

## Vestibular Evoked Myogenic Potentials Might Differentiate the Diagnosis of Vestibular Migraine and Meniere's Disease

Kazim Bozdemir<sup>1</sup>  
HesnaBektaş\*<sup>2</sup>  
Bülent Ulusoy<sup>3</sup>  
Hayati Kale<sup>4</sup>  
Hakan Korkmaz<sup>1</sup>  
Orhan Deniz<sup>2</sup>

<sup>1</sup>Department of Ear-Nose-Throat, Medical School, Yildirim Beyazit University, Turkey  
<sup>2</sup>Department of Neurology, Medical School, Yildirim Beyazit University, Turkey  
<sup>3</sup>Department of Ear-Nose-Throat, Medical School, Konya University, Turkey  
<sup>4</sup>Department of Ear-Nose-Throat, Sami Ulus Training and Research Hospital, Turkey

## Abstract

Patient history, physical examination; audiovestibular and imaging findings do not always help to make a proper differential diagnosis between Vestibular Migraine (VM) and Meniere's disease (MD). The goal of our study was to compare the Vestibular Evoked Myogenic Potential (VEMP) findings of the patients with migraine, VM, MD and healthy controls to determine if cVEMP or oVEMP responses can differentiate VM from MD.

## Methods

49 migraine patients, 27 MD patients and 29 healthy controls were tested by the cervical and ocular VEMP (c/oVEMP) and these results were compared.

## Results

The left C amplitude values of the control group were higher than migraine and MD and this difference was statistically significant ( $p = 0.045$ ). There was a significant difference between the right and left VEMP values of VM patients compared with healthy controls. The Right CP1N1 values were significantly different between VM and MD ( $p = 0.048$ ). The Right-O amplitude values of VM and MD were calculated as 7.51 (IQR = 6.00) and 4.02 (IQR = 7.00) respectively. The median of the Right-O amplitude and the left C amplitude values of MD were found to be lower and that there was no significant difference ( $p = 0.050$ ,  $p = 0.044$ ).

## Conclusion

The diagnoses of VM and MD could be made according to clinical findings and C/oVEMP testing might also help to differentiate them.

## Conflict of Interest:

The authors declare that they have no conflict of interests.

## Introduction

Patients with migraine often suffer from vestibular symptoms, including vertigo during migrainean episodes. Vestibular migraine (VM) is defined as vestibular symptoms that are related to migraine. In 2001 the criteria for VM was first presented by Neuhauser et al. [1] and then was validated in 2012 by the International Headache Society (IHS) and the Barany Society [2].

Meniere's disease (MD) is another disorder that patients suffer from vestibular symptoms during episode. MD is generally diagnosed by the criteria of Barany Society [3].

Many studies have demonstrated a significant overlap between the symptoms of MD and VM. However, the diagnosis of these diseases is based on clinical criteria. In a clinical study, patients with MD represented with a late age of onset, hearing loss, tinnitus, aural fullness, abnormal nystagmus, abnormal caloric testing results or abnormal vestibular evoked myogenic potential and endolymphatic hydrops, whereas patients with VM indicated more headaches, photophobia, vomiting and aura during episodes. Currently, there are no known definitive diagnostic tests that can easily distinguish between VM and MD and unfortunately, their differentiation is often difficult for patients who suffer from vertigo [4].

Patient history, physical examination and audiovestibular and imaging findings do not always help to make a proper differential diagnosis between VM and MD. Objective methods are needed to differentiate these two diseases.

Vestibular Evoked Myogenic Potential (VEMP) test is one of the non-invasive and

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## \*Corresponding author:

**HesnaBektaş**  
Associate Professor  
Yildirim Beyazit University  
Medical School  
Department of Neurology  
Ankara, BilkentYolu 3. Km. Cankaya  
06800 Ankara, Turkey  
Tel: 0090- 0312 291 25 25  
E-mail id: hesnabek-1@hotmail.com

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practical tests which has been used to assess the vestibular system. As first reported by Colebatch and Halmagyi in 1992, VEMP is a clinical test of the otolith organs, sensors of linear acceleration and related reflex pathways.

