

Effect of age on ocular vestibular-evoked myogenic potentials using air-conducted sound

Samir Asal

Department of Otorhinolaryngology
Audiology Unit, Alexandria Petrol Hospital,
Faculty of Medicine, Alexandria University,
Alexandria, Egypt

Correspondence to Samir Asal, MD,
Department of Otorhinolaryngology
Audiology Unit, Alexandria Petrol Hospital,
Faculty of Medicine, Alexandria University,
182 Omar Lofty Street Sporting Tram Station,
Alexandria 21111, Egypt
Tel: +20 122 454 9955;
e-mail: samir_asal@yahoo.com

Received 02 November 2013

Accepted 25 January 2014

The Egyptian Journal of Otolaryngology
2014, 30:166–170

Rationale/purpose

Diagnostic testing of the vestibular system is an essential component for the correct treatment and rehabilitation of patients with balance dysfunction. Stimulus-related electromyogenic changes can be recorded from the extraocular muscles and is termed ocular vestibular-evoked myogenic potential (oVEMP). These changes are a reflection of the otolith organ functionality. The purpose of this study was to investigate the effect of age on the amplitude, threshold, and latency of the oVEMP, to establish age-appropriate norms that will help in the correct diagnosis of balance dysfunction accordingly.

Participants and methods

This study was carried out in the Audiology Unit of Alexandria Petrol Hospital (Egypt). Participants with no medical history, normal hearing, and who were neurologically free participated in this study. The study was carried out on 50 ears (50 individuals) divided into five groups according to age: the first group from 10 to 25 years, the second group from 25 to 35 years, the third group from 35 to 45 years, the fourth group from 45 to 55 years, and the fifth group over 55 years of age. Each group contained 10 participants.

Results and conclusion

The main outcome measures are amplitude, latency, and threshold of the oVEMP. In this study, oVEMP was present contralaterally in 88% of healthy participants (44 of 50 ears), and the percentage of the presence of oVEMP decreased with age stratification to 60% in the oldest age group (>55 years). When we examined the younger groups in this study, we found 100% response rate for participants under the age of 45 years, whereas the response rate was only 80% in the fourth group (age range, 45–55 years) and 60% in the fifth group (age > 55 years). In the current study, an age effect on oVEMP N1–P1 amplitude and threshold was observed. Significantly reduced amplitude and a significantly increased threshold were observed in the two oldest age groups (>45 years) compared with other age groups. However, oVEMP N1 latency was stable for all age groups less than 55 years but significantly increased in the oldest age group above 55 years. The well-documented neuroanatomic age-related changes that occur in the peripheral vestibular system may explain the commonly reported decrease in the response rate and a decrease in the amplitude with age. However, oVEMP N1 latency represents the function of the time required for the afferent limb of reflex, central transmission and the efferent limb of reflex, and muscle activation. Therefore, the age-dependent increase in N1 latency may occur as a result of degradation of central vestibular system processing, rather than as a result of diminished peripheral vestibular system function.

Keywords:

oVEMP, aging, balance dysfunction, otolith organ

Egypt J Otolaryngol 30:166–170

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1012-5574

Introduction

Diagnostic testing of the vestibular system is an essential component of treating patients with balance dysfunction. Until now, very recent 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). VEMP is a short latency muscle potential that is created when the vestibular system is presented with loud sound. This sonomotor response can be easily recorded from surface electrodes placed over sternocleidomastoid muscles (SCMs) [1], and

it represents signal averaged attenuation of tonic electromyogenic (EMG) activity. A VEMP response recorded from SCM, also referred to as cervical vestibular-evoked myogenic potential or 'cVEMP' emanates from the saccule and has been a well-established clinical test of vestibular functions [2].

In addition to the SCM, stimulus-related EMG changes can be recorded from the extraocular muscles. Rosengren *et al.* [3] and Todd *et al.* [4] recorded short latency (10 ms) negative-going evoked myogenic potential from surface electrodes placed beneath the eye in response to acoustic stimulation. They termed these potentials as ocular vestibular-evoked myogenic

potentials, or 'oVEMPs'. The oVEMP represents stimulus-evoked initiation of EMG activity [1].

