https://doi.org/10.23925/2176-2724.2020v32i3p406-413

Comparison of cervical and ocular VEMP responses in individuals with and without otoneurological diseases

Comparação das respostas do VEMP cervical e ocular em indivíduos com e sem doenças otoneurológicas

Comparación de respuestas VEMP cervicales y oculares en individuos con y sin enfermedades otoneurológicas

*Marlon Bruno Nunes Ribeiro**
*Patricia Cotta Mancini**

Abstract

Introduction: The vestibular assessment is traditionally carried out with the caloric test to evaluate the labyrinth in individuals with dizziness. However, this examination does not evaluate the entire vestibular pathway. The vestibular evoked myogenic potentials (VEMP) are a quick test, considered a choice method to assess the otolith organs and the vestibular nerve. **Purpose**: To analyze the responses of the cervical (cVEMP) and ocular VEMP (oVEMP) examinations in individuals with vestibular diseases and compare them with the results obtained in individuals of the same age group and gender without previous and current complaints of dizziness. **Methods:** In this observational, cross-sectional, analytical study, the participants were divided into two groups: the dizziness group (DG), composed of individuals with several vestibular diseases, and the group without complaints of dizziness (CG). Both groups underwent meatoscopy, and cervical and ocular VEMP. **Results:** The sample comprised 45 individuals aged 23 to 68 years – 27 individuals in the CG and 18 in the DG. In the cVEMP exam, the latencies, amplitudes, asymmetry index, and the corrected asymmetry index were the same in the GT when compared to the GC. In the cVEMP examination, the latencies, amplitudes, asymmetry index, and corrected asymmetry index were equal in the DG when compared with the CG. In the oVEMP examination, the left amplitude was statistically greater and the N10 latency, smaller in the DG when compared with the CG. Of the diseases in the DG, individuals with superior canal dehiscence had higher left amplitude values, which may have interfered with the results.

* Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brazil.

Authors' contributions:
MBNR - idealized the study, performed the data collection, participated in the statistical analysis, writing and review of the manuscript.
PCM - participated, as supervisor, in the idealization of the study, statistical analysis, writing and review of the manuscript.

Correspondence e-mail: Marlon Bruno Nunes Ribeiro - marlonfono16@gmail.com
Received: 26/06/2019
Accepted: 30/06/2020

Conclusion: There were no differences in cVEMP responses between the groups in this study. An increase in the left amplitude and the lower value in the right N10 latency were found in the DG in the analysis of the oVEMP examination. It is believed that the heterogeneity of vestibular diseases in the DG and the small number of participants in both groups have contributed to this outcome.

Keywords: Inner Ear; Postural Balance; Dizziness; Motor Evoked Potential; Saccule and Utricle

Resumo

Introdução: a avaliação vestibular é realizada tradicionalmente por meio da prova calórica para avaliação do labirinto em indivíduos com tonturas, porém este exame não avalia toda a via vestibular. Os potenciais evocados miogênicos vestibulares (VEMP) consistem em um exame de rápida execução, considerado método de escolha para avaliação dos órgãos otolíticos e do nervo vestibular**. Objetivo:** analisar as respostas do exame VEMP cervical (cVEMP) e ocular (oVEMP) em indivíduos com doenças vestibulares e compará-las àquelas obtidas em indivíduos de mesma faixa etária e sexo sem queixas de tontura pregressas e atuais. **Métodos:** Estudo observacional, transversal e analítico. Os participantes foram divididos em dois grupos: grupo com tontura (GT), composto por indivíduos com diversas doenças vestibulares e o grupo sem queixa de tontura (GC). Ambos os grupos foram submetidos à meatoscopia, ao VEMP cervical e ocular. **Resultados:** A amostra foi composta por 45 indivíduos com a idade entre 23 e 68 anos, sendo 27 indivíduos do grupo GC e 18 do grupo GT. No exame cVEMP as latências, amplitudes, índice de assimetria e o índice de assimetria corrigido foram iguais no GT quando comparado com o GC. No exame oVEMP encontrou-se a amplitude esquerda maior e a latência N10 menor estatisticamente no grupo GT quando comparado ao grupo GC. Dentre as doenças do grupo GT os indivíduos com deiscência de canal superior tiveram valores maiores na amplitude esquerda, o que pode ter interferido nos resultados. **Conclusão**: Não foram evidenciadas diferenças nas respostas do cVEMP entre os grupos neste estudo. Encontrou-se aumento da amplitude esquerda e o valor menor da latência N10 direita no grupo com tontura na análise do exame oVEMP. Acredita-se que a heterogeneidade de doenças vestibulares no grupo com tontura e o reduzido número de participantes em ambos os grupos tenham contribuído para esse desfecho.