Cervical VEMP (cVEMP) helps assess the functional status of the saccule and inferior vestibular nerve connections [5]. Ocular VEMP (oVEMP) helps assess the functions of the utricle as well as medial longitudinal fasciculus, oculomotor nerve and extraocular muscles. The combined informations obtained by cVEMP and oVEMP help us understand the ascending and descending vestibular connections in the brainstem [6].

Although VEMP test has been in the practice of neurootology, the evidence in neurological diseases as migraine is still limited [7-10]. In this study, we aimed to compare the VEMP findings of the patients with VM, MD and controls to determine if cVEMP or oVEMP responses can differentiate MD from VM.

## Method

We designed a prospective study. Patients with VM diagnosed by the Barany Society and the Third International Classification of Headache Disorders (ICHD-3) 2012; unilateral MD, as defined by the criteria of Barany Society; and age-matched healthy controls with no history of neurootological symptoms were included to our study. The patients had no other neurological, systemic diseases or medication usage history. Neurootological examination and magnetic resonance imaging of the patients were made to confirm the diagnoses and to exclude the differential diseases.

The patients and controls were tested with cVEMP and oVEMP by a blinded otologist with GN otometrics ICS CHARTR machine.

In cVEMP testing, the active electrode was placed on the upper one third of the sternocleidomastoid muscle which was ipsilateral to the test ear. The reference and ground electrodes were placed on the clavicle and in the midline on the forehead, respectively. The test was performed in the sitting position as the head was in flexion for 30 degrees while tilted 30 degrees to the contralateral side.

In oVEMP testing, the active electrode was placed 1 cm below the contralateral lower eyelid. The reference electrode was placed 15 cm inferior to the active electrode. The ground electrode was placed in the midline on forehead. The patient was instructed to look above by 30 degrees on the horizontal plain.

In VEMP testing, the electromyography signals were amplified and filtered between 30 to 3000 Hz. The stimulus was a 95 dB click at the frequency of 10 Hz. The deflections, P13 and N23, were obtained [5,11]. P1 and N1 latencies, intervals and amplitudes were recorded.

This study was approved by the Institutional Review Board at Ankara Atatürk Training and Research Hospital. The informed consent was given to all participants.

## Statistical Analysis

Distributions of migraine, meniere and control groups were studied. General descriptive statistics, [mean, standard deviation, median, (interquartile range, min, max)], age, duration, number of attacks (in months), duration of attacks (in hours), MIDAS scores, VAS values of migraine patients, contributing symptoms to migraine attacks like vomiting, photophobia, phonophobia, aura, vertigo and medication history were analysed.

The Shapiro Wilks test was used to determine whether the VEMP values were normally distributed and the Kruskal Wallis non parametric test was used when the VEMP values were not distributed normally. Significant variables were shown with box - plot graphics. The Bonferroni corrected post hoc test was used to find out the statistically significant group.

For the comparison of the right and left VEMP values of the three groups dependent samples test was used for normally distributed variables, and the Wilcoxon sign rank test was used for the variables that did not show normal distribution. Significant different VEMP values were defined and box-plot graphs were drawn.

Independent samples't test and Mann Whitney U non-parametric tests were used to determine whether there was a statistically significant difference in the VEMP values between migraine and control, migraine and MD, and MD and control values.

The Mann Whitney U nonparametric test was used to compare the VEMP values between VM and MD and migraine patients without vertigo and control groups. Box plot graphics were drawn for variables with significant difference.

Receiver operating characteristic (ROC) curves were drawn for the right and left VEMP variables in the patient and healthy group (control - migraine, control - MD) analysis, and the area under the curve (AUC) and 95% confidence intervals of this area were determined. Also, the sensitivity, specificity, positive and negative predictive values of these variables were calculated.

