Literature Review

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Ocular vestibular evoked myogenic potential: literature review

Potencial evocado miogênico vestibular ocular: revisão de literatura

Tatiana Rocha Silva[1], Luciana Macedo de Resende[2], Marco Aurélio Rocha Santos[1]

ABSTRACT

Purpose: To identify and systematize the main studies on the ocular vestibular evoked myogenic potentials and their applications in the diagnosis of various vestibular diseases. **Research strategy:** Articles that describe the use of ocular vestibular evoked myogenic potentials the evaluation of vestibular diseases were located in PubMed, Web of Science, MEDLINE, Scopus, LILACS e SciELO. **Selection criteria:** Original studies, with available abstract, published in the period 2010 to March 2016 were included. **Data analysis:** The study design was described, and the characteristics for the evaluation of ocular vestibular evoked myogenic potentials were listed. **Results:** 265 studies were found, but just 14 contemplated the proposed selection criteria. In relation to the population / sample of patients with vestibular disorders included in the study, it was observed that the most researched diseases were the vestibular neuritis, benign paroxysmal positional vertigo, vestibular Schwanoma and Meniere's disease. **Conclusion:** The most of the research realized in recent years and published in the databases PubMed, Web of Science, MEDLINE and Scopus revealed that the ocular vestibular evoked myogenic potentials is an effective method to evaluate the utricular function in various vestibular disorders.

Keywords: Vestibular nerve; Vestibular evoked myogenic potentials; Reflex, Vestibulo-ocular; Vestibular function tests; Saccule and utricle

RESUMO

Objetivo: Identificar e sistematizar os principais estudos sobre o potencial evocado miogênico vestibular ocular e suas aplicações no diagnóstico das diversas doenças vestibulares. **Estratégia de pesquisa:** Foram localizados artigos que descrevem a utilização do potencial evocado miogênico vestibular ocular na avaliação de doenças vestibulares nas bases PubMed, Web of Science, MEDLINE, Scopus, LILACS e SciELO. **Critérios de seleção:** Foram incluídos estudos originais, com resumo disponível, publicados no período de janeiro de 2010 a março de 2016. **Análise dos dados:** Foi realizada a descrição do delineamento do estudo e elencados os achados para a avaliação de potencial evocado miogênico vestibular ocular. **Resultados:** Foram encontrados 265 estudos, dos quais 14 contemplaram os critérios de seleção propostos. Em relação à população/amostra de pacientes com alterações vestibulares incluída nos estudos, observou-se que as doenças mais investigadas foram a neurite vestibular, a vertigem posicional paroxística benigna, o Schwanoma vestibular e a doença de Ménière. **Conclusão:** A maior parte das pesquisas realizadas nos últimos anos e publicadas nas bases de dados PubMed, Web of Science, MEDLINE e Scopus revelou que o potencial evocado miogênico vestibular ocular representa um método eficaz para avaliar a função utricular nas mais diversas doenças vestibulares.

Descritores: Nervo vestibular; Potenciais evocados miogênicos vestibulares; Reflexo vestíbulo-ocular; Testes de função vestibular; Sáculo e utrículo

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(1) Graduate Program in Speech Therapy Sciences, Faculty of Medicine, Universidade Federal de Minas Gerais – UFMG – Belo Horizonte (MG), Brazil.

(2) Department of Speech Therapy, Faculty of Medicine, Universidade Federal de Minas Gerais – UFMG – Belo Horizonte (MG), Brazil.

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Corresponding author: Tatiana Rocha Silva. E-mail: tatiana.rochas@gmail.com

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INTRODUCTION

The ocular vestibular evoked myogenic potential (oVEMP) is generated from extraocular muscles, in response to sounds with an elevated intensity. The oVEMP evaluates the superior vestibular pathway and the ascending contralateral pathway, through the vestibulo-ocular reflex[1,2,3,4,5].

The vestibulo-ocular reflex is responsible for stabilizing vision during head and body movements. Non physiologic stimuli, such as high-intensity sounds, can cause eye reflex movements in the absence of cephalic displacement, thereby providing a method to evaluate the vestibular-ocular reflex[6,7].