Further research confirmed that this negative peak at 10 ms (N10) component response was vestibular in origin and most likely originating from the otolith-ocular pathway. Whether it is utricular in origin or saccular and utricular in origin is still a matter of debate in the most contemporary literature [3–8].

oVEMP are optimally recorded as a response from extraocular muscles slightly below the eye contralateral to stimulation, as it originates from the otolith organs [3]. This response is myogenic in nature rather than being a response to eye movement, and arises from the vestibulo-ocular reflex [3,4,9,10]. The oVEMP is recorded from the contralateral inferior oblique muscle when in a flexed state [3], although some hypothesize that the inferior rectus may also contribute to the response [10]. Previous cVEMP research [4,11] suggested that the oVEMP response at the level of the extraocular muscles is excitatory because of its initial negative peak response.

The inferior extraocular muscles are best activated when the eyes are in superomedial gaze [3,5,6,8,10]. Rosengren *et al.* [12] described the neuronal pathway for oVEMP by the vestibulo-ocular reflex; activation of the vestibular nerve and vestibular nuclear complex traveling up the medial longitudinal fasciculus decussate at some point, ending at the oculomotor nuclei, ocular nerves, and the extraocular muscles.

The oVEMP response could be elicited by variable stimuli such as air conduction, bone conduction, forehead tap, and galvanic stimulation, although air-conducted and bone-conducted stimulation are the most studied. A 500-Hz tone burst when using an air-conducted stimulus is more effective in producing optimal results than when using a click stimulus [9].

There has not yet been a large-scale study examining the effect of age on the amplitude, latency, and threshold of an air-conduction oVEMP.

The oVEMP, if found to be generated from the utricle, may provide diagnostic information that is complementary to the cVEMP. Accordingly, the purpose of this study was to investigate the effect of age on the amplitude, latency, and threshold of the oVEMP.

Participants and methods

The study was carried out on healthy participants with normal hearing, who were neurologically free. Tests were carried out in the Audiology Unit of Alexandria Petrol Hospital (Egypt). The study was carried out

on 50 ears (50 participants) divided into five groups according to age, and each group contained 10 participants: the first group from 10 to 25 years, the second group from 25 to 35 years, the third group from 35 to 45 years, the fourth group from 45 to 55 years, and the fifth group over 55 years old. Exclusion criteria for all participants included complaints of dizziness or imbalance, known otologic disease, neurologic disease, conductive hearing loss or known disease affecting the cervical vertebrae or spinal cord, and any significant findings on bedside tests examination (spontaneous and positional nystagmus, Romberg's test positive).

Ethical considerations

Ethical approvals from the Alexandria Petrol Hospital were granted to carry out this study. Patients were informed that they will be a part of a research study and were asked to sign written consent.

Preparation

Otoscopy was performed to confirm no occlusion in the external auditory canal. Hearing sensitivity and middle ear status were determined by conducting air-conduction and bone-conduction threshold audiometry, tympanometry, and acoustic reflex.

Recording of ocular vestibular-evoked myogenic potential

For oVEMP recording, participants were seated in a comfortable chair. An electrode montage and recording characteristics similar to those reported by Chihara *et al.* [9] were used to record oVEMP.

Disposable silver chloride electrodes were used. The active electrodes were placed infraorbitally beneath the eye (i.e. infraorbital 1 cm), and the reference electrodes were placed directly beneath the active electrode (i.e. infraorbital 3 cm). The ground electrode was placed at Fpz. Electrode impedances were maintained below 5 k Ω (Fig. 1). When recording oVEMP, the participants were seated and instructed to keep their head at midline and gaze at target positioned 30° upward at midline. This eye position was maintained for 30 s, which permitted the acquisition of 100–150 samples per run.

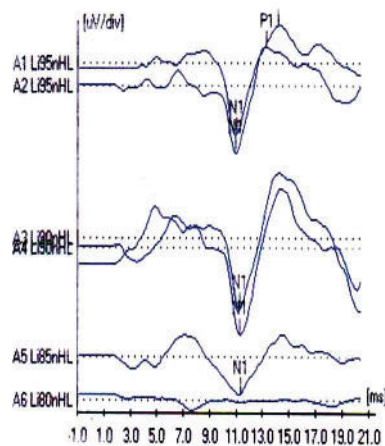
A Natus Bio-Logic Navigator Pro auditory-evoked potential unit (Natus Medical Incorporated, San Carlos, CA, USA) was used to obtain and average oVEMP activity. Stimuli for oVEMP recording were presented monaurally through Bio-Logic standard foam insert earphones. Stimuli consisted of 500 Hz Blackman-gated tone bursts with a 2 ms increase/decrease time, and no plateau presented at a rate of 5.1/s. All participants were presented with 95 dB nHL stimulus. If no oVEMP was

recorded at this level, the recording session was terminated, and the participant was entered into database as having absent response. In all others, oVEMP thresholds were obtained in descending 5 dB steps. One channel recording was conducted for contralateral oVEMP waveforms. One hundred sweeps of EMG activity were recorded on the side contralateral to acoustic stimulation. The activity was collected with a -10.5 ms pre/poststimulus time, was amplified $\times 100\,000$, and was filtered (1–1000 Hz). An artifact-rejection system was used. All tracings were replicated a minimum of one time so that repeatability of the data could be assessed.