IBM SPSS Statistics 21.0 (IBM Corp. released 2012. IBM SPSS Statistics for Windows, Version 21.0, Armonk, NY: IBM Corp.) programme was used for statistical analysis and calculations. Statistical significance level was accepted as  $p < 0.05$ .

## Results

71.1% (n = 81) of the individuals involved in the study were female and 22.9% (n = 24) were male. 29 (8 male, 21 female) individuals were in the healthy control group, 49 (7 male, 42 female) were in the migraine group and 27 (9 male, 18 female) were in the MD ( $p = 0.129$ ) (Table 1).

The mean age of migraine patients was  $35.37 \pm 10.024$  (19-55) years, the mean age of MD was  $37.59 \pm 10.104$  (18-59), the mean age of control group was  $39.62 \pm 11.888$  (19-60). There was no significant difference between groups in terms of age ( $p = 0.226$ ). The mean duration of migraine disease was  $6.00 \pm 6.48$  years (1-30), the number of attacks in a month was  $4.88 \pm 3.48$  (1-12), the mean duration of attack was  $42.71 \pm 25.74$  hours (4-96), the MIDAS score (day) was  $23.65 \pm 20.28$  (2-70), and the VAS score mean was  $7.94 \pm 1.63$  (5-10).

8 (16.3%) of the patients in the migraine group had grade 1, 7 had (14.3%) grade 2, 15 had (30.6%) grade 3 and 19 had (38.8%) grade 4 MIDAS scores.

The distribution of contributing symptoms like nausea, vomiting, photophobia, phonophobia, and pre-attack aura during migraine were shown in (Table 2,3 and 4) patients had VM, 47 patients were

	n (%)
<b>Gender</b>	
Female	81 (71.1)
Male	24 (22.9)
<b>Group</b>	
Control	29 (27.6)
Migraine	49 (46.7)
Meniere	27 (25.7)

**Table 1:** Demographic characteristics of the patients

Symptoms	No	Yes
	n (%)	n (%)
Emesis	2 (4.1)	47 (95.9)
Vomiting	33 (67.3)	16 (32.7)
Photophobia	4 (8.2)	45 (91.8)
Phonophobia	5 (10.2)	44 (89.8)
Aura	38 (77.6)	11 (22.4)
Vertigo	15 (30.6)	34 (69.4)
Analgesic	2 (4.1)	47 (95.9)
Prophylaxis	41 (83.7)	8 (16.3)

**Table 2:** The symptoms of migraine patients

using analgesics during attacks. Migraine prophylaxis was started in 8 patients (Table 2).

There was no statistically significant difference in the right VEMP values between healthy controls, migraine, and MD patients. However, median of the left C amplitude values of the patients in the healthy control group was calculated as 135.00 (IQR = 100.34), 104.49 (IQR = 88.38) in the migraine group and 60.50 (IQR = 73.25) in MD. There was significantly different difference between the 3 groups ( $p = 0.004$ ) (Table 3) (Figure 1).

The left C amplitude value was the highest in the control group and was the lowest in the MD (Table 3.1). The other amplitudes of the left VEMP values did not show statistically significant difference. There were no statistically significant differences between the right and left VEMP values of migraine and MD patients (Table 4).

The left C amplitude mean was  $136.92 \pm 72.71$  in the control group and  $102.45 \pm 51.90$  in the migraine group. The left C amplitude values of the individuals in the control group were higher than the migraine group and this difference was statistically significant ( $p = 0.045$ ). As a result of ROC analysis between the control and migraine groups, AUC = 0.351 was found to be significantly different, especially for the left C amplitude parameter ( $p = 0.044$ ). When the cut off level of the left C amplitude was taken  $\geq 270.75$ , the sensitivity was 22.44%, the specificity was 82.75%, the positive predictive value was 68.75% and the negative predictive value was 38.70%. (95% CI 0.214 - 0.487) There was a no statistically significant difference in terms of other VEMP values (Table 5) (Figure 2).