The origin of the oVEMP is controversial, since there is still no consensus among researchers. Some authors consider the utricle to be responsible for the responses of the oVEMP, others believe it is the saccule, and a third group of researchers suggests that both—saccule and utricle—are responsible for generating the oVEMP. We emphasize that the utricular origin hypothesis is more widely accepted among researchers[8,9].

Researchers agree that the responses of the oVEMP are mediated by the upper branch of the vestibular nerve. Studies have shown that in patients with superior vestibular neuritis, the responses are absent for oVEMP and present for the cervical VEMP (cVEMP). In patients with inferior vestibular neuritis, the responses are present for the oVEMP and absent for the cVEMP[9,10,11].

These findings suggest the dependence of oVEMP on the superior vestibular nerve. As utricular afferences travel to the superior vestibular nerve, some authors concluded that oVEMP responses might be mediated by activation of the utricle[8].

In short, the hypothesis that the responses of the oVEMP are mediated by the utricle is based, principally, in two arguments. First, oVEMP depends on the superior vestibular nerve, which contains utricular fibers, while the course of afferent saccular fibers is predominantly in the lower vestibular nerve. Second, the projections of otoliths in the extraocular muscles originate in the utricle[1,8].

These arguments are still much discussed and questioned. All of the afferent fibers of the utricle pass through the superior vestibular nerve, whereas the saccular fibers have their course in both divisions of the vestibular nerve. In other words, the superior vestibular nerve innervates not only the utricle, but also the anterior portion of the saccule and the horizontal semicircular canals, whereas the lower vestibular nerve innervates the posterior semicircular canal and most of the saccule[1,4].

However, the motor projections between the saccule and the ocular system are less extensive, whereas the neural connections between the utricle and the ocular system and the connections between the saccule and the vestibular system are more numerous. Thus, the saccule is denoted as the origin of cVEMP and the utricle as the origin of oVEMP[12].

The oVEMP is an evoked myogenic potential of average latency that evaluates the muscle response resulting from sound stimulation. The oVEMP can be initiated via acoustic stimulation by either air pathway or bone pathway. In the presentation by air pathway, the response is logged in musculature contralateral to the stimulated ear. In the presentation by bone pathway, the two ears are stimulated simultaneously. The inferior oblique muscle is the most superficial of the six extraocular muscles responsible for eye movement. The oVEMP is performed using surface electrodes on skin located just below the eye, on the side contralateral to that of the auditory stimulation[1,2,3].

The oVEMP is composed of two sets of biphasic waveforms. The first biphasic potential has a negative peak (N) with an average latency of 10 ms, followed by a positive peak (P) with an average latency of 15 ms, making it known as N1–P1.

Recent investigations have utilized the oVEMP in the study of a range of vestibular disorders. Among them, Ménière's disease, vestibular neuronitis, benign paroxysmal positional vertigo, and vestibular Schwannomas stand out [8,13,14,15,16,17,18].

Just as the cVEMP does, the oVEMP presents various characteristics that are favorable to its utilization: it is an objective, noninvasive examination that is easily executed; further, it is fast, inexpensive, and does not cause the patient any discomfort. However, studies for technique standardization are necessary to determine the clinical value[13].

OBJECTIVE

This review was performed to identify and systematize the main studies on the oVEMPs and their applications in the diagnosis of various vestibular diseases.

RESEARCH STRATEGY

For this study, was conducted a systematic review of the literature, without meta-analysis, of studies that used the technique of ocular vestibular evoked myogenic potential to investigate vestibular disorders. We searched electronic databases, including PubMed, Web of Science, MEDLINE, Scopus, LILACS, and SciELO, to obtain articles published from January 2010 to March 2016. In the search, the following keywords were used: "*vestibular evoked myogenic potential*, *vestibular diseases*, *reflex vestibulo-ocular,* and *utricle*." The keywords were selected by consulting the DeCS (*Descritores em Ciências da Saúde*) (Health Sciences Descriptors) and MeSH (Medical Subject Headings) and were combined using the Boolean operator AND (Chart 1).

