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A Study on Cervical and Ocular Vestibular Evoked Myogenic Potential Measures in Jugglers

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ABSTRACT

Background: VEMP is a relatively diagnostic tool that is used for assessing the functioning of the inferior vestibular nerve and the structures it innervates. VEMP is recorded from tonically contracted neck muscle and from inferior extraocular muscles of the eye by acoustic stimulation are referred to as cervical VEMP (cVEMP) and ocular VEMP (oVEMP).
Need of the study: VEMP has been utilised as a good tool to assess the sacculo-collic pathways. Therefore, there is a need to study the VEMP as a tool to assess the plasticity in the sacculo-collic pathway. However, there is a dearth of information regarding the effect of juggling training on vestibular system, so, there is a need to study whether the training improves the neurophysiologic responses from the utricle and saccule. The present study aimed to find out the differences between cVEMP and oVEMP parameters in jugglers and nonjugglers.
Method: Total 60 participants divided into two groups such as jugglers and nonjugglers were studied for cVEMP and oVEMP in terms of latency, amplitude, interamplitude ratio and threshold. Latency was studied for P13 and N23 peaks in milliseconds. Amplitude was studied in microvolts and thresholds were studied in terms of intensity. Data was calculated separately for right ear and left ear in different intensities for cVEMP and oVEMP in terms of mean, standard deviation and effect size. The data was analysed by SPSS software version 25.0 (Windows CJ278ML, IBM computers Pvt. Ltd, 2017). For normality analysis of data, Shapiro wilk test was done. Between groups analysis was done using Wilcoxon signed rank test and Mann Whitney U-test at 95% confidence interval.
Results: The results suggested lower latencies, delayed amplitudes and equal in thresholds for both the groups. When comparison was done between the groups, the juggler group had better results in comparison to nonjuggler group. cVEMP had lower latencies and reduced amplitudes for jugglers than nonjugglers.
Conclusion: The findings of the study showed the Jugglers group had significant better result than nonjugglers group in terms of parameters of cVEMP.

Key word: cVEMP; oVEMP; jugglers.

INTRODUCTION

Juggling is a physical skill performed by a juggler involving manipulation of objects for recreation, entertainment, and art. The temporal constraints on juggling are elegantly summarized by Shannon’s theorem (1993). Juggling includes the trick of balancing an object which may create an impact on the vestibular system.

In 2009 the UK researchers published a paper and demonstrated physical skill, juggling can increase not only grey matter but also white matter (Scholz et. al., 2009). Vestibular nucleus neurons contribute to a variety of circuits that are responsible for initiating compensatory movements of the eyes, head and body in addition to providing information about head direction to forebrain circuits and for signalling postural changes to the autonomic nervous system.

Remarkable plasticity occurs in the vestibular system throughout life. Behavioural analyses of vestibular plasticity have focused primarily on the vestibulo-ocular reflex (VOR), which enables retinal images to remain stable during head motion by driving compensatory eye movements. Vestibular evoked myogenic potential (VEMP) is a relatively new diagnostic tool that is used for assessing the functioning of the inferior vestibular nerve and the structures it innervates. Colebatch and colleagues (1994) in Sydney, Australia, first reported systematic clinical investigation of “myogenic potentials generated by click evoked vestibulocollic reflex,” also referred to by the authors as “vestibular evoked potentials”. Robertson and Ireland (1995) apparently coined the specific term “vestibular evoked myogenic potential” abbreviated VEMP and were first described by Bickford et al., in 1964.

VEMP is recorded from tonically contracted neck muscle and from inferior extraocular muscles of the eye by acoustic stimulation which are referred to as cervical VEMP (cVEMP) and ocular VEMP (oVEMP) respectively. It can be used to evaluate the functioning of the peripheral vestibular nerve, as well as central lesions in the vestibuolospinal tract (Lee et al., 2008).Hence, in reference to plasticity there are no such studies about the jugglers. VEMP could possibly measure the plasticity for jugglers. There is a dearth of literature about the jugglers VEMP study. So, different supportive literature like: dancers vs nondancers, drivers vs nondrivers was taken for the study.

Singh, Pandey, & Mahesh (2014) performed a study on functioning of the otolith organ using cVEMP and oVEMP in individuals with motion sickness. These were recorded from 30 individuals with motion sickness, 30 professional drivers and 30 healthy individuals. The results revealed no significant difference in latencies and amplitudes between the groups ($p>0.05$). However, thresholds were significantly elevated and inter-aural asymmetry ratio significantly higher in motion sickness susceptible group ($p < 0.001$) for both the potentials. All the individuals in the motion sickness group had a high asymmetry ratio at least on one of the two potentials. Thus, reduced response or asymmetric otolithic function seem the likely reasons behind motion sickness susceptibility.