Palavras-chave: Orelha interna; Equilíbrio Postural; Tontura; Potencial Evocado Motor; Sáculo e Utrículo

Resumen

Introducción: La evaluación vestibular se lleva a cabo tradicionalmente a través de la prueba calórica para evaluar el laberinto en individuos con mareos, sin embargo, este examen no evalúa toda la vía vestibular. Los potenciales miogénicos evocados vestibulares (VEMP) consisten en una prueba de funcionamiento rápido, considerada el método de elección para evaluar los órganos otolíticos y el nervio vestibular. **Objetivo:** Analizar las respuestas del examen VEMP cervical y ocular en individuos con enfermedades vestibulares y compararlas con las obtenidas en individuos del mismo grupo de edad y sexo sin quejas de mareos previas y actuales. Métodos:Estudio observacional, transversal y analítico. Los participantes se dividieron en dos grupos: grupo con mareos (GT), compuesto por individuos con varias enfermedades vestibulares y el grupo sin quejas de mareos (CG). Ambos grupos se sometieron a meatoscopia, VEMP cervical y ocular. **Resultados:** La muestra consistió en 45 individuos con edades comprendidas entre 23 y 68 años, 27 individuos del grupo GC y 18 del grupo GT. En el examen cVEMP, las latencias, amplitudes, índice de asimetría y el índice de asimetría corregido fueron los mismos en el GT en comparación con el CG. En el examen oVEMP, la amplitud izquierda fue mayor y la latencia N10 fue estadísticamente menor en el grupo GT en comparación con el grupo CG. Entre las enfermedades en el grupo GT, los individuos con dehiscencia del canal superior tenían valores más altos en la amplitud izquierda, lo que puede haber interferido con los resultados. **Conclusión:** No hubo diferencias en las respuestas de cVEMP entre los grupos en este estudio. Se encontró un aumento en la amplitud izquierda y un valor más bajo de la latencia N10 derecha en el grupo con mareos en el análisis del examen oVEMP. Se cree que la heterogeneidad de las enfermedades vestibulares en el grupo de mareos y el pequeño número de participantes en ambos grupos contribuyeron a este resultado.

Palabras clave: Oído Interno, Equilibrio Postural, Mareo, Potenciales Evocados Motores, Sáculo y Utrículo

Introduction

Body balance is essential to the postural changes that enable movements to be made harmoniously, with physical and mental comfort, maintaining an erect posture, and avoiding falls[1]. For balance to be maintained, there needs to be an interaction between the vestibular, visual, and proprioceptive systems[2]. An alteration in the vestibular system can manifest as dizziness[2,3].

The most frequent vestibular symptoms, according to the vestibular symptom classification developed and published by the Bárány Society, manifest as an illusion of movement – either rotation (vertigo) or not –, or a sensation of altered spatial orientation (dizziness)[3]. They can affect individuals from any age group, though more common among the adult and older adult population, aged over 40 years[3].

The vestibular system assessment consists of static and dynamic balance tests, ocular tests, and the traditional caloric test, which assesses the lateral semicircular canals. There are complementary examinations – such as the vestibular evoked myogenic potential, posturography, Video Head Impulse Test (v-HIT), damped pendular rotation test, and imaging examinations – that aid in the topodiagnosis of the lesion[4].

Of these complementary otoneurologic examinations, the vestibular evoked myogenic potentials (VEMP) have been studied since 1960. However, they started being used to assess sacculocollic reflexes only in 1992[5,6]. The cervical and ocular VEMP are currently choice tests to assess the otolith organs and vestibular nerve[5,6].