Through our search strategies, we found 265 publications (66 in PubMed, 42 in Web of Science, 28 in MEDLINE, and 129 in Scopus). It is emphasized that no publications were found in the LILACS or SciELO databases. We primarily analyzed article titles in order to select those that have any correlation with the theme proposed. The second round of the selection process involved analyzing the abstracts.

Chart 1. Combinations used for the search

Strategy	Combination
Strategy 1	*vestibular evoked myogenic potential* AND *vestibular diseases* AND *reflex vestibulo-ocular*
Strategy 2	*vestibular evoked myogenic potential* AND *utricle* AND *vestibular diseases*
Strategy 3	*vestibular evoked myogenic potential* AND *reflex vestibulo-ocular* AND *utricle*

SELECTION CRITERIA

To be included in this review, the publications must meet the following inclusion criteria: articles published from January 2010 to March 2016, in Portuguese, English, or Spanish; articles available in full; and studies that used the oVEMP to investigate vestibular diseases.

The following exclusion criteria were adopted: literature review articles, letters, and editorials.

DATA ANALYSIS

The analysis of the material was performed in stages. First, the duplicate references in the databases consulted were eliminated. Second, by virtue of reading the abstracts, we excluded articles that did not meet the established objectives. In the third stage, articles that met the objectives of this study were obtained in full.

Each selected article was then evaluated in terms of locale, publication period, design/basis of study, and population. Then, we listed our findings for the evaluation of oVEMP.

RESULTS

We initially found 265 articles in our search of the electronic databases. However, only 14 were selected for this literature review (Chart 2).

All publications were written in English, as we were unable to find publications in Portuguese. The countries with the highest number of publications were Japan, with 5 (36%) publications[19,22,23,25,30] and Australia, with 3 (21%)[5,24,28]. The sample size of the studies ranges from 12 to 133 patients with vestibular alterations.

In relation to the population/sample of patients with vestibular alterations included in the study, it was observed that the diseases most investigated were the vestibular

Chart 2. Characterization of studies that investigated vestibular diseases through the use of oVEMP

Author	Locale of the study	Study design	Population/sample	Study context	Study findings
Govender et al.[5]	Sidney	Case control	Case group: 12 patients with unilateral vestibular dysfunction; Control group: 11 individuals without auditory or vestibular complaints	Comparison of the responses of the oVEMP utilizing side electrodes (stimulation lateral transmastoid) with the responses of the oVEMP utilizing inferior electrodes (inferior oblique muscles) in patients with vestibular Schwannoma. Utilization of the oVEMP with auditory stimulation by air pathway, tone burst, in the frequency of 500 Hz.	The oVEMP was altered only on the affected side, when inferior electrodes were used. However, by using side electrodes the oVEMP was abnormal both in the affected side, as well as in the asymptomatic side. In the control group, there were no observed alterations in the oVEMP.
Chiarovano et al.[14]	Paris	Case control	Case group: 74 patients with vestibular disorders (12 with vestibular Schwannoma, 5 with dehiscence of the superior canal, 26 with Ménière's disease, 12 with vestibular neuronitis in the acute phase, 9 with arreflexia bilateral horizontal canal, and 17 with unilateral vestibular function loss); Control group: 32 individuals without auditory or vestibular complaints	Evaluation of the oVEMP through auditory stimulation, by air pathway, clicks or tone burst in the frequency of 500 Hz.	The amplitude of the oVEMP was less in most patients with vestibular disorders. In the control group, there were no observed alterations in the oVEMP.
Iwasaki et al.[19]	Tokyo	Case control	Case group: 14 patients with unilateral vestibular dysfunction (9 with Schwannoma and 5 with vestibular neuritis); Control group: 24 individuals without auditory or vestibular complaints.	Evaluation of the oVEMP with binaural stimulation in individuals with unilateral vestibular dysfunction. Utilization of the oVEMP with auditory stimulation by air pathway, tone burst, in the frequency of 500 Hz.	In the patients with unilateral vestibular dysfunction, there was no significant difference in amplitude and latency of response with binaural stimulation. In the control group, no alterations were observed in the oVEMP.

