

# Ocular Vestibular Evoked Myogenic Potentials

Lilian Felipe<sup>1</sup> Herman Kingma<sup>2</sup>

<sup>1</sup> Department of Speech and Hearing Therapy, Veiga de Almeida University, Rio de Janeiro/RJ, Brazil

<sup>2</sup> Department of Otolaryngology and Vestibulology, School for Mental Health and Neuroscience (MHeNS), Maastricht University Medical Centre (MUMC), Maastricht, Limburg, The Netherlands

**Address for correspondence** Lilian Felipe, MD, PhD, Department of Speech and Hearing Therapy, Universidade Veiga de Almeida, Rua Ibituruna, 109, Maracanã, Rio de Janeiro, Brazil (e-mail: lilianfelipefono@gmail.com).

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## Abstract

**Introduction** Diagnostic testing of the vestibular system is an essential component of treating patients with balance dysfunction. Until recently, testing methods primarily evaluated the integrity of the horizontal semicircular canal, which is only a portion of the vestibular system. Recent advances in technology have afforded clinicians the ability to assess otolith function through vestibular evoked myogenic potential (VEMP) testing. VEMP testing from the inferior extraocular muscles of the eye has been the subject of interest of recent research.

**Objective** To summarize recent developments in ocular VEMP testing.

**Results** Recent studies suggest that the ocular VEMP is produced by otolith afferents in the superior division of the vestibular nerve. The ocular VEMP is a short latency potential, composed of extraocular myogenic responses activated by sound stimulation and registered by surface electromyography via ipsilateral otolithic and contralateral extraocular muscle activation. The inferior oblique muscle is the most superficial of the six extraocular muscles responsible for eye movement. Therefore, measurement of ocular VEMPs can be performed easily by using surface electrodes on the skin below the eyes contralateral to the stimulated side.

**Conclusion** This new variation of the VEMP procedure may supplement conventional testing in difficult to test populations. It may also be possible to use this technique to evaluate previously inaccessible information on the vestibular system.

## Keywords

- ▶ vestibular evoked myogenic potentials
- ▶ vestibulo-ocular reflex
- ▶ postural balance
- ▶ evaluation

## Introduction

Recent research has described a new vestibular evaluation test, the ocular vestibular evoked myogenic potential (o-VEMP). This type of vestibular potential is evoked by sound stimulation and registered in the presence of ocular myogenic responses, in the same way as the cervical vestibular evoked myogenic potential (c-VEMP).<sup>1</sup>

Based on the results of anatomical and physiologic experimental studies in animals, it was realized that the o-VEMP can be used to evaluate otolithic activity. Differently from the c-VEMP, which analyzes the ipsilateral descending vestibular pathway, the o-VEMP has been validated for evaluation of the

ascending vestibular pathway via the vestibulo-ocular reflex (VOR).<sup>1,2</sup> The VOR is responsible for stabilizing vision on the retina during head and body movements.<sup>2–4</sup> Nonphysiologic stimuli such as high-intensity sounds can provoke ocular reflex movements in the absence of cephalic displacement, thus providing a method to evaluate the VOR.<sup>5</sup>

Information from the utricle stimulates the six ocular muscles. The utricular macula is divided into different functional regions, and each one is able to generate stimuli to a particular ocular muscle.<sup>3,5</sup> Utricular excitatory inputs protrude to the superior oblique, superior rectus, and medial rectus eye muscles ipsilaterally and the inferior oblique and inferior rectus eye muscles on the contralateral side.<sup>2</sup>

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Every movement or new cephalic displacement causes excitement of one of the regions of the utricular macula, leading to eye movement in the opposite direction. Information from the utricle converges with information from the semicircular canals (SCCs) in the vestibular nuclei and passes through the same neural pathways to the ocular motor nuclei. The fundamental difference between the information coming from the SCCs and that from the utricle is the type of stimulation involved; the SCCs are in charge of angular acceleration (i.e., rotational movements), and the utricle is in charge of linear acceleration, especially changes in static and gravitational orientation.<sup>6</sup>

The connections between the saccule and the ocular system are less extensive when compared with those related to the utricle. Thus, it is believed that there is a functional difference between the otolithic organs; although the utricle is principally related to eye movement, the saccule plays a major role in the control of postural adjustment.<sup>6,7</sup>

## Concept

The o-VEMP is a short latency potential, composed of extraocular myogenic responses activated by sound stimulation and registered by surface electromyography via ipsilateral otolithic and contralateral extraocular muscle activation.<sup>3-8</sup> The inferior oblique muscle is the most superficial of the six extraocular muscles responsible for eye movement. Therefore, measurement of o-VEMPs can be performed easily by using surface electrodes on the skin below the eyes, contralaterally to the stimulated side.<sup>8</sup>

Research has shown that this potential is not affected by the neural activity of the cochlear and facial nerves, providing evidence that the o-VEMP has a vestibulo-ocular origin. Although clinical studies suggest that this potential is of vestibular origin, its exact origin and pathway are not known.<sup>6-8</sup>

## Methodology and Recording Protocol

The o-VEMP can be obtained by sound stimulation, vibrations, or head taps. The stimuli used are clicks or tone bursts (~100 to 250 promediations). Consecutive recordings are performed to evaluate reproducibility. The stimulation threshold for this potential is reported to be from 95 dB normal hearing level.<sup>6-10</sup>

In the literature, a higher incidence of achievement of o-VEMP measurement is described using a frequency of 500 Hz. Stimulation rates vary from 3 to 5 Hz. The window for analysis is 50 milliseconds.<sup>5,6</sup> Positive electrodes are placed on the lower eyelid of each eye, with reference electrodes situated 1 to 2 cm below these and the ground electrode placed on the breastbone. Electrode impedance must be less than 7 kΩ. Electromyographic signals are amplified and reported band-pass filter values range from 5 to 500 Hz, 1 to 1,000 Hz, and 3 to 500 Hz.