The cervical VEMP (cVEMP) is an objective, noninvasive, quick, easily performed, relatively low-cost examination that causes no discomfort to the patient. It consists of a short-latency myogenic response, picked up on the cervical musculature when the saccule (and consequently the inferior branch of the vestibular nerve) is stimulated by a high-intensity sound stimulus[5,6,7]. The cVEMP is a manifestation of the vestibulocollic reflex, an inhibitory contraction response of the sternocleidomastoid muscle that generates a biphasic potential[5,6,7].

The ocular VEMP (oVEMP) is a short-latency myogenic response as well, evoked by a high-intensity sound stimulus, which activates the utricle (and consequently, the superior vestibular nerve)[8,9]. It is a manifestation of the vestibulo-ocular reflex presented as a biphasic potential, contralateral to the stimulus[9].

The parameters assessed in the VEMP are the presence of biphasic potentials, latencies, interamplitudes or peak-to-peak amplitudes, and response asymmetry index. Calculating the asymmetry index is greatly important, as the interamplitude of the wave obtained in the VEMP varies depending on the intensity of the muscle contraction force exerted, which changes from person to person[8,9]. Correcting the interamplitude according to the contraction force obtained from surface electromyography allows a corrected asymmetry index to be achieved[5,6,8,9].

Any lesion in vestibulo-cervical and vestibulo-ocular pathway structures can lead to alterations in response potentials[9,10]. Hence, alterations in the saccular macula or inferior vestibular nerve can cause asymmetry of the amplitude or absence of response on the affected side[7,8,9]. Prolonged latencies can suggest retrolabyrinthine lesions, especially in the vestibulospinal tract[9,10]. The VEMP is a quickly performed test that can be used to early detect some vestibular disorders, such as Ménière's disease, in which the saccule is one of the first structures to be impaired[9,10].

New vestibular assessment technologies help in diagnosis and support possible interventions in the patient with dizziness. Thus, it is necessary to know the main characteristics of the cervical and ocular VEMP in vestibular diseases[9,10]. This study aimed to analyze the cervical and ocular VEMP responses in individuals with vestibular diseases and compare them with the ones obtained in people of the same age group and gender without complaints of previous or current dizziness.

Methods

The procedures in this research were approved by the Ethics Committee of the *Universidade Federal de Minas Gerais* (UFMG) under no. CAAE 56877316.1.0000.5149 (complying with resolution 466/12 of the *Conselho Nacional de Saúde* – CONEP). This is an observational, analytical, cross-sectional study conducted at the speech-language-hearing functional health observatory of the School of Medicine at UFMG. The sample comprised 45 individuals aged 23 to 68 years – 27 individuals of the control group (CG) and 18 of

the dizziness group (DG), matched for gender ($p = 0.232$) and age ($p = 0.114$).

The individuals included in the research were over 18 years old who agreed voluntarily to participate in the study, signing the informed consent form. Patients with alteration in the outer ear as perceived in the meatoscopy, history of otologic surgery or trauma, self-reported cervical rotation difficulty, and with any self-reported important emotional disorder were excluded from the study. The convenience sample was formed with individuals from the academic community.

The dizziness group comprised participants who were being followed up in the otorhinolaryngology sector of the audiology service at the *Hospital das Clínicas* of UFMG. The individuals included were those who had otoneurological diagnosis based on the analysis of the result of the VEMP, v-HIT, caloric test, and clinical history by an experienced otoneurologist – however, this study approached only the VEMP data. The individuals were invited to participate in the research before performing the VEMP. The control group comprised individuals from the academic community without a self-reported previous or current history of dizziness.

Initially, the participants answered a questionnaire with information about their otologic past and the presence of possible auditory and vestibular alterations. Then, they were analyzed with meatoscopy and acoustic immittance, to dismiss middle ear alterations[11]. The cervical and ocular VEMP were performed with the auditory evoked potentials equipment manufactured by Otometrics®, model ICS Chartr EP 200, insert earphones, and self-adhesive electrodes.