Chart 2. Characterization of studies that investigated vestibular diseases through the use of oVEMP (cont.)

Author	Locale of the study	Study design	Population/sample	Study context	Study findings
Lee et al.[20]	Jeonju (South Korea)	Transversal	36 patients with benign paroxysmal positional vertigo (VPPB). Of these, 16 presented recurrent VPPB and 20 presented non-recurrent VPPB.	Utilization of the oVEMP (auditory stimulation by air pathway, tone burst, in the frequency of 500 Hz) to test the hypothesis that the otolith dysfunction can be the cause of recurrence of VPPB.	The responses of the ocular VEMP showed alterations in 8 individuals in the recurrent VPPB group and in 3 individuals in the non-recurring BPPV group.
Bremova et al.[21]	Munich	Longitudinal	30 patients with unilateral VPPB.	Utilization of the oVEMP (auditory stimulation by bone pathway, tone burst, in the frequency of 500 Hz) to evaluate the success of liberatory maneuvers.	After treatment, observed increase in the amplitude of the responses of the oVEMP.
Seo et al.[22]	Osaka (Japan)	Transversal	16 patients with VPPB.	Utilization of the oVEMP (auditory stimulation by air pathway, tone burst, in the frequency of 500 Hz) to evaluate the utricular dysfunction in patients with VPPB.	The oVEMP showed reduced responses in 5 patients with VPPB in the pre-treatment period.
Nakahara et al.[23]	Fujisawa (Japan)	Case control	Case group: 12 patients with VPPB; Control group: 12 individuals without auditory or vestibular complaints.	Utilization of the oVEMP (auditory stimulation by air pathway, tone burst, in the frequency of 500 Hz) to evaluate the utricular dysfunction signals in patients with VPPB.	The patients with VPPB showed alterations in the responses of the oVEMP to the affected side. In the control group, no alterations were observed in the oVEMP.
Manzari et al.[24]	Sidney	Transversal	133 patients with superior vestibular neuritis.	Analysis of the activation of the potential n1 of the oVEMP (auditory stimulation by air pathway, tone burst, in the frequency of 500 Hz) in patients with superior vestibular neuritis.	The amplitude of the potential n1 was lower for patients with superior vestibular neuritis on the affected side.
Kinoshita, et al.[25]	Tokyo	Transversal	45 patients with unilateral vestibular Schwannoma.	Comparison of the responses of the oVEMP (auditory stimulation by air pathway and by bone pathway, tone burst, in the frequency of 500 Hz), with the responses of the oVEMP by auditory stimulation by bone pathway in patients with vestibular Schwannoma.	There was no difference between the responses of the oVEMP by auditory stimulation tone burst and the responses of the oVEMP by auditory stimulation by bone pathway.
Lin and Young[26]	Taipei (Taiwan)	Transversal	20 patients with unilateral vestibular neuritis.	Utilization of the oVEMP (auditory stimulation by bone pathway, tone burst, in the frequency of 500 Hz) to evaluate the vestibular nerve branches affected in patients with vestibular neuritis.	11 patients showed altered responses to the oVEMP. After treatment, 3 patients showed normal responses to the oVEMP.
Sandhu et al.[27]	Brighton (England)	Cohort	Diseased group: 12 patients with Ménière's disease; Not diseased group: 8 individuals without auditory or vestibular complaints.	Evaluation of the oVEMP (auditory stimulation by bone pathway, tone burst, in the frequency of 500 Hz) in various frequencies in patients with Ménière's disease.	The amplitude of response of the oVEMP was higher for the frequency of 500 Hz.
Manzari et al.[28]	Sidney	Transversal	26 patients with dehiscence of the superior semicircular canal.	Utilization of the oVEMP (auditory stimulation by bone pathway, tone burst, in the frequency of 500 Hz) to investigate the effect of dehiscence of the superior semicircular canal on the potential N10.	The amplitude of the potential N10 was higher contralaterally to the affected side.