Krishnamurty, Brock, & Watts (2015) performed a study on checking the symmetry of VEMP responses across swimmers and non-swimmers. The result showed no significant difference in amplitudes between swimmers and non- swimmers even when corrected for effects of tonic neck muscle activity. Hence the clinical interpretation of these potentials does not appear to be confounded by swimming related asymmetries. Repeated analysis of variance showed no significant difference between interaural VEMP amplitude ($F=3.99$; $P>0.05$) differences (p13- n23). Thus the results signified no significant differences across swimmers and non-swimmers ($F=4.07$; $p>0.05$).

NEED OF THE STUDY:

According to earlier studies practicing the juggling skill has even found to produce changes in specific areas in the brain and affect the neural plasticity of the vestibular system. This study has been conducted in order to find out the changes in plasticity of jugglers and nonjugglers using cVEMP and oVEMP. Many studies have been reported in the literature with reference to change of plasticity in the professionals who require fine motor coordination like dancers (Watson et. al., 2017), swimmers (Krishnamurti et. al., 2015). As there is a dearth of information about the changes and the pattern of changes in the VEMP parameters in jugglers, there is a vivid need of this study.

However, these studies are subjective studies, therefore an objective study is required to evaluate such changes. Also, in a recent study by Lavon et al., (2010), it has been shown that there is a synchronized plasticity not only in the VOR system but also the utricle and the saccule. They recorded the VEMPs to evaluate saccular function and revealed a better latency of VEMP in divers compared to the normal group indicating a better sacculocollic pathway in divers compared to the non-divers which may assume the replica in the juggling scenario. Therefore, this information is fruit for thought to converge the relationship spectrum towards jugglers. Subsequently, in tandem with the above thought it was seen that web searches did not provide any data for jugglers. Thus, there is a need to study VEMP based evidences to compare non jugglers and their counterparts.

METHODS

For this study comparative ex-post facto design & purposive sampling was done on a total of 60 participants divided into two groups of 30 participants each. Group I consist of professionally jugglers & Group II consists of non-jugglers.

Inclusion criteria:

Jugglers	Non-jugglers
Without any cognitive or intellectual difficulties.	Without any cognitive or intellectual difficulties.
Without any hearing impairment.	Without any hearing impairment.
Minimum 10 years juggling experience.	
Age range within 20 - 40 yrs.	Age range should be within 20 - 40 yrs.
Formal training of fine motor coordination.	
Without a history of vestibular dysfunction.	Without a history of vestibular dysfunction.

Resonance r37a dual channel diagnostics audiometer was used for screening hearing status & GSI tympstar pro clinical Tympanometer was used to verify the possibility of a middle ear pathology for both the groups.

Exclusion Criteria:

Jugglers	Non-jugglers
With any disease of muscular dystrophy, motor neuron disease, cervical spondylosis or motor problem in head and neck region.	With a history of vestibular dysfunction or any hearing impairment.
With premorbid history of any neurological disorder.	With premorbid history of any neurological disorder.
Having history of use of alcohol. No intake of alcohol or other recreational drugs at least 24 hours prior to testing.	Having history of use of alcohol. No intake of alcohol or other recreational drugs at least 24 hours prior to testing.
Having history of intake of drugs at the time of testing that may lead to vestibulotoxicity and symptoms of vestibular problem such as vertigo, nausea, giddiness, and blurring of vision.	Having history of intake of drugs at the time of testing that may lead to vestibulotoxicity and symptoms of vestibular problem such as vertigo, nausea, giddiness, blurring of vision in all the participants.
With self-reported low vision and reduced visual acuity were excluded.	With self-reported low vision and reduced visual acuity were excluded.

The study was carried out in Audio-vestibular lab in Ali Yavar Jung National Institute of Speech and Hearing Disabilities (divyanjan), RC, Kolkata from April 2021 to March 2022.For the study IHS 37 Duet (FX2LP) evoked potential instrument with smartEP software version (5.50) manufactured and fitted with insert ER- 3A (04) insert earphones was used. The instrument was calibrated under manufactures specifications.

PROCEDURE:

The study was conducted in six phases

Phase 1: Consent form: Participants were explained basic rationale of the study and written consent were taken from all the participants taking part in the study.

Phase 2: Detailed history taking for jugglers and non-jugglers: Elementary assessment procedure was carried out. Detailed case history of individual was acquired through informal interview.