For the cVEMP, the participant remained seated on a chair in an acoustically treated room. The skin was first cleaned with abrasive paste. The ground electrode was placed on the forehead and the active electrodes were placed on the right and left sternocleidomastoid muscles. The second-channel electrodes were positioned below the active ones, on the right and left, to record the surface electromyography, and the reference electrode was fixed on the area of the sternum. Insert phones were used to produce the air-conduction tone-burst stimulus. The participants were instructed to rotate their head laterally, to the side opposite to the ear tested, in order to pick up the muscle contraction inhibitory response (Figure 1). The responses accepted had muscle contraction intensity between 50 and 200 µV. Impedance values below 5 kOhms were accepted. The intensity initially tested was 95 dBnHL at 500 Hz[4,5].

For the oVEMP, the active electrode was placed on the infraorbital region, contralateral to the side tested, and the reference electrode was placed right below the active electrode. Insert phones were used to produce the air-conduction tone-burst stimulus. The responses accepted had muscle contraction intensity between 50 and 200 µV. Impedance values below 5 kOhms were accepted. The intensity initially tested was 95 dBnHL at 500 Hz[4,5]. The participants were instructed to hold their head upright and look as far up as they could while the stimulus was being presented (Figure 2). The analysis of the cVEMP and oVEMP wave latency values considered the definition given in the literature – i.e., the altered latency values are those 2.5 standard deviations higher than the normality suggested[4,5].

The variables analyzed in the cervical VAMP were the P13 and N23 latencies, amplitude, asymmetry index, and corrected asymmetry index. In the oVEMP, the N10 and P15 latencies, amplitude, and asymmetry index were assessed. After collecting the data, they were entered into an Excel spreadsheet and submitted to descriptive and inferential statistical analysis with the Statistical Package for Social Sciences (SPSS) software, version 20.0. The descriptive analysis encompassed measures of central tendency (mean and median), dispersion (standard deviation), and position (maximum and minimum). The normality of the samples was observed with the Kolmogorov-Smirnov and Shapiro-Wilk tests.

The groups were compared with Student's t-test (for data with normal distribution) and Mann-Whitney test (when the variables did not have normal distribution). The chi-square test was used to compare the frequencies obtained by calculating the asymmetry index, to compare the genders of both groups, and to compare the altered, normal and absent examinations of both groups. The significance level of 5% ($p \leq 0.05$), and the 95% confidence interval were adopted in all the analyses.

Results

The studied population's mean age was 45.67 (±15.60) years for the CG and 51.0 (±15.41) years for the DG. The CG had 7 (26%) males and 20 (74%) females, while the DG had 2 (11%) males and 16 (88%) females. The sample had more female individuals both in the DG and CG, but there was no statistically significant difference between the groups regarding gender (p = 0.232) and age (p = 0.114).

In the percentage distribution of the individuals by diseases, it was verified that vestibular migraine was present in 8 (44%) individuals, followed by benign paroxysmal positional vertigo (BPPV) in 4 (22%), vestibular neuritis in 1 participant (6%), superior canal dehiscence in 2 (11%), Ménière's disease in 2 (11%), and Ramsay Hunt syndrome in 1 participant (6%).

In the cervical VEMP examination, the P13 and N23 latency mean values and wave amplitude presented no statistical difference, on either the right or left ear, in the comparison between the groups. The asymmetry and corrected asymmetry indexes were also statistically equal when the two groups were compared.

In the oVEMP examination, it was verified that the N10 latency on the right side was shorter in the DG, and the left amplitude presented higher values in the DG when compared with the CG. The asymmetry indexes had no statistical difference between both groups.

When the left oVEMP amplitude means were compared, it was verified that the superior semicircular canal dehiscence presented higher values when compared with the other vestibular diseases.

Table 1. Comparison of the measures of central tendency, dispersion, and position of the latency (ms), amplitude (μV), asymmetry index (μV), and corrected asymmetry index (μV) for the cervical VEMP between the groups with and without dizziness.