Chart 2. Characterization of studies that investigated vestibular diseases through the use of oVEMP (cont.)

Author	Locale of the study	Study design	Population/sample	Study context	Study findings
Winters et al.[29]	Utrecht (Netherlands)	Case control	Case group: 27 patients with otosclerosis; Control group: 26 individuals without auditory or vestibular complaints.	Utilization of the oVEMP (auditory stimulation by bone pathway, tone burst, in the frequency of 500 Hz) to investigate the utricular function in patients with otosclerosis.	No differences were observed between the study group and the control group. In control group, no alterations were observed in the oVEMP.
Murofushi et al.[30]	Fujisawa (Japan)	Case control	Case group: 26 patients with unilateral peripheral vestibular disorder (20 with Ménière's disease and 6 with unilateral vestibular neuritis); Control group: 7 individuals without auditory or vestibular complaints	Analysis of the responses of the oVEMP by auditory stimulation tone burst, by air pathway, in the frequency of 500 Hz with the answers caloric test of the vestibular test.	The results of the oVEMP allowed researchers to observe significant association with the findings of the caloric test. Therefore, the oVEMP reflects, exclusively, the utricular function. In control group, no alterations were observed in the oVEMP.

Subtitle: VEMP = vestibular evoked myogenic potential

neuritis (176 patients), the benign paroxysmal positional vertigo (VPPB) (106 patients), the vestibular Schwannomas (66 patients) and the Ménière's disease (58 patients). The age of individuals with vestibular alterations ranges from 21 to 94 years[5,14,19,20,21,22,23,24,25,26,27,28,29,30].

As for design of the selected studies, it was observed that 43% were transversal studies (7 studies)[20,22,24,25,26,28], 43% were transversal case control studies (6 studies)[5,14,19,23,29,30], 7% were cohort studies (1 study)[27], and 7% were longitudinal studies (1 study)[21]. Therefore, most studies were transversal studies.

All studies (100%) used auditory stimulus tone burst rarified, with a frequency of 500 Hz and varying intensity of 125-135 dBNPS[5,14,19,20,21,22,23,24,25,26,27,28,29,30].

We observed that 8 (57%) studies used the technique of the oVEMP with conduction of stimuli by air pathway[5,14,19,20,21,22,23,30], 5 (36%) by bone pathway[24,26,27,28,29], and 1 (7%) by air pathway and by bone pathway[25].

In relation to the terminology adopted for the complex of biphasic waves, there was variation between studies. The terminology N1-P1 was adopted in 8 (57%) studies, whereas the terminology N10-P15 was adopted in 6 (43%) studies[5,14,19,20,21,22,23,24,25,26,27,28,29,30].

DISCUSSION

Due to differences in the methodology of the studies, it was sometimes difficult to make comparisons between the results. Furthermore, some studies did not show important data, such as if the alteration found in the oVEMP was in relation to amplitude or latency, or if the alteration found was an absence of waves, attenuated or increased amplitude, or latency delay.

The comparisons between oVEMP with stimulation by air pathway and by bone pathway should be considered with caution, since the mechanisms' stimulus of transduction are different for stimulation by air pathway and by bone pathway. As these stimuli activate different otologic pathways, differences in the responses and frequency of the oVEMP can be expected[1,3,4].

The use of auditory stimulus tone burst in most studies is justified by the fact that the threshold of saccular excitability is lower, when compared with the click, and is more comfortable for the subject being evaluated. The repeated use of the 500 Hz frequency is justified because the responses generated are more homogeneous and constant[8].