In comparison of migraine and meniere groups; the median of the left CP1 was 20.92 (IQR = 5.43) in the migraine group and 19.08 (IQR= 3.85) in the MD. Individuals in the migraine group had higher left CP1 values, and the difference was statistically significant ( $p = 0.025$ ). The median of the left C amplitude was 62.75 (IQR = 97.29) in the migraine group and 75.93 (IQR = 81.00) in the MD. Individuals in the migraine group had lower left C Amplitude values. This difference was statistically significant ( $p = 0.011$ ). The ROC analysis was applied for migraine and MD and AUC = 0.297 was found to be statistically significant for the left C amplitude parameter ( $p= 0.011$ ). When the cut off level was taken  $\geq 152.00$  for left C amplitude, the sensitivity was 40.81%, the specificity was 70.37%, positive predictive value was 71.42% and negative predictive value was 39.58% (95% CI 0.162 - 0.432). There was no statistically significant difference between the other groups in terms of the other VEMP values (Table 6) (Figure 3) (Figure 4).

The median value of the left C amplitudes was calculated as 60.50 (IQR = 73.25) for patients in the MD and 122.00 (IQR = 100.34) in the control group. The C left amplitude values in the control group were higher than those in the MD and the difference was statistically significant ( $p= 0.001$ ). According to the ROC analysis for control and MD variables, AUC= 0.215 was found to be statistically significant for the left C amplitude parameter ( $p= 0.001$ ). When the cut-off value the left C amplitude was taken  $\geq 152$ , the sensitivity was 29.62% and the specificity was 55.17%, the positive predictive value was 38.09% and the negative predictive value was 45.71%. (95% CI 0.083 - 0.347)