Wave parameters	Parameters analyzed	Control Group	Dizziness Group	p-value*
	Mean	15.30	14.56	
	Median	15.17	14.42	
P13L	Standard deviation	1.76	1.65	**0.061
	Minimum	11.00	9.33	
	Maximum	20.00	17.67	
	Mean	24.24	23.33	
	Median	24.00	23.50	
N23L	Standard deviation	2.51	2.23	**0.203
	Minimum	19.33	17.67	
	Maximum	29.17	28.33	
	Mean	135.91	164.73	
	Median	119.14	136.20	
L.Cerv.Ampl	Standard deviation	99.10	101.21	*0.334
	Minimum	17.82	29.15	
	Maximum	445.74	388.60	
	Mean	29.28	26.35	
	Median	27.01	27.05	
Corr.A.I	Standard deviation	22.31	17.07	*0.641
	Minimum	0.56	4.96	
	Maximum	80.59	55.16	
	Mean	22.43	24.64	
	Median	19.39	19.88	
c.A.I	Standard deviation	18.04	20.58	**0.708
	Minimum	1.20	0.55	
	Maximum	79.53	66.58	
	Mean	15.16	15.02	
	Median	15.33	14.50	
P13R	Standard deviation	0.74	1.43	**0.191
	Minimum	13.83	13.50	
	Maximum	16.83	19.83	

Wave parameters	Parameters analyzed	Control Group	Dizziness Group	p-value*
	Mean	23.96	23.95	
	Median	23.58	23.83	
N23R	Standard deviation	1.51	1.79	*0.996
	Minimum	21.50	21.33	
	Maximum	26.50	28.33	
	Mean	130.10	150.48	
	Median	107.79	110.02	
R.Cerv.Ampl.	Standard deviation	88.07	101.78	*0.466
	Minimum	30.01	39.84	
	Maximum	396.77	419.91	

*t-test **Mann-Whitney test
Legend: L.Cerv.Ampl = left cervical VEMP wave amplitude, Corr.A.I = corrected asymmetry index, c.A.I = cervical VEMP asymmetry index, R.Cerv.Ampl. = right cervical VEMP wave amplitude.

Table 2. Comparison of the measures of central tendency, dispersion, and position of the latency (ms), amplitude (μV), and asymmetry index (μV) for the ocular VEMP between the groups with and without dizziness.

Wave parameters	Parameters analyzed	Control Group	Dizziness Group	p-value*
	Mean	14.63	14.33	
	Median	14.25	14.38	
P15L	Standard deviation	1.34	1.64	**0.530
	Minimum	12.67	10.67	
	Maximum	17.33	16.50	
	Mean	10.95	10.25	
	Median	10.63	9.92	
N10L	Standard deviation	1.20	1.22	*0.054
	Minimum	9.25	8.75	
	Maximum	13.63	13.00	
	Mean	2.95	6.84	
	Median	2.02	3.82	
L.oc.Ampl	Standard deviation	3.28	7.21	*0.024
	Minimum	0.32	0.70	
	Maximum	15.67	26.48	
	Mean	38.25	27.42	
	Median	32.62	19.55	
ocA.I	Standard deviation	24.26	22.19	**0.116
	Minimum	2.27	7.73	
	Maximum	78.42	92.93	
	Mean	15.23	14.76	
	Median	14.88	14.63	
P15R	Standard deviation	1.21	1.65	**0.316
	Minimum	13.25	12.33	
	Maximum	17.33	17.17	
	Mean	10.94	10.03	
	Median	10.59	9.84	
N10R	Standard deviation	1.38	0.91	*0.018
	Minimum	9.25	8.33	
	Maximum	14.33	12.25	
	Mean	4.22	5.21	
	Median	3.35	3.83	
R.oc.Ampl	Standard deviation	4.52	4.38	*0.502
	Minimum	0.26	0.44	
	Maximum	21.25	14.22	

*t-test **Mann-Whitney test
Legend: L.oc.Ampl = left ocular VEMP wave amplitude, oc.A.I = ocular asymmetry index, ocular VEMP, R.oc.Ampl = right ocular VEMP wave amplitude.

Table 3. Mean of the left ocular VEMP amplitudes between the vestibular diseases.