Results

The study was carried out on 50 healthy participants (50 ears). The ages ranged from 15 to 73 years (Table 1).

Figure 1



Ocular vestibular-evoked myogenic potential waveform in response to 500-Hz air-conducted tone burst.

In 88% of the healthy participants (44 of 50 ears), negative/positive biphasic responses with short latency in response to air-conducted 500 Hz tone bursts were obtained from electrodes placed beneath the eye contralateral to the stimulation. When we examined the younger groups in this study, we found 100% response rate for participants under the age of 45 years, whereas the response rate was only 80% in the fourth group (age range, 45–55 years) and 60% in the fifth group (age >55 years). The percentage of absence of oVEMP increases with age reaching up to 40% in the last age group (>55 years) (Table 2).

We carried out analysis of variance analysis to investigate the effect of age on characteristic parameters of oVEMP. No significant differences were found among the first four age groups for N1 latency, but there was a significant increase in N1 latency in the oldest age group (>55 years) compared with the young age groups (Fig. 2). The effect of age was significant for N1–P1 amplitude and threshold. N1–P1 amplitude decreased and threshold increased in the oldest age groups (>45 years) when compared with the first three age groups (<45 years) (Figs. 3 and 4).

Correlation study was performed between age and different oVEMP parameters (Table 3), which showed no correlation between age and N1 latency. However, there was significant negative correlation for N1–P1 amplitude and positive correlation for oVEMP threshold.

Discussion

The purpose of this study was to further describe the normal characteristics of oVEMP with respect to

Table 1 Comparison between the different studied groups according to demographic data

	Group I	Group II	Group III	Group IV	Group V	P
Age	19.80 \pm 4.18	31.0 \pm 1.94 ^a	40.70 \pm 2.26 ^{a,b}	50.60 \pm 2.76 ^{a,b,c}	64.40 \pm 7.66 ^{a,b,c,d}	$F P < 0.001^*$
Sex						
Male	6 (60.0)	6 (66.7)	6 (60.0)	6 (60.0)	6 (60.0)	$MC P = 1.000$
Female	4 (40.0)	3 (33.3)	4 (40.0)	4 (40.0)	4 (40.0)	

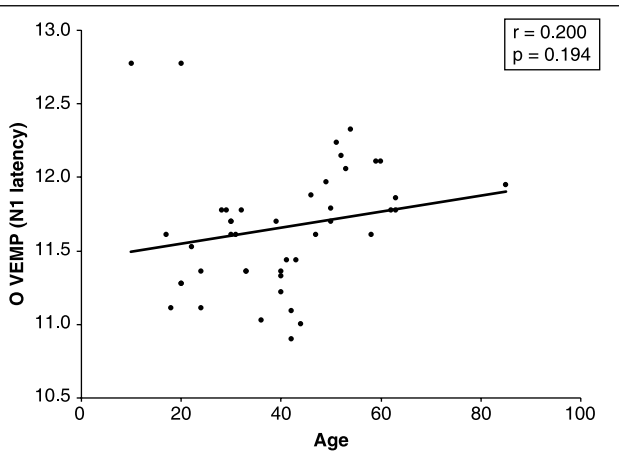
P value for F test (analysis of variance) for comparing between the different studied group; ^aSignificant with group I; ^bSignificant with group II; ^cSignificant with group III; ^dSignificant with group IV; *Statistically significant at $P \leq 0.05$; MC, Monte Carlo test of significance.

Table 2 Comparison between the different studied groups according to ocular vestibular-evoked myogenic potential parameters

	Group I	Group II	Group III	Group IV	Group V	P
Presence						
Absent	0 (10.0)	0 (10.0)	0 (0.0)	2 (10.0)	4 (30.0)	$MC P = 0.482$
Present	10 (90.0)	10 (90.0)	10 (100.0)	8 (90.0)	6 (70.0)	
N1 latency	11.65 \pm 0.66	11.63 \pm 0.17	11.25 \pm 0.25	11.45 \pm 0.25	11.89 \pm 0.18 ^c	$F P = 0.001^*$
N1–P1 amplitude	7.16 \pm 3.49	11.29 \pm 1.75 ^a	9.77 \pm 1.27	6.16 \pm 0.49 ^{b,c}	3.25 \pm 1.09 ^{a,b,c}	$F P < 0.001^*$
Threshold	86.11 \pm 3.33	84.0 \pm 3.94	83.50 \pm 3.37	90.56 \pm 5.27 ^{b,c}	90.71 \pm 3.45 ^{b,c}	$F P < 0.001^*$