Phase 3: Administration of cVEMP and oVEMP (10 – 15 minutes for cVEMP and oVEMP)
Phase 4: Measurement of test parameters for cVEMP and oVEMP: The instrument was calibrated under manufacturer's specifications. The protocol of cVEMP and oVEMP were administered differently. Trials of both cVEMP and oVEMP were administered for each participant at different intensity. Test was conducted in a sound treated room (ANSI S3.1 – 1999). Skin preparation was done by cleaning the skin using preparation paste (Nuprep gel) and non-disposable silver chloride cup electrodes with conduction paste (TEN-20) was placed for recording potentials.
Recording of cVEMP was done by instructing the subject to sit relaxed on a chair with pressing his/her chin strongly on the contralateral shoulder. The electrodes were placed at symmetrical sites over the upper half of the Sternocleidomastoid muscle. The active electrode was placed at the upper half of the SCM muscles, the ground at the forehead and the reference electrode at the sternoclavicular junction or the sternal notch. The bandpass filter was set at 30-1500Hz. The stimulus was presented by the ER-3A insert earphone. Repetition rate was 5.1Hz. As a stimulus 500Hz tone burst was used at 90dBnHL. The time window was 200ms for each trial. Each test was taken for 10 to 15 minutes (cVEMP) to perform (Murofushi et al., 1999). 75 – 115 dBnHL intensity was used during testing.
For recording of oVEMP Subjects were instructed to sit in the relaxed position on the chair and were instructed to maintain an upward gaze of 30^{o} above the visual plane as this provides the highest oVEMP amplitude. The ground electrode was placed on the forehead or chin and active electrode was placed just inferior to the eye and reference electrode was placed 2-3 cm below the active electrode. The band-pass filter was set at 10-1000Hz. The air conduction stimulus was provided by ER-3A insert earphone to the contralateral ear. Each test was taken for 10 to 15 minutes (oVEMP) to perform (Manzari et al., 2010). 75 – 115 dBnHL intensity was used during testing.

Parameters setting of cVEMP & oVEMP:

PARAMETERS	cVEMP	oVEMP
Transducer	TDH-39 headphones or ER-3A insert earphone	TDH-39 headphones or ER-3A insert earphone
Type	500Hz tone burst	500Hz tone burst
Ramping	Blackman	Blackman
Duration	2 cycles plateau; 1 cycle rise/fall	2 cycles plateau; 1 cycle rise/fall
Intensity	90dBnHL	90 dBnHL
Polarity	Rarefaction	Rarefaction
Rate	5.1 stim/sec	5.1 Hz stim/sec
Electrode type	Surface (Ag/AgCl)	Surface (Ag/AgCl)
Electrode location	cVEMP	oVEMP
Ground	Forehead	Forehead
Active	Upper half of the SCM muscle	Just inferior to the eye
Reference	At the sternal notch	2-3 cm below the active electrode
Filter settings	30-1500 Hz	10-1000 Hz
Notch	None	None
Amplification	5KHz	5KHz
Sweeps	200	200

The following parameters were measured during cVEMP and oVEMP testing
Latency of the cVEMP and oVEMP.
Amplitude of the cVEMP and oVEMP.
Interaural amplitude difference ratio.
Threshold of cVEMP and oVEMP.
Phase 5: Recording and tabulation of data: The data were recorded and analysed in MS office excel spreadsheet. Separate tabulations were made for cVEMP and oVEMP. SPSS software version 25.0 (Windows CJ278ML, IBM computers Pvt. Ltd, 2017) was used to analyse the data.
Phase 6: Statistical analysis: Shapiro-Wilk test ($p<0.05$) of normality was explored to determine whether the data distributions may fall under normal distribution or not based on probability functions of measured data. Two

types of statistics were used mainly descriptive and inferential statistics.

Descriptive Statistics:

Descriptive statistics was done to calculate the mean standard deviation of cVEMP and oVEMP parameters obtained data from two groups of participants.

Inferential statistics:

1) The nonparametric Mann Whitney U test, the Friedman test, & the Wilcoxon signed rank test were incorporated to compare between the jugglers and non-jugglers on c-VEMP and o-VEMP measures. The whole statistical analysis was done by using SPSS (version 21.0). The significant values were compared with 0.05 or 0.01 level of significance.

This study included 60 no of participants, further divided into two groups' jugglers and nonjugglers. cVEMP and oVEMP was administered on both of this groups and the parameters of this tests were included for the comparison between these two groups of participants.

c- VEMP and o-VEMP parameters were studied as listed below:

Latency of cVEMP (P13, N23)

Latency of oVEMP (P13, N23

Amplitude of cVEMP (P13, N23)

Amplitude of oVEMP (P13, N23)

Interamplitude ratio of cVEMP and oVEMP.

Thresholds measurement.

In the beginning of the descriptive statistic of this study were furnished followed by inferential statistics measured under headings.

