. Thus, it can be seen that the mean and SD for group I was higher as

compared to group II.
Further, to find the difference the right and left latency parameters of cVEMP. Independent'‘t’ test was applied. Values are given in Table 5.

Table 5: The ‘t’ value & ‘p’ value of cVEMP parameters for group I and group II

Parameters	‘T’	DF	Level of significance *(P)*
Right p13	1.525	38	$p>0.05$
Right n23	1.214	38	$p>0.05$
Left p13	.365	38	$p>0.05$
Left n23	.871	38	$p>0.05$

Note: P is not significant at >0.05 at level

As observed in the table 5 it is evident that the p value for both the groups are not significant. Whereas, no significant difference was found in both the groups of parameters *viz*: right p13, n23 and left p13, n23. The t value obtained for the parameters were p13 [t (1, 38)=1.525, $p>0.05$], and n23 [t (1, 38)=1.214, p>0.05] for the right. Similarly, for the left p13 [t (1, 38)=.365, p>0.05] and n23 [t (1, 38)=.871, $p>0.05$] latencies. To study the significant difference between the right and left latency parameter of oVEMP, independent sample‘t’ test was applied. The values are given below in table.

Table 6: ‘T’ value and *‘p’* value of oVEMP parameter for group I and group II.

Parameters	‘T’	DF	Level of Significance *(P)*
Right n10	2.63	58	0.01**
Right p16	2.63	58	0.01**
Left n10	0.83	58	0.41
Left p16	0.89	58	0.37

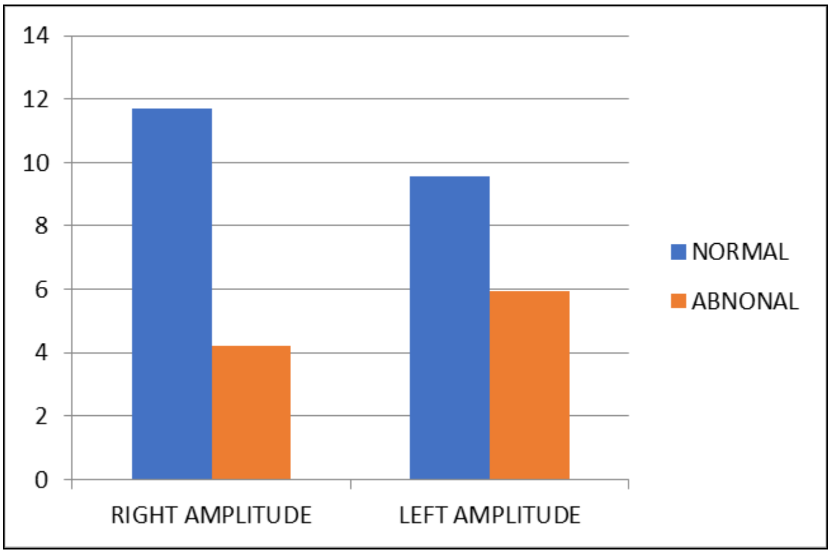
** P is highly significant at 0.05 level

From the table it evident that the p value for right latencies of n10 & p16 was less than 0.05 level of significance. Thus, suggesting significant difference between two groups for right side. However, no significant difference was obtained for the latency on the left side. The t values obtained for parameter of oVEMP latency were *viz*: n10 [t (1, 58) =2.63, $p\leq 0.01$], p16 [t (1, 58)=2.63, $p\leq 0.01$] for the right, similarly for the left n10 [t (1,58)=0.83, $p>0.05$] and p16 [t (1, 58)=0.89, $p>0.05$].
Similarly, the fourth objective to investigate and compare the amplitude of cVEMP and oVEMP in person with dizziness. Independent Sample‘t’ test with Levene’s test for equality of variances was applied along with mean and standard deviation.