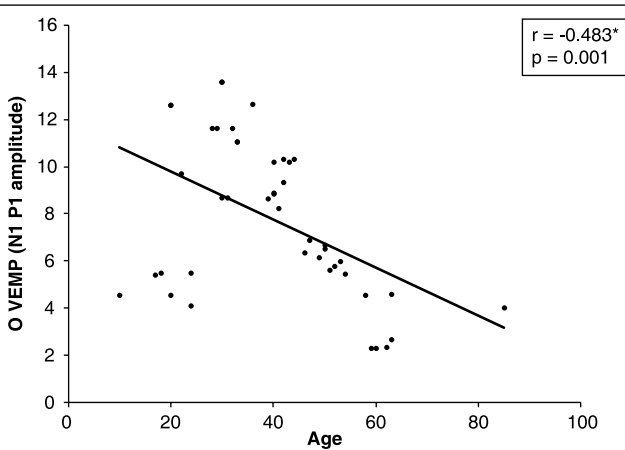
P value for F test (analysis of variance) for comparing between the different studied groups; ^aSignificant with group I; ^bSignificant with group II; ^cSignificant with group III; ^dSignificant with group IV; *Statistically significant at $P \leq 0.05$.

Figure 2



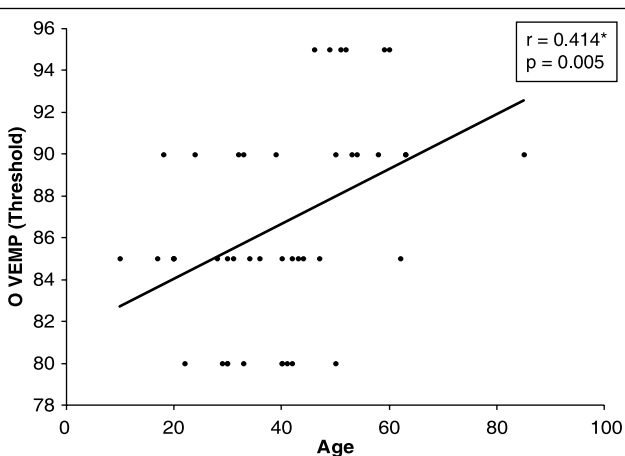
Correlation between age and ocular vestibular-evoked myogenic potential (oVEMP) (N1 latency).

Figure 3



Correlation between age and ocular vestibular-evoked myogenic potential (oVEMP) (N1-P1 amplitude).

Figure 4



Correlation between age and ocular vestibular-evoked myogenic potential (oVEMP) (threshold).

Table 3 Correlation between age and ocular vestibular-evoked myogenic potential

oVEMPs	Age	
	r	P
N1 latency	0.200	0.194
N1-P1 amplitude	-0.483*	0.001
Threshold	0.414*	0.005

oVEMP, ocular vestibular-evoked myogenic potential; r, Pearson's coefficient; *Statistically significant at $P \leq 0.05$.

age-stratified normal participants. In this study, oVEMP was present contralaterally in 88% of the healthy participants (44 of 50 ears), and the percentage of the presence of oVEMP decreased with age to 60% in the oldest age group (>55 years). Chihara *et al.* [9] also reported 90% oVEMP response rate with a sample of only 10 participants, all under the age of 60 years. Others have reported 100% response rate, although each of these studies were limited to a small number of participants, all below 35 years of age [4,13,14].

In the current study, an age effect on oVEMP N1-P1 amplitude and threshold was observed. A significantly reduced amplitude and a significantly increased threshold were observed in the oldest age groups (>45 years) compared with others. However, oVEMP N1 latency was stable for all age groups less than 55 years but significantly increased in the oldest age group above 55 years. Similar age effect was observed for cVEMP recording [10,15]. Several recent studies have also examined the effect of age on the oVEMP response [7,16,17]. Both Iwasaki *et al.* [7] and Tseng *et al.* [17] recorded oVEMP in response to bone-conducted vibration stimuli, and Nguyen *et al.* [16] recorded oVEMP in response to air-conducted click, air-conducted 500 Hz tone burst, and vibratory stimuli for participants ranging from young to elderly adults. Similar to this study, the previous studies [7,16,17] reported significant decrease in amplitude with increasing age. Our current study and that by Nguyen *et al.* [16] reported that age did not affect N1 latency in individuals with age less than 55 years, but in this study N1 latency was significantly increased in the oldest age group above 55 years, which was similar to Iwasaki *et al.* [7] and Tseng *et al.* [17] who reported significant increase in N1 latency with increasing age.