Vestibular diseases	Left ocular VEMP amplitude
Superior canal dehiscence	14
Ménière's disease	8.8
Vestibular migraine	6.2
Benign paroxysmal positional vertigo	6.1
Vestibular neuritis	1.7
Ramsay Hunt syndrome	1.5

Discussion

In this study, most of the population in the DG were older than 40 years. This agrees with the literature, which reveals the high prevalence of vestibular signs and symptoms in individuals of this age group – these symptoms increase with advancing age[3,5,6,7]. These signs and symptoms manifest as dizziness, hearing loss, tinnitus, postural balance alterations, and falls. After 65 years old, dizziness is the most common symptom with direct interference in the quality of life[3,6,12]. As the vestibular system grows old, due to functional loss in the hair cells, the cervical and ocular VEMP have altered responses, such as the decrease in response amplitude and increase in latencies and thresholds. These alterations occur due to the aging of the saccular macula and the muscle fibers[8,12].

The predominant gender in the DG was the female. This also agrees with the literature, which shows dizziness as predominant among females (1.3 to 1). Its incidence increases in direct proportion to age, reaching its peak by 65 to 75 years old[3,6,9,12]. In the present study, the most frequent vestibular disease was the vestibular migraine, followed by BPPV – which is one of the most frequent affections of the vestibular system, prevalent among females. It is believed that women's monthly hormonal variations trigger episodes of migraine and dizziness in the premenstrual period. Taking hormones with contraceptive purposes is another cause – which can be motivated by factors such as hormonal cycle variations[3,13]. BPPV is the most prevalent vestibular disease according to the literature. However, as it is easily diagnosed and clinically treated with otolith repositioning maneuvers, most of the time these people are treated in primary health care[14,15].

The absence of statistical difference between the VEMP results in the comparison between DG and CG is due to the heterogeneity of the DG, composed of individuals with various otoneurological diseases. Moreover, each disease counted with a small number of participants, which may have also led to the absence of differences between the groups. These findings disagree with the literature, which found a difference between the VEMP responses in the comparison between individuals with and without vestibular diseases[6,8,10].

The oVEMP examination revealed that the left amplitude value was higher in the DG, with statistical significance. When comparing this mean amplitude value, it was verified that the individuals with superior canal dehiscence had a higher result than the other diseases, which may have also influenced the result. This finding corroborates the literature, which reveals that the wave amplitude increases along with the intensity of the stimulus in this type of disease[16,17]. Such an increase occurs because the superior canal dehiscence (or "third window") decreases the inner ear impedance, allowing greater movement of the membranous labyrinth fluids, and, consequently, enabling a greater deflection of the vestibular sensors with pressure and sound stimuli[16,17].

The right side N10 latency was smaller in the DG when compared with the CG. This finding, which does not corroborate the literature, may result from the small sample in this study and the heterogeneity of the DG. This was also found in another study that compared the ear responses in individuals without otoneurological complaints[5].

Regarding the limitations of this study, attention is called to the variety of vestibular diseases, with a small number of individuals with each vestibulopathy. This may have led to the absence of statistical difference between the groups. New studies with larger populations are necessary to contrast with the findings of this study.

The present study evidences the contribution of the VEMP to the battery of conventional

otoneurological examinations in the diagnosis of the various vestibular diseases[5,6,7,18]. It is known that the cervical and ocular VEMP are sensitive to vestibular diseases, confirming the importance of this examination and its applicability to clinical practice[9,18,19].

The VEMP is a noninvasive, relatively low-cost, easily performed and interpreted examination, which does not require any previous preparation and does not cause any discomfort to the patient. Nevertheless, it needs to be standardized to maintain its reliability in clinical routine[18,19,20,21,22]. Using new technologies in clinical practice contributes to a more detailed diagnosis of the vestibular affections, enables a precise examination, and contributes to a more efficient clinical practice, with better therapeutic results.

Conclusion

No differences were evidenced in the cVEMP responses between the groups in this study. The left amplitude was found to be increased and the right N10 latency value was smaller in the dizziness group, in the analysis of the oVEMP examination. It is believed that the heterogeneity of the otoneurological diseases in the dizziness group and the small number of participants have contributed to this outcome.

References

1. Kleiner AFR, Schlitter DXC, Arias MDRS. The role of visual, vestibular, somatosensory and auditory systems for the postural control. Rev Neurocienc. 2011;19: 349-57.

2. Bisdorff A, Brevern MV, Lempert T, Newman-Toker DE. Classification of vestibular symptoms: Towards an international classification of vestibular disorders. J Vestib Res. 2009;19:1-13.