RESULTS

Table -1: cVEMP parameters (latency, amplitude, interamplitude, thresholds) of jugglers:

Mean	PEAK	RIGHT		LEFT	
		MEAN	SD	MEAN	SD
LATENCY (ms)	P13	15.81	3.81	18.19	4.76
	N23	22.35	3.42	22.35	3.82
Amplitude (mic. Volt)	P13-N23	67.27	26.27	73.89	32.97
Interaural amplitude ratio (percentage)	P13-N23	MEAN – 14.64 SD – 9.22			
Thresholds	75 - 115	Mean – 95			

Table-1 1showed the accumulated data of (mean & standard deviation) cVEMP parameters of jugglers in both the ears.

TABLE -2: cVEMP parameters (latency, amplitude, interamplitude, thresholds) of nonjugglers:

PARAMETER	PEAK	Right		Left	
		Mean	SD	Mean	SD
Latency (ms)	P13	16.09	1.69	14.1	1.51
	N23	20.42	1.249	17.67	2.32
Amplitude (mic.Volt)	P13-N23	1.59	1.19	1.42	0.81
Inter Amplitude ratio (percentage)	P13-N23	Mean-20.36 SD- 11.96			
Thresholds	75 - 115	Mean – 95			

Table-2 showed the accumulated data ((mean & standard deviation) of cVEMP parameters of nonjugglers in both the ears.

Table – 3: oVEMP parameters (latency, amplitude, interamplitude, thresholds) of jugglers:

Mean	PEAK	RIGHT		LEFT	
		MEAN	SD	MEAN	SD
LATENCY (ms)	P13	15.81	3.81	18.19	4.76
	N23	22.35	3.42	22.35	3.82
Amplitude (mic. Volt)	P13-N23	67.27	26.27	73.89	32.97
Interaural amplitude ratio (percentage)	P13-N23	MEAN – 14.64 SD – 9.22			
Thresholds	75 - 115	Mean – 95			

Table-3 showed the accumulated data ((mean & standard deviation) of oVEMP parameters of jugglers in both the ears.

TABLE – 4: oVEMP parameters (latency, amplitude, interamplitude, thresholds) of nonjugglers:

PARAMETER	PEAK	Right		Left	
		Mean	SD	Mean	SD
Latency (ms)	P13	16.09	1.69	14.1	1.51
	N23	20.42	1.249	17.67	2.32
Amplitude (mic.Volt)	P13-N23	1.59	1.19	1.42	0.81
Inter Amplitude ratio (percentage)	P13-N23	Mean-20.36 SD- 11.96			
Thresholds	75 - 115	Mean – 95			

Table-4 showed the accumulated data (mean & standard deviation) of oVEMP parameters of nonjugglers in both the ears.

Inferential statistics were conducted to evaluate and compare the cVEMP and oVEMP parameters between the two groups of participants.

Table – 5: Latency of cVEMP for both ears for both the groups:

Parameters	Intensity levels	Juggler (n=30)			Non jugglers (n=30)			Mann-Whitney U Test	
		Mean	Median	SD	Mean	Median	SD	|Z|	p-value
P13(ms)(R)	85 dB	12.373	11.850	2.598	14.850	14.850	0.661	4.875	0.000**
	90 dB	13.143	12.500	2.352	15.150	15.150	1.678	4.287	0.000**
	95 dB	16.870	16.800	1.450	16.550	16.550	2.695	0.451	0.652
	100 dB	23.333	23.000	2.529	21.950	21.950	3.509	0.902	0.367
	105 dB	29.773	28.400	5.540	22.450	22.450	6.052	3.383	0.001**
N23 (ms)	85 dB	18.050	18.100	1.416	22.450	22.450	0.051	6.779	0.000**
	90 dB	20.267	20.700	1.927	22.550	22.550	0.356	5.910	0.000**
	95 dB	20.843	20.200	3.362	21.550	21.550	2.187	0.798	0.425
	100 dB	27.090	26.900	1.762	26.650	26.650	2.899	0.113	0.910
	105 dB	33.803	34.300	4.307	23.550	23.550	6.764	5.320	0.000**
P13(ms)(L)	85 dB	9.867	9.700	2.630	13.800	13.800	0.407	4.520	0.000**
	90 dB	12.933	12.200	1.741	14.000	14.000	0.509	2.267	0.023*
	95 dB	15.783	16.300	1.263	15.100	15.100	1.221	2.557	0.011*
	100 dB	17.407	18.000	1.596	16.850	16.850	1.678	1.129	0.014*
	105 dB	21.683	21.800	1.230	19.300	19.300	6.001	0.000	1.000
N23 (ms)	85 Db	13.187	12.500	2.058	22.750	22.750	0.254	6.782	0.000**
	90 dB	17.217	18.200	2.558	23.550	23.550	0.661	6.769	0.000**
	95 dB	19.433	20.500	2.599	20.400	20.400	1.017	0.680	0.011*
	100 dB	25.110	25.550	2.790	23.550	23.550	0.254	3.992	0.000**
	105 dB	25.317	25.700	1.415	21.500	21.500	7.120	0.000	1.000

Table-5 showed the p-value for juggler and non-juggler for P13 & N23 were within the level of 0.05 significance, except at the 95 dBHL and 105 dBHL in right ear & at 105dBHL in left ear. Thus, it was showed that there is a statistically significant differences present between these two groups of participants.