In the transversal case control studies, it was verified that there was a difference between the case group and the control group for oVEMP; in other words, there were differences between the responses of the oVEMP among individuals with vestibular disease and individuals without auditory or vestibular complaints. The main differences found were for the affected ear, in relation to the amplitude and latency of the waves. In some studies, an absence of oVEMP was observed; in others, there was alteration only in one of the waves, N1 or P1. Other studies showed latency delays in both waves. In relation to the amplitude, all the studies verified reduction in the response amplitude[5,14,19,23,29,30].

In the cohort study selected for review, absence of oVEMP in the ear affected by Ménière's disease was observed. However, the most interesting observation in this study was the fact that patients with asymptomatic, unilateral Ménière's disease showed alteration in the oVEMP[27]. Therefore, the oVEMP can be a diagnostic method of endolymphatic hydrops in early stages and may serve as a prognostic factor for bilateral involvement of Ménière's disease[16,17,27].

Among the longitudinal studies, the one that evaluated the amplitude of the oVEMP in patients with VPPB stands out the. This study compared the responses of the oVEMP before and after performing the liberatory maneuvers. After performing the maneuvers, there was an increase in the response amplitude of the oVEMP. This finding can indicate a successful replacement of otocones that become displaced back to the utricular macula[21].

Another relevant transversal study utilized the oVEMP in patients with vestibular neuritis who did not produce caloric responses in the affected side. The authors observed that some patients presented normal responses, others presented reduced responses, and a third group of patients presented absence of responses[26]. This fact shows that some patients present involvement of both portions of the vestibular nerve, while others have lesions only in the superior portion—a very important aspect regarding the prognosis for patients with vestibular neuritis[11,24,26].

Of the selected studies, 13 (93%) investigated the utricular function through the oVEMP. The authors emphasized the importance of evaluating the utricular function in various vestibular disorders. Therefore, most of the authors agree that the utricle is responsible for the origin of the oVE MP[5,14,20,21,22,23,24,25,26,27,28,29,30].

The methodological differences between the studies limited the generalizations of the estimates. However, we observed the importance of using the oVEMP to evaluate utricular function and the ascending contralateral vestibular pathway in the most diverse vestibular diseases.

The promising trends that characterize the new investigations related to oVEMP suggest that, by using it coherently, important results can be achieved for diagnostic studies. The oVEMP can contribute, along with other vestibular tests, to the diagnosis of various vestibular diseases.

It is important to emphasize that even with the simplified recording methodology and low operating cost, it is necessary for clinical application that this exam have uniform parameters. Methodological standardization is a fundamental criterion for the reliability and sensitivity of the examination.

CONCLUSION

Most of the research conducted in recent years and published in the databases PubMed, Web of Science, MEDLINE, and Scopus showed that oVEMP is an effective method to evaluate the utricular function in a diverse array of vestibular diseases. The oVEMP results were altered in most individuals with vestibular conditions.