3. Oiticica J, Bittar RS. Population epidemiological study on the prevalence of dizziness in the city of São Paulo. Braz J Otorhinolaryngol. 2015; 81:167-761

4. Gonçalves DU, et al. Otoneurological evaluation: current good practice. Braz J Otorhinolaryngol. 2014; 80: 80-95

5. Silva TR, Resende LM, Santos MAR. Ocular and cervical vestibular evoked myogenic potential simultaneous in normal individuals. CoDAS. 2016; 28: 34-40.

6. Silva TR, Santos MAR, Resende LM, Labanca L, Caporali JFM, Sousa MR, Gonçalves DU. Applications of vestibular-evoked myogenic potential: a systematic literature review. Audiol Commun Res. 2019; 24: e2037.

7. Silva BMP, Didoné DD, Sleifer P. Cervical vestibular evoked myogenic potentials in children and adolescents without vestibular complaints. Audiol Commun Res. 2017; 22: e1885.

8. Pereira AB, Silva GSM, Felipe L, Assunção ARM, Atherino CCT. Vestibular evoked myogenic potential (VEMP). Revista HUPE, Rio de Janeiro, 2015;14: 56-59

9. Curthoys IS, et al. A review of mechanical and synaptic processes in otolith transduction of sound and vibration for clinical VEMP testing. J Neurophysiol. 2019;112: 259–276.

10. Felipe L, Santos MAR, Gonçalves DU. Vestibular evoked myogenic potential (Vemp): evaluation of responses in normal subjects. Pró-Fono. 2008; 20: 249-54.

11. Jerger J. Clinical experience with impedance audiometry. Arch Otolaryngol. 1970; 92: 311-24.

12. Ribeiro MBN, Morganti LOG, Mancini PC. Evaluation of the influence of aging on vestibular function by the video Head Impulse Test (v-HIT). Audiol Commun Res. 2019; 24: e2209.

13. Bittar RSM. Hormonal Labyrinth Diseases: Steroid Hormones, Estrogen and Progesterone. Int Arch Otorhinolaryngol. 1997;1(4): 32

14. Evren C, Demirbilek N, Elbistanli MS, Köktürk F, Çelik M. Diagnostic value of repeated Dix-Hallpike and roll maneuvers in benign paroxysmal positional vertigo. Braz J Otorhinolaryngol. 2017; 83: 243-8.

15. Messina A, Casani AP, Manfrin M, Guidetti G. Italian survey on benign paroxysmal positional vertigo. Acta Otorhinolaryngol Ital. 2017; 37: 328–335

16. Valente MCMB, Carnaúba ATL, Menezes PL, Cavalcanti MED. Cervical and Ocular VEMP Testing Diagnosing Superior Semicircular Canal Dehiscence. Distúrb Comum. 2017; 29: 613-614.

17. Camilo FFM, Gomes WRV, Lima CG, Vilella UPD, Siqueira LB. The Superior Semicircular Canal Dehiscence Syndrome. Revista Científica da FMC. 2018; 13: 2.

18. Silva TR, Resende LM, Santos MAR. Ocular vestibular evoked myogenic potential: literature review. Audiol Commun Res. 2016; 21: e1651.

19. Macambira YK, Carnaúba AT, Fernandes LC, Bueno NB, Menezes PL. Aging and wave-component latency delays in oVEMP and cVEMP: a systematic review with meta-analysis. Braz J Otorhinolaryngol. 2017; 83: 475-87.

20. Silva TR, de Resende LM, Santos MA. Combined ocular and cervical vestibular evoked myogenic potential in individuals with vestibular hyporeflexia and in patients with Ménière's disease. Braz J Otorhinolaryngol. 2017; 83: 330-40.

21. Rodriguez AL, et al. Optimization of Cervical and Ocular Vestibular Evoked Myogenic Potential Testing Using an Impulse Hammer in Adults, Adolescents, and Children. Otology & Neurotology 2020; 41: 817-827.

22. Oya R, et al. Clinical significance of cervical and ocular vestibular evoked myogenic potentials in benign paroxysmal positional vertigo: a meta-analysis. European Archives of Oto-Rhino-Laryngology. 2019; 276: 3257–3265.