Table – 6: Amplitude of cVEMP for both ears for both the groups:

Parameters	Intensity levels	Juggler (n=30)			Non jugglers (n=30)			Mann-Whitney U Test	
		Mean	Median	SD	Mean	Median	SD	|Z|	p-value
Rt. Amplitude (mic. Volt)	85 dB	88.683	90.550	13.672	113.450	113.450	5.441	6.769	0.000**
	90 dB	49.867	38.200	18.226	69.450	69.450	12.866	3.165	0.002**
	95 dB	48.560	50.800	6.832	47.600	47.600	12.612	0.000	1.000
	100 dB	31.370	32.500	4.283	53.850	53.850	12.358	6.778	0.000**
	105 dB	18.233	15.800	6.615	52.000	52.000	0.000	7.171	0.000**

Parameters	Intensity levels	Juggler (n=30)			Non jugglers (n=30)			Mann-Whitney U Test	
		Mean	Median	SD	Mean	Median	SD	|Z|	p-value
Lt. Amplitude (mic. Volt)	85 dB	62.467	52.800	16.634	110.950	110.950	26.088	5.652	0.000**
	90 dB	54.767	52.400	15.946	96.950	96.950	21.817	5.641	0.000**
	95 dB	38.023	32.000	11.574	54.200	54.200	28.682	0.000	1.000
	100 dB	30.073	28.000	4.331	65.350	65.350	8.289	6.770	0.000**
	105 dB	29.783	31.800	8.913	42.000	42.000	6.306	5.642	0.000**

Table-6 showed p-value for juggler and non-juggler for amplitude was within the level of 0.01 significance, except at 95 dBHL in both ears which means there is a significant difference between the groups.

Table - 7: Interamplitude ratio of cVEMP for both ears for both the groups:

Parameters	Intensity levels	Juggler (n=30)			Non jugglers (n=30)			Mann-Whitney U Test	
		Mean	Median	SD	Mean	Median	SD	|Z|	p-value
Inter amplitude Ratio (R)	85 dB	19.636	21.355	9.370	21.669	23.805	7.841	1.080	0.280
	90 dB	12.242	10.225	8.333	19.667	21.220	5.489	3.671	0.000**
	95 dB	15.162	11.580	9.394	15.456	15.280	7.114	0.281	0.059
	100 dB	6.962	3.810	6.207	8.636	6.585	7.077	1.229	0.219
	105 dB	25.319	30.080	15.094	7.794	4.935	8.990	4.427	0.000**
Parameters	**Intensity levels**	**Juggler (n=30)**			**Non jugglers (n=30)**			**Mann-Whitney U Test**	
		Mean	**Median**	**SD**	**Mean**	**Median**	**SD**	**|Z|**	**p-value**
Inter amplitude Ratio (L)	85 dB	19.636	21.355	9.370	21.669	23.805	7.841	1.080	0.280
	90 dB	12.242	10.225	8.333	19.667	21.220	5.489	3.671	0.000**
	95 dB	15.162	11.580	9.394	15.456	15.280	7.114	0.281	0.779
	100 dB	6.962	3.810	6.207	8.636	6.585	7.077	1.229	0.011
	105 dB	25.319	30.080	15.094	7.794	4.935	8.990	4.427	0.000**

Table-7 showed the p-value for juggler and non-juggler for interamplitude was within the level of 0.05 significance, except at 85 dBHL and 100 dBHL in right ear & at 85 dBHL and 95 dBHL in left ear. Thus it was showed that there is a statistically significant differences present between these two groups of participants.

Table - 8: Threshold of cVEMP for both ears for both the groups:

Parameters	Intensity levels	Juggler (n=30)			Non jugglers (n=30)			Mann-Whitney U Test	
		Mean	Median	SD	Mean	Median	SD	|Z|	p-value
Threshold (R)	85 dB	115.000	115.000	0.000	115.000	115.000	0.000	0.000	1.000
	90 dB	105.000	105.000	0.000	105.000	105.000	0.000	0.000	1.000
	95 dB	95.000	95.000	0.000	95.000	95.000	0.000	0.000	1.000
	100 dB	85.000	85.000	0.000	85.000	85.000	0.000	0.000	1.000
	105 dB	75.000	75.000	0.000	75.000	75.000	0.000	0.000	1.000

Parameters	Intensity levels	Juggler (n=30)			Non jugglers (n=30)			Mann-Whitney U Test	
		Mean	Median	SD	Mean	Median	SD	|Z|	p-value
Threshold (L)	85 dB	115.000	115.000	0.000	115.000	115.000	0.000	0.000	1.000
	90 dB	105.000	105.000	0.000	105.000	105.000	0.000	0.000	1.000
	95 dB	95.000	95.000	0.000	95.000	95.000	0.000	0.000	1.000
	100 dB	85.000	85.000	0.000	85.000	85.000	0.000	0.000	1.000
	105 dB	75.000	75.000	0.000	75.000	75.000	0.000	0.000	1.000

Table -8 showed the p-value for juggler and non-juggler for amplitude was within the level of 1.00 significance. Thus it was showed that there was no statistically significant differences present between these two groups of participants in terms of thresholds.