REFERENCES

1. Todd NPM. The origin of the ocular vestibular evoked myogenic potential (OVEMP). Clin Neurophysiol. 2010;121(6):978-80. http://dx.doi.org/10.1016/j.clinph.2010.01.026
2. Murofushi T, Nakahara H, Yoshimura E. Assessment of the otolith-ocular reflex using ocular vestibular evoked myogenic potentials in patients with episodic lateral tilt sensation. Neurosci Lett. 2012;515(2):103-6. http://dx.doi.org/10.1016/j.neulet.2012.02.084
3. Chihara Y, Iwasaki S, Ushio M, Fujimoto C, Kashio A, Kondo K et al. Ocular vestibular-evoked myogenic potentials (oVEMPs) require extraocular muscles but not facial or cochlear nerve activity. Clin Neurophysiol. 2009;120(3):581-7. http://dx.doi.org/10.1016/j.clinph.2008.12.030
4. Piker EG, Jacobson GP, McCaslin DL, Hood LJ. Normal characteristics of the ocular vestibular evoked myogenic potential. J Am Acad Audiol. 2011;22(4):222-30. http://dx.doi.org/10.3766/jaaa.22.4.5
5. Govender S, Rosengren SM, Todd NPM, Colebatch JG. Ocular vestibular evoked myogenic potentials produced by impulsive lateral acceleration in unilateral vestibular dysfunction. Clin Neurophysiol. 2011;122(12):2498-504. http://dx.doi.org/10.1016/j.clinph.2011.04.024
6. Park HJ, Lee IS, Shin JE, Lee YJ, Park MS. Frequency-tuning characteristics of cervical and ocular vestibular evoked myogenic potentials induced by air-conducted *tone bursts*. Clin Neurophysiol. 2010;121(1):85-9. http://dx.doi.org/10.1016/j.clinph.2009.10.003
7. Felipe L, Kingma H. Ocular vestibular evoked myogenic potentials. Int Arch Otorhinolaryngol. 2014;18(1):77-9. http://dx.doi.org/10.1055/s-0033-1352503
8. Kantner C, Gürkov R. Characteristics and clinical applications of ocular vestibular evoked myogenic potentials. Hear Res. 2012;294(1-2):55-63. http://dx.doi.org/10.1016/j.heares.2012.10.008
9. Curthoys IS, Iwasaki S, Chihara Y, Ushio M, McGarvie LA, Burgess AM. The ocular vestibular-evoked myogenic potential to air-conducted sound: probable superior vestibular nerve origin. Clin Neurophysiol. 2011;122(3):611-6. http://dx.doi.org/10.1016/j.clinph.2010.07.018
10. Manzari L, Burgess AM, Curthoys IS. Dissociation between cVEMP and oVEMP responses: different vestibular origins of each VEMP? Eur Arch Otorhinolaryngol. 2010;267(9):1487-9. http://dx.doi.org/10.1007/s00405-010-1317-9
11. Shin BS, Oh SY, Kim JS, Kim TW, Seo MW, Lee H et al. Cervical and ocular vestibular-evoked myogenic potentials in acute vestibular neuritis. Clin Neurophysiol. 2012;123(2):369-75. http://dx.doi.org/10.1016/j.clinph.2011.05.029
12. Uchino Y, Kushiro K. Differences between otolith- and semicircular canal activated neural circuitry in the vestibular system. Neurosci Res. 2011;71(4):315-27. http://dx.doi.org/10.1016/j.neures.2011.09.001
13. Martínez JR, López JR, Fernández NP, Guzmán RBD. ¿Cómo analizar un potencial evocado miogénico vestibular? aplicación de un método no lineal. Acta Otorrinolaringol Esp. 2011;62(2):126-31. http://dx.doi.org/10.1016/j.otorri.2010.10.004
14. Chiarovano E, Zamith F, Vidal PP, Waele C. Ocular and cervical VEMPs: a study of 74 patients suffering from peripheral vestibular disorders. Clin Neurophysiol. 2011;122(8):1650-9. http://dx.doi.org/10.1016/j.clinph.2011.01.006
15. Oh SY, Kim JS, Yang TH, Shin BS, Jeong SK. Cervical and ocular vestibular-evoked myogenic potentials in vestibular neuritis: comparison between air- and bone-conducted stimulation. J Neurol. 2013;260(8):2102-9. http://dx.doi.org/10.1007/s00415-013-6953-8
16. Manzari L, Tedesco AR, Burgess AM, Curthoys IS. Ocular and cervical vestibular-evoked myogenic potentials to bone conducted vibration in Ménière's disease during quiescence vs during acute

attacks. Clin Neurophysiol. 2010;121(7):1092-101. http://dx.doi.org/10.1016/j.clinph.2010.02.003