Table 7: Mean and Standard Deviation values of amplitude of cVEMP in Group I and Group II

	Group I		Group II	
Parameters	**Mean**	**SD**	**Mean**	**SD**
Right Amplitude	11.70	7.263	4.20	2.895
Left Amplitude	9.55	4.524	5.95	5.385

Note: M-Mean, SD-Standard Deviation



The mean value for the right amplitude was 11.70µV (SD± 7.263) whereas for the left was 9.55µV (SD±4.524) for group I. Similarly, the mean for the group II was 4.20µV (SD±2.895) and 5.95µV (SD±5.385) for the right and left amplitude. It was studied that the amplitude in the group I was considerably higher than group II. When right compared with left amplitude. It was found that the left side amplitude was higher for both the group than right side. It revealed that amplitude was reduced for participants in group II.

Similarly, the mean and SD was calculated for the amplitude of oVEMP given in table.

Table 8: Mean and Standard Deviation values of amplitude of oVEMP in group I and group II

	Group I		Group II	
Parameters	**Mean**	**SD**	**Mean**	**SD**
Right Amplitude	0.73	1.94	1.23	4.71
Left Amplitude	0.33	0.75	0.23	0.77

Note: M-Mean, SD-Standard Deviation

It was evident that the amplitude for the right oVEMP was 0.73µV (SD ± 1.94) for the group I, whereas for group II the mean was 1.23µV (SD± 4.71). Similarly, for the left it was 0.33µV (SD± 0.75) and 0.23µV (SD± 0.77) group I and II respectively as shown in table. In the present study it was observed that the amplitude of the right oVEMP was higher than the left.

Additionally, to study the difference between the right and left amplitude parameter of cVEMP. Independent Sample't' test was applied. The values are given in table 8.

Table 9: The't' values & 'p' values of cVEMP amplitude parameters of group I and group II

Parameters	'T'	DF	Level of significance *(p)*
Amplitude, Right p13 & n23	4.290	38	$p<0.01$*
Amplitude, Left p13 & n23	2.007	38	$p<0.05$

*P is highly significant at 0.01 level

It was evident that there is statistically significant difference present between the two groups of amplitude of right and left p13 and n23. The't' value for the right amplitude was [t (1, 38) =4.290, $p \leq 0.01$], whereas for the left it was [t (1, 38)=2.007, $p<0.05$].

Similarly, to calculate the difference between the left and right amplitude parameters of oVEMP independent Sample't' test was applied.

Table 10: The't' value & 'p' value for amplitude of oVEMP parameter for group I and group II

Parameter	'T'	DF	Level of Significance (p)
Amplitude (Right n10 & p16)	0.53	58	0.59
Amplitude (Left n10 & p16)	0.50	58	0.61

It can be seen that The't' value for amplitude of n10 & p16 for the right side is [t (1, 58)=0.53, $p>0.05$], whereas, for the left side it was [t (1, 58)=0.50, $p>0.05$]. This clearly shows that p values for both ears and amplitude for both groups are higher than 0.05 significance level. Thus, this indicated no significant difference for both amplitude parameters. The possible reason for this could be the variation in the angle of gaze during testing. Through the clinician tried monitoring the angle of gaze during testing, the possibility of deviation could not be ruled out.

Conclusion

Statistical analysis was performed by using the SPSS software version 20, to investigate the objective of study.

Results of the present study affirmed that, there was significant deviation seen on the Fukuda test between the group I and group II as per the norms available. In the cVEMP, latency p13 & n23 and the amplitude was calculated and compared between Group I and group II. The results revealed that statistically no significance for latency and for amplitude there was statistically significance difference was observed. Similarly, in oVEMP latency n10, p16 and amplitude was calculated. It showed statistically difference for the latency but not for the amplitude.

Moreover, in the Romberg test the positive sway and negative sway was calculated for the both the groups. The group I was revealed that the negative Romberg and for the group II it was positive Romberg. Which means if the sway was absent than it was considered as a normal Romberg or negative Romberg & if the sway was present than it was observed as an abnormal Romberg or positive Romberg.

Therefore, it can be concluded from the above study that the Fukuda test and Romberg test are useful in test battery for the audio-vestibular evaluation. It should be used along with the formal test like the VEMP. Both subjective and objective test has their own pros & cons, and both are equally important in clinical setup.

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