Table -9: Latency of oVEMP for both ears for both the groups:

Parameters	Intensity levels	Juggler				Non jugglers				Mann-Whitney U Test	
		n	Mean	Median	SD	n	Mean	Median	SD	|Z|	p-value
P13(ms)	85 dB	30	15.500	15.900	1.808	30	13.150	13.150	0.356	4.546	0.000**
	90 dB	30	14.833	14.300	2.945	30	16.150	16.150	0.356	4.546	0.000**
	95 dB	30	20.700	20.900	1.886	30	13.300	13.300	1.017	6.779	0.000**
	100 dB	30	22.133	20.500	2.815	30	15.200	15.200	1.017	6.876	0.000**
	105 dB	26	22.827	20.300	4.855	30	12.700	12.700	0.509	6.556	0.000**
N23 (ms)	85 dB	30	18.467	18.600	0.758	30	15.500	15.500	1.119	6.832	0.000**
	90 dB	30	17.450	16.900	2.340	30	21.050	21.050	0.763	4.539	0.000**
	95 dB	30	22.537	22.500	1.606	30	17.700	17.700	1.017	6.777	0.000**
	100 dB	30	23.950	22.500	3.002	30	18.900	18.900	0.509	6.808	0.000**
	105 dB	26	26.712	23.200	5.628	30	15.200	15.200	0.000	7.036	0.000**

Parameters	Intensity levels	Juggler				Non jugglers				Mann-Whitney U Test	
		n	Mean	Median	SD	n	Mean	Median	SD	|Z|	p-value
P13(ms)	85 dB	30	19.100	18.500	1.247	30	17.100	17.100	1.526	3.167	0.002**
	90 dB	30	20.530	20.650	2.186	30	18.000	18.000	1.526	4.542	0.000**
	95 dB	30	24.083	25.200	3.515	30	16.100	16.100	0.509	5.661	0.000**
	100 dB	30	23.683	23.900	2.729	30	15.050	15.050	0.458	6.783	0.000**
	105 dB	30	32.533	32.200	2.264	30	14.200	14.200	0.000	7.160	0.000**
N23 (ms)	85 dB	30	21.333	21.500	0.928	30	20.800	20.800	0.610	4.115	0.000**
	90 dB	30	22.783	23.300	1.812	30	20.800	20.800	0.509	4.011	0.000**
	95 dB	30	26.250	27.500	4.196	30	20.600	20.600	0.000	4.759	0.000**
	100 dB	30	26.400	27.400	3.629	30	19.700	19.700	1.526	5.646	0.000**
	105 dB	30	31.133	32.600	5.926	30	20.200	20.200	2.034	5.649	0.000**

Table-9 showed the p-value for juggler and non-juggler for P13 & N23 were within the level of 0.01 significance. Thus it was showed that there is a statistically significant differences present between these two groups of participants.

Table -10: Amplitude of oVEMP for both ears for both the groups:

Parameters	Intensity levels	Juggler				Non jugglers				Mann-Whitney U Test	
		n	Mean	Median	SD	n	Mean	Median	SD	|Z|	p-value
Rt. Amp (Mic. Volt)	85 dB	30	1.867	1.800	1.363	30	2.160	2.300	0.152	1.209	0.227
	90 dB	30	1.607	1.500	1.034	30	1.400	1.400	0.000	0.000	1.000
	95 dB	30	1.143	0.800	0.800	30	2.450	2.450	0.356	5.263	0.000**
	100 dB	30	0.620	0.500	0.471	30	0.600	0.600	0.203	1.707	0.051*
	105 dB	26	0.865	0.200	0.949	30	0.500	0.500	0.000	1.084	0.278

Parameters	Intensity levels	Juggler				Non jugglers				Mann-Whitney U Test	
		n	Mean	Median	SD	n	Mean	Median	SD	|Z|	p-value
Lt. Amp (mic. Volt)	85 dB	30	2.433	2.600	0.461	30	3.957	3.950	0.068	6.799	0.000**
	90 dB	30	1.983	2.100	0.238	30	1.100	1.100	0.000	7.061	0.000**
	95 dB	30	1.170	1.200	0.511	30	0.800	0.800	0.000	4.569	0.000**
	100 dB	30	0.823	0.800	0.148	30	1.250	1.250	0.051	6.811	0.000**
	105 dB	30	0.503	0.400	0.227	30	0.850	0.850	0.051	4.664	0.000**

Table -10 showed the p-value for juggler and non-juggler for right ear amplitude was within the level of 0.01 significance and left ear amplitude was within the level of 0.05 significance at 95dBHL. Thus it was showed that there is a statistically significant differences present between these two groups of participants.