The amplitude of the o-VEMP is widely influenced by eye direction. It is high when looking up, low when looking ahead, and abolished when looking down.<sup>6-8</sup> During

measurement of o-VEMPs, therefore, the patient is instructed to look upward, staring at a fixed point, because responses are of higher amplitude when the subject looks in this direction.<sup>3,6-8</sup> It is recommended that the fixed point is more than 2 m from the patient's eyes. Throughout the examination, the eyes must remain steady. The registered responses are ipsilateral to the applied stimulation and contralateral to the inferior oblique extraocular muscle. Thus, the amplitude of the potential becomes more prominent when looking up, as in this situation the inferior oblique muscle stays near the register electrode.<sup>2</sup> A possible additional explanation for this phenomenon is that when the muscle contracts during looking up, more motor units are activated synchronously, producing a component of larger amplitude.<sup>2,6</sup> Continuous and repetitive testing can cause eyestrain and/or involuntary blinking, deteriorating the quality of the waveform. Therefore, binaural stimulation has been suggested as an option for reducing the duration of testing.<sup>7</sup>

The o-VEMP tracing obtained consists of a biphasic waveform. The first peak has a negative deflection (N) latency of ~10 milliseconds, followed by a positive peak (P) with a mean latency of 15 milliseconds, which are called N1 and P1, respectively. Because responses are recorded by surface electromyography, control of muscle contraction is imperative for reproducible and reliable results.<sup>6-8</sup>

## Clinical Usefulness

Pathologic studies have been performed to verify the clinical applicability of this test. The most commonly studied vestibular changes are superior canal dehiscence syndrome (SCDS) and multiple sclerosis. In SCDS, the threshold for responses is lower and the amplitude of recorded o-VEMPs is 5 to 20 times higher when compared with control group responses. Research has suggested that o-VEMP testing can be performed as a screening test for SCDS.<sup>6</sup> A delay in latency was observed in individuals with multiple sclerosis; this was justified by the finding of plaques of demyelination in the vestibular nerve. In addition, o-VEMP testing could aid in obtaining information on brainstem lesions.<sup>9,10</sup>

## Discussion

To identify the cause of dizziness in patients, it is necessary to obtain information concerning the function of the vestibular end organs of both ears. Although SCC function can be tested with caloric or head impulse testing,<sup>11</sup> safe and simple tests of otolith function are not common. Recently, two important tests of otolith function have been reported: the c-VEMP and the o-VEMP.<sup>12</sup> Unlike the c-VEMP test, which assesses the descending vestibular pathway via the ipsilateral saccolcollic reflex, the o-VEMP test has been validated for evaluation of the ascending vestibular pathway via the crossed VOR.<sup>13</sup>

The o-VEMP may be easily obtained from the skin surface beneath the eye, contralaterally to the acoustically stimulated ear.<sup>14,15</sup> The amplitude of the o-VEMP becomes more prominent when the subject looks upward, as the belly of the inferior

oblique muscle is brought close to the recording electrode. An additional possible explanation for this phenomenon is that when this muscle contracts during looking upward, its motor units (motor neurons and/or muscle fibers) are activated more synchronously, producing compound action potentials of larger amplitude. However, continuous and repeated upward gaze may cause eye strain and involuntary blinking, deteriorating the quality of the waveforms obtained.<sup>16</sup> Binaural acoustic stimulation with bilateral recordings can help to reduce the duration of the recording session.

Eliciting o-VEMPs by bone-conducted stimulation requires the extra cost of adding an amplifier to the original instrument. Vestibular activation by air-conducted sound in healthy adults is highly reproducible between experiments and more symmetrical than activation by head taps or bone-conducted vibration.<sup>17</sup> Binaural air-conducted sound selectively stimulates the saccular macula, and bone-conducted vibration stimulates both the utricular and saccular maculae.<sup>18</sup> Consequently, binaural air-conducted acoustic stimulation is plausibly more specific, reliable, and practicable than bone-conducted vibration in eliciting o-VEMPs to investigate the function of the saccule and inferior vestibular nerve in subjects without conductive hearing loss, which can be excluded by conventional audiometry.<sup>9,16</sup>

Studies presenting the latencies and amplitudes of monaural o-VEMPs and binaural o-VEMPs showed similar results.<sup>2,16</sup> In addition, significant correlations without differences between monaural o-VEMPs and binaural o-VEMPs were demonstrated with respect to threshold, latency, and amplitude, indicating that the binaural o-VEMP test provides the same information as the monaural o-VEMP test. However, the recording duration of the former is shorter than that of the latter. Thus, the binaural test may be a more convenient screening tool for assessment of the crossed VOR.<sup>16</sup>

## Conclusion

The number of studies investigating the o-VEMP is increasing. However, to define the clinical usefulness of measurement of the o-VEMP, it is very important to establish its neural course. In addition, it is vital to document normal values, standardized protocols, and defined applications in vestibular pathologies for this technique. Once this information has been established, the o-VEMP may be an alternative measurement in the otoneurologic battery of tests used for the assessment of otolith function, as it can be used as an assessment tool for the vestibulo-ocular pathway to complement the findings of c-VEMP testing.

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