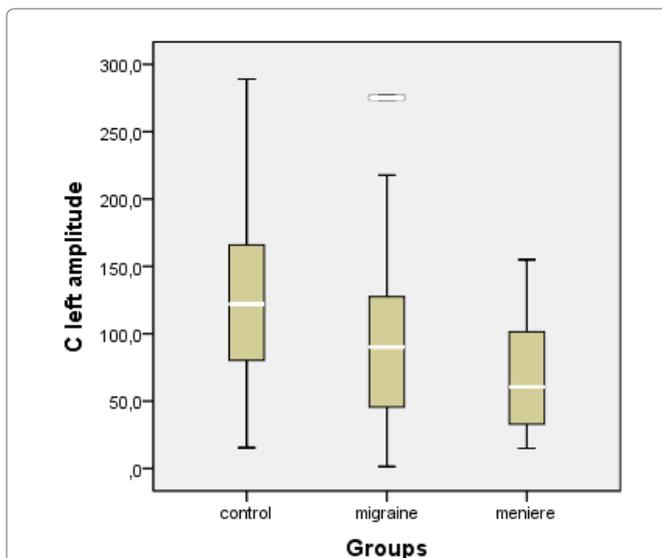


Figure 1: Comparison of C left amplitude values between groups

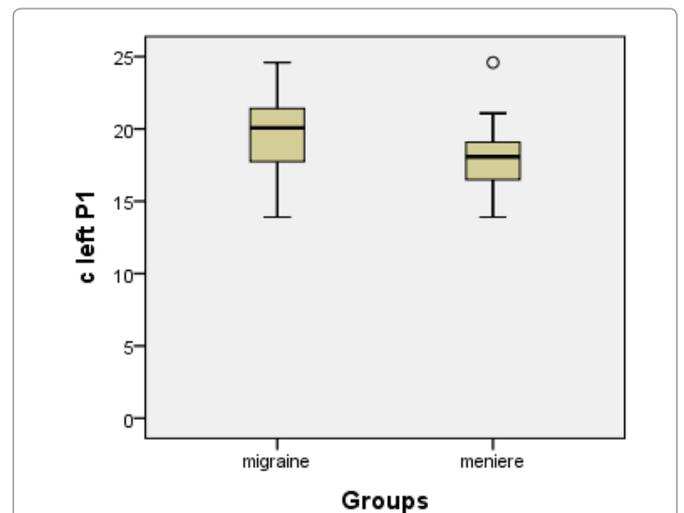


Figure 3: The comparison of c left P1 between migraine and meniere patients

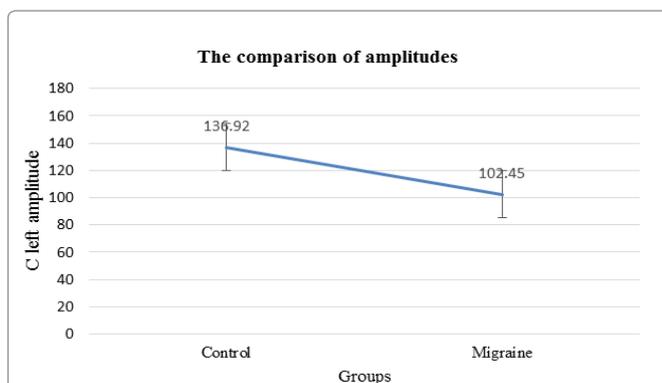


Figure 2: The comparison of C Left amplitudes between control and migraine patients

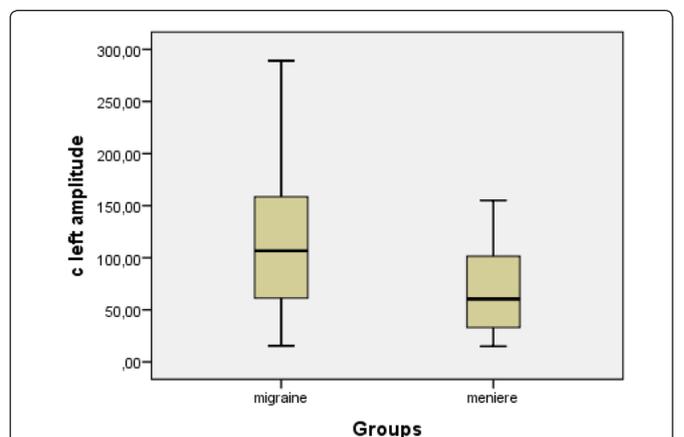


Figure 4: The comparison of left C amplitude between migraine and meniere patients

VEMP Values	Group				$\chi^2$	p
	Control (n=29) Median (IQR)	Migraine (n=49) Median (IQR)	Meniere (n=27) Median(IQR)			
<b>Right</b>						
CP1	20.00 (4.82)	18.58 (5.05)	19.00 (4.00)	0.018	0.797	
CN1	26.71 (3.04)	27.43 (4.04)	27.00 (4.00)	0.385	0.182	
CP1N1	7.09 (3.99)	7.85 (3.69)	8.00 (3.00)	0.785	0.257	
C amplitude	109.98 (62.79)	90.82 (86.67)	80.00 (71.00)	2.269	0.214	
OP1	14.90 (2.20)	15.07 (3.35)	14.90 (1.40)	1.849	0.397	
ON1	9.89 (1.00)	10.31 (2.71)	9.89 (1.00)	0.708	0.702	
OP1N1	5.00 (1.59)	4.43 (1.46)	5.00 (1.25)	4.009	0.135	
O amplitude	7.65 (7)	7.51 (6)	4.02 (7)	5.734	0.057	
<b>Left</b>						
CP1	19.08 (3.68)	20.08 (4.00)	18.08 (3.00)	3.862	0.145	
CN1	26.59 (2.84)	27.43 (3.80)	26.59 (4.17)	2.350	0.309	
CP1N1	7.52 (1.84)	7.52 (3.18)	7.00 (4.00)	0.179	0.914	
C amplitude	135.00 (100.34)	104.49 (88.38)	60.50 (73.25)	10.859	0.004	
OP1	14.40 (1.00)	14.57 (1.33)	15.00 (2.00)	0.468	0.791	
ON1	9.89 (1.23)	9.73 (0.92)	10.00 (1.00)	2.288	0.319	
OP1N1	5.00 (0.00)	4.68 (1.17)	5.00 (1.00)	1.206	0.547	
O amplitude	7.00 (5.00)	6.56 (4.21)	5.00 (6.00)	1.466	0.480	