The well-documented neuroanatomic age-related changes that occur in the peripheral vestibular system [18] may explain the commonly reported decrease in the response rate and a decrease in the amplitude with age. However, oVEMP N1 latency occurs as a function of the time required for the afferent limb of reflex, central transmission and the efferent limb of reflex, and muscle activation. Therefore, the age-dependent increase in N1 latency may occur as

a result of degradation of central vestibular system processing, rather than as a result of diminished peripheral vestibular system function.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

References

- 1 Colebatch J, Halmagyi G. Vestibular evoked potentials in human neck muscles before and after unilateral vestibular deafferentation. *Neurology* 1992; 42:1635–1636.
- 2 Colebatch J, Halmagyi G, Skuse, N. Myogenic potentials generated by a click-evoked vestibulocollic reflex. *J Neurol Neurosurg Psychiatry* 1994; 57: 190–197.
- 3 Rosengren S, McAngus Todd N, Colebatch J. Vestibular-evoked extraocular potentials produced by stimulation with bone-conducted sound. *Clin Neurophysiol* 2005; 116:1938–1948.
- 4 Todd N, Rosengren S, Aw S, Colebatch J. Ocular vestibular evoked myogenic potentials (OVEMPs) produced by air- and bone-conducted sound. *Clin Neurophysiol* 2007; 118:381–390.
- 5 Chihara Y, Iwasaki S, Ushio M, Murofushi T. Vestibular-evoked extraocular potentials by air-conducted sound: another clinical test for vestibular function. *Clin Neurophysiol* 2007; 118:2745–2751.
- 6 Govender S, Rosengren S, Colebatch J. The effect of gaze direction on the ocular vestibular evoked myogenic potential produced by air-conducted sound. *Clin Neurophysiol* 2009; 120:1386–1391.
- 7 Iwasaki S, Smulders YE, Burgess AM, McGarvie LA, MacDougall HG, Halmagyi GM, *et al.* Ocular vestibular evoked myogenic potentials in response to bone-conducted vibration of the midline forehead at fz: a new indicator of unilateral otolithic loss. *Audiol Neurotol* 2008; 13:396–404.
- 8 Wang S, Jaw F, Young Y. Ocular vestibular-evoked myogenic potentials elicited from monaural versus binaural acoustic stimulations. *Clin Neurophysiol* 2009; 120:420–423.
- 9 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; 120:581–587.
- 10 Welgampola M, Migliaccio A, Myrie O, Minor L, Carey J. The human sound-evoked vestibulo-ocular reflex and its electromyographic correlate. *Clin Neurophysiol* 2009; 120:158–166.
- 11 Colebatch J, Rothwell J. Motor unit excitability changes mediating vestibulocollic reflexes in the sternocleidomastoid muscle. *Clin Neurophysiol* 2004; 115:2567–2573.
- 12 Rosengren S, Welgampola M, Colebatch J. 2010; Vestibular evoked myogenic potentials: past, present and future. *Clin Neurophysiol* 121:636–651.
- 13 Chou CH, Wang SJ, Young YH. Feasibility of the simultaneous ocular and cervical vestibular-evoked myogenic potentials in unilateral vestibular hypofunction. *Clin Neurophysiol* 2009; 120:1699–1705.
- 14 Hsu YS, Wang SJ, Young YH. Ocular vestibular-evoked myogenic potentials in children using air conducted sound stimulation. *Clin Neurophysiol* 2009; 120:1381–1385.
- 15 Su HC, Huang TW, Young YH, Cheng PW. Aging affect on vestibular evoked myogenic potential. *Otol Neurotol* 2004; 25:977–980.
- 16 Nguyen KD, Welgampola MS, Carey JP. Test-retest reliability and age-related characteristics of the ocular and cervical vestibular evoked myogenic potential tests. *Otol Neurotol* 2010; 31:793–802.
- 17 Tseng CL, Chou CH, Young YH. Aging effect on the ocular vestibular-evoked myogenic potentials. *Otol Neurotol* 2010; 31:959–963.
- 18 Rosenhall U. Degenerative patterns in the aging human vestibular neuro-potentials. *Acta Otolaryngol* 1973; 76:208–220.