Table -11: Interamplitude ratio of oVEMP for both ears for both the groups

Parameters	Intensity levels	Juggler (n=30)			Non jugglers (n=30)			Mann-Whitney U Test	
		Mean	Median	SD	Mean	Median	SD	|Z|	p-value
Inter amplitude Ratio (R)	85 dB	19.636	21.355	9.370	21.669	23.805	7.841	1.080	0.080
	90 dB	12.242	10.225	8.333	19.667	21.220	5.489	3.671	0.000**
	95 dB	15.162	11.580	9.394	15.456	15.280	7.114	0.281	0.021
	100 dB	6.962	3.810	6.207	8.636	6.585	7.077	1.229	0.121
	105 dB	25.319	30.080	15.094	7.794	4.935	8.990	4.427	0.000**

Parameters	Intensity levels	Juggler (n=30)			Non jugglers (n=30)			Mann-Whitney U Test	
		Mean	Median	SD	Mean	Median	SD	|Z|	p-value
Inter amplitude Ratio (L)	85 dB	19.636	21.355	9.370	21.669	23.805	7.841	1.080	0.180
	90 dB	12.242	10.225	8.333	19.667	21.220	5.489	3.671	0.000**
	95 dB	15.162	11.580	9.394	15.456	15.280	7.114	0.281	0.008*
	100 dB	6.962	3.810	6.207	8.636	6.585	7.077	1.229	0.015
	105 dB	25.319	30.080	15.094	7.794	4.935	8.990	4.427	0.000**

Table -11 showed the p-value for juggler and non-juggler for interamplitude was within the level of 0.05 significance, except at 85 dBHL and 100 dBHL in right ear and at 85 dBHL and 95 dBHL in left ear. Thus it was showed that there is a statistically significant differences present between these two groups of participants.

Table -12: Threshold of oVEMP for both ears for both the groups:

Parameters	Intensity levels	Juggler				Non jugglers				Mann-Whitney U Test	
		n	Mean	Median	SD	n	Mean	Median	SD	|Z|	p-value
Threshold (R)	85 dB	30	115.000	115.000	0.000	30	115.000	115.000	0.000	0.000	1.000
	90 dB	30	105.000	105.000	0.000	30	105.000	105.000	0.000	0.000	1.000
	95 dB	30	95.000	95.000	0.000	30	95.000	95.000	0.000	0.000	1.000
	100 dB	30	85.000	85.000	0.000	30	85.000	85.000	0.000	0.000	1.000
	105 dB	30	75.000	75.000	0.000	30	75.000	75.000	0.000	0.000	1.000

Parameters	Intensity levels	Juggler (n=30)			Non jugglers (n=30)			Mann-Whitney U Test	
		Mean	Median	SD	Mean	Median	SD	|Z|	p-value
Threshold (L)	85 dB	115.000	115.000	0.000	115.000	115.000	0.000	0.000	1.000
	90 dB	105.000	105.000	0.000	105.000	105.000	0.000	0.000	1.000
	95 dB	95.000	95.000	0.000	95.000	95.000	0.000	0.000	1.000
	100 dB	85.000	85.000	0.000	85.000	85.000	0.000	0.000	1.000
	105 dB	75.000	75.000	0.000	75.000	75.000	0.000	0.000	1.000

Table-12 showed the p-value for juggler and non-juggler for threshold was within the level of 1.00 significance (p>0.05). Thus it was showed that there was no statistically significant differences present between these two groups of participants.

DISCUSSIONS

Vestibular plasticity is a kind of reactive plasticity that helps in repairing the damaged hair cells and fibres of the vestibular nerves to restore the peripheral sensory input. This present study reflected changes in vestibular parameters with reference to juggling scenario, juggling influences grossly counterpart. In term this may contribute to vestibular plasticity as a whole as in case of jugglers matured tunning of pathway. cVEMP is much more supportive as compare to oVEMP saccular plasticity.

This finding explained that cVEMP latencies, amplitudes and thresholds for jugglers and nonjugglers. All these Parameters showed statistically significant difference between both the groups. When the effect size was compared between the groups it was found out that for latencies, the effect size was larger for jugglers' group in comparison to nonjuggler participants whereas for amplitude it was larger for nonjuggler group than juggler participants and for thresholds it was larger for both the groups. It also showed that a very large effect size was observed for the juggler participants rather than nonjugglers for latency and amplitude whereas for thresholds, both the groups showed a very large effect size.