-Kruskal Wallis nonparametric test was used.

**Table3:** The comparison of VEMP values in control, migraine and meniere group

Group	p
Meniere - Migraine	1.000
Meniere - Control	0.015
Migraine- Control	0.693

--Bonferroni Corrected post-hoc test was used.

**Table 3.1:** Comparison test of significant variables

VEMP values	Right Mean $\pm$ SD Median (IQR)	Left Mean $\pm$ SD Median (IQR)	t, *Z	Statistical test p
<b>Migraine (n=49)</b>				
CP1	19.06 $\pm$ 3.14	19.25 $\pm$ 2.83	0.451	0.655
CN1	27.34 $\pm$ 4.43	26.72 $\pm$ 4.29	1.245	0.221
CP1N1	8.60 $\pm$ 2.42	7.83 $\pm$ 2.32	1.936	0.061
Camplitude	104.49 $\pm$ 109.75	104.37 $\pm$ 51.90	0.986	0.330
OP1	15.29 $\pm$ 2.03	15.65 $\pm$ 0.97	0.828	0.412
OP1N1	4.06 $\pm$ 0.90	4.98 $\pm$ 0.84	0.726	0.471
ON1	11.23 $\pm$ 1.84	10.67 $\pm$ 1.18	0.720	0.475
<b>Meniere (n=27)</b>				
CP1	18.58 (5.26)	19.08 (4.10)	*0.852	*0.394
CN1	27.04 (4.00)	26.59 (4.13)	*0.682	*0.496
CP1N1	7.85 (3.62)	7.35 (3.14)	*1.404	*0.160
Camplitude	90.82 (86.37)	92.00 (84.79)	*0.313	*0.754
OP1	14.90 (1.40)	14.57 (1.40)	*1.078	*0.281
OP1N1	5.00 (1.16)	4.68 (1.18)	*1.264	*0.206
ON1	9.89 (1.00)	10.00 (1.17)	*0.564	*0.572
Oamplitude	4.19(7)	5.00 (6)	*0.608	*0.543

-Paired sample t test and \*Wilcoxon Sign Rank test were used.

**Table 4:** Comparison of right and left VEMP values

There was no statistically significant difference in the right VEMP values between the control and MD (Table 7) (Figure 4).

There were 49 migraine patients in the study. 34 of them had VM. There was no statistically significant difference between the right and left VEMP values between patients with VM and the control group (Table 8).

The median of the right C P1N1 values of the subjects with VM were calculated as 8.02 (IQR = 3.93) and 8.00 (IQR = 3.00) in the MD. The right C P1N1 values of patients in the MD were found to be lower. The Right CP1N1 values were significantly different between the two groups (p=0.048). The Right O amplitude values of patients with VM were calculated as 7.51 (IQR = 6.00) and 4.02 (IQR = 7.00) in the MD respectively. The median of the Right-Oamplitude values of individuals in the MD were found to be lower. The median of the left C

amplitude values of patients with VM was calculated as 106.20 (IQR = 83.74) and 60.50 (IQR = 73.25) in the MD. The Left C amplitude values of patients in the MD were found to be lower, but there was no significant difference in the left C amplitude values between the two groups (p = 0.044). Other VEMP values did not differ statistically between VM and in the MD (Table 9) (Figure 5) (Figure 6).