17. Ribeiro S, Almeida RR, Caovilla HH, Ganança MM. Dos potenciais evocados miogênicos vestibulares nas orelhas comprometida e assintomática na Doença de Ménière unilateral. Rev Bras Otorrinolaringol. 2005;71(1):60-6. http://dx.doi.org/10.1590/S0034-72992005000100011
18. Lin KY, Young YH. Role of ocular VEMP test in assessing the occurrence of vertigo in otosclerosis patients. Clin Neurophysiol. 2015;126(1):187-93. http://dx.doi.org/10.1016/j.clinph.2014.03.032
19. Iwasaki S, Egami N, Inoue A, Kinoshita M, Fujimoto C, Murofushi T et al. Ocular vestibular evoked myogenic potential elicited from binaural air-conducted stimulations: clinical feasibility in patients with peripheral vestibular dysfunction. Acta Otolaryngol. 2013;133(7):708-13. http://dx.doi.org/10.3109/00016489.2013.767476
20. Lee JD, Park MK, Lee BD, Lee TK, Sung KB, Park JY. Abnormality of cervical vestibular-evoked myogenic potentials and ocular vestibular-evoked myogenic potentials in patients with recurrent benign paroxysmal postitional vertigo. Acta Otolaryngol. 2013;133(2):150-3. http://dx.doi.org/10.3109/00016489.2012.723823
21. Bremova T, Bayer O, Agrawal Y, Kremmyda O, Brandt T, Julian T et al. Ocular VEMPs indicate repositioning of otoconia to the utricle after successful liberatory maneuvers in benign paroxysmal positioning vertigo. Acta Otolaryngol. 2013;133(12):1297-303. http://dx.doi.org/10.3109/00016489.2013.829922
22. Seo T, Saka N, Ohta S, Sakagami M. Detection of utricular dysfunction using ocular vestibular evoked myogenic potential in patients with benign paroxysmalpositional vertigo. Neurosci Lett. 2013;550:12-6. http://dx.doi.org/10.1016/j.neulet.2013.06.041
23. Nakahara H, Yoshimura E, Tsuda Y, Murofushi T. Damaged utricular function clarified by oVEMP in patients with benign paroxysmal positional vertigo. Acta Otolaryngol. 2013;133(2):144-9. http://dx.doi.org/10.3109/00016489.2012.720030
24. Manzari L, Tedesco A, Burgess AM, Curthoys IS. Ocular vestibular-evoked myogenic potentials to bone-conducted vibration in superior vestibular neuritis show utricular function. Otolaryngol Head Neck Surg. 2010;143(2):274-80. http://dx.doi.org/10.1016/j.otohns.2010.03.020
25. Kinoshita M, Iwasaki S, Fujimoto C, Inoue A, Egami N, Chihara Y et al. Ocular vestibular evoked myogenic potentials in response to air-conducted sound and bone-conducted vibration in vestibular schwannoma. Otol Neurotol. 2013;34(7):1342-8. http://dx.doi.org/10.1097/MAO.0b013e31828d6539
26. Lin CM, Young YH. Identifying the affected branches of vestibular nerve in vestibular neuritis. Acta Otolaryngol. 2011;131(9):921-8. http://dx.doi.org/10.3109/00016489.2011.573504
27. Sandhu JS, Low R, Rea PA, Saunders NC. Altered frequency dynamics of cervical and ocular vestibular evoked myogenic potentials in patients with Ménière's disease. Otol Neurotol. 2012;33(3):444-9. http://dx.doi.org/10.1097/MAO.0b013e3182488046
28. Manzari L, Burgess AM, McGarvie LA, Curthoys IS. Ocular and cervical vestibular evoked myogenic potentials to 500 Hz Fz bone-conducted vibration in superior semicircular canal dehiscence. Ear Hear. 2012;33(4):508-20. http://dx.doi.org/10.1097/AUD.0b013e3182498c09
29. Winters SM, Klis SFL, Kool ACM, Kraaijenga SAC, Tange RA, Grolman W. Perioperative bone-conducted ocular vestibular-evoked myogenic potentials in otosclerosis patients. Otol Neurotol. 2013;34(6):1109-14. http://dx.doi.org/10.1097/MAO.0b013e318283969a
30. Murofushi T, Nakahara H, Yoshimura E, Tsuda Y. Association of air-conducted sound oVEMP findings with cVEMP and caloric test findings in patients with unilateral peripheral vestibular disorders. Acta Otolaryngol. 2011;131(9):945-50. http://dx.doi.org/10.3109/00016489.2011.580003