A study done by Sinha et.al, 2013 on dancers and control group showed that the latency of P13 and N23 peak was early for the control group & the latency of P13- was more for the dancers compared to the control. Likewise a study done by Lavon et.al, 2010 showed that the decreased Latency of the VEMP N23 wave in the diver group compared with the non-diver control group.

Another study was done on healthy hearing subjects where cVEMP amplitude increases significantly with increasing the EMG levels. With amplitude correction cVEMP amplitude did not changed with EMG target levels. The absolute peak to peak amplitude of p13-N23, absolute latency of p13 were measured. MANNOVA was used to check the significant amplitude reduced following amplitude correction (McCaslin et al., 2014).

oVEMP pathway emerges from the saccular hair cells to vestibular nucleus in the brainstem and ends up finally through the contraction of the sternocleidomastoid muscle. oVEMP latencies depend upon various factors and pathological conditions, some subject related and some non-subject related. Zuniga et al., (2013) described factors like stimulus type, rate and intensity and subject related factors like neck length, electrode location and other factors.

In the present study, oVEMP latencies, amplitudes and thresholds were having statistically significant difference between groups. While comparing the effect size for all these parameters it showed the results are in consonance with the cVEMP findings.

A supportive study where descriptive statistics was done to find out the mean and standard deviation (SD) of amplitude complex of N10-P14 complex. The mean and SD of both the control group and the experimental group, the amplitude of N10-P14 complex is higher for the experimental group compared to the control group. Non parametric Mann-Whitney U test was done and was found to be statistically non-significant between the control and the experimental group amplitude of N10-P14 complex. There were no differences in amplitude parameters in either oVEMP between dancers and non-dancers (Sinha et al., 2013).

Another study showed the VEMP threshold was higher when the age was increased (Welgampola and Colebatch, 2001; Ochi et.al., 2003). This study was only investigated threshold differences across age in response to click stimuli.

A study done by Janky and Shepard, 2009 revealed no significant difference between the ears in different parameters like: n23 latency, amplitude and thresholds but VEMP threshold was positively correlated and amplitude was negatively correlated with the age.

In the perspective of both groups comparison of the current study, it was stated that null hypothesis of this study was rejected for latency and amplitude for both cVEMP & oVEMP as there were significant differences between the two groups at 95% confidence interval. Nonparametric Mann- Whitney U test was done, P-value of 0.000 ($p<0.05$) for P13 peak, and p-value for N23 peak 0.00 ($p<0.05$) was observed for right ear. For left ear, p-value of 0.000 ($p>0.05$) was seen for P13 peak, p value of 0.001 ($p>0.05$) was observed for N23 peak. Both these were smaller than 0.05 level of significance. Whereas for thresholds the null hypothesis of this study was accepted as there were no significant differences between the two groups at 95% confidence interval. Nonparametric Mann- Whitney U test was done. P-value of 1.000 ($p>0.05$) for threshold was observed for right ear. For left ear, p-value of 1.000 ($p>0.05$) was seen for threshold. Both these values were greater than 0.05 level of significance.

Though the study has contributed information on a new set of professional, still it has some limitations such as the sample size & other correlated findings. It needs to be done on a larger sample size to correlate various VEMP findings with reference to vestibular plasticity of jugglers or other related professionals with other vestibular test findings such as VNG, VHIT etc. as well as to radiological studies (CT scan, MRI, fMRI etc.) with reference to juggler.

CONCLUSION

VEMPs are seen as an effective tool for the assessment of the peripheral vestibular system specifically the otolithic organs (Saccule and Utricle). The use of VEMP was started clinically from 1990s before that Vestibular stimulation to sound was not much discussed topic in Audiology.

Since the evolution of VEMPs in the 1960s, there have been many studies regarding thresholds, amplitudes and presence of absence of VEMPs in various vestibular pathologies. Due to similarities between the cochlear hair cells and the saccular hair cells, the working principle behind both of them has been regarded to be similar. However, there are many studies relating to the VEMP findings in the vestibular dysfunction. Some studies have indicated VEMPs being affected in the dancers, swimmers and drivers.

In this study threshold estimation was done. c-VEMP and o-VEMP were obtained in the different intensity as threshold estimation. Though it was time taking and on the other hand it was debatable. The overall conclusion that can be drawn from this study is juggler showed better results in terms of VEMP latencies and amplitudes in comparison to the nonjuggler group. The probable reasons for this could be the central compensations in the juggler groups that affect the VEMP findings. Poor results of oVEMP might be due to the lower activation of the eye muscles in response to sound stimulation or the affectedness of the proposed Utriculocollic pathway of the oVEMP.

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