### Discussion

Recurrent episodes of vertigo and headaches as well as otological symptoms can be seen in migraine. These symptoms can also be seen in MD, except for headache. Different types of mechanisms in MD and VM may present similar inner ear symptoms. It is speculated that both of the two diseases could share common pathophysiological mechanisms. We could find endolymphatic hydrops in both diseases. The common vascular mechanism could be a link between VM and

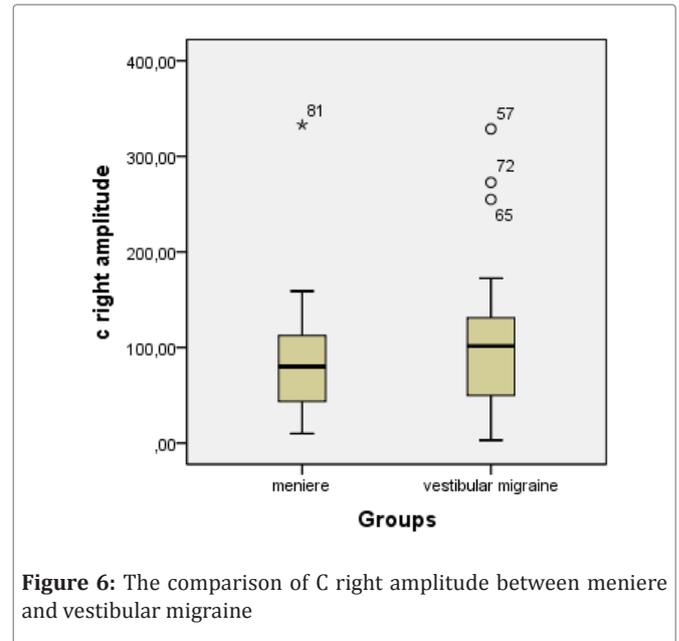
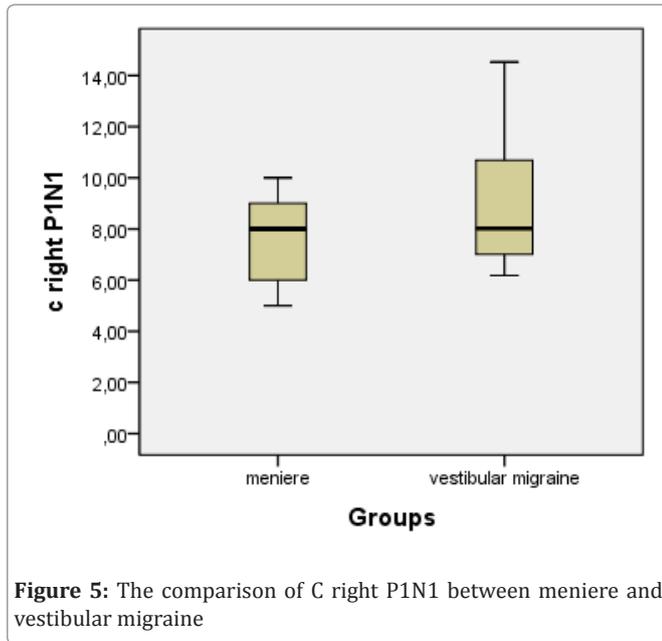


Figure 5: The comparison of C right P1N1 between meniere and vestibular migraine

Figure 6: The comparison of C right amplitude between meniere and vestibular migraine

VEMP values	Group		Statistic test	
Right	Control (n=29) Mean ± SD Median (IQR)	Migraine (n=49) Mean ± SD Median (IQR)	*t, Z	p
CP1	18.89 ± 2.74	18.97 ± 3.07	*0.062	*0.672
CN1	26.80 ± 2.43	27.45 ± 1.51	*0.624	*0.494
CP1N1	7.09 (3.99)	8.43 (2.92)	1.168	0.243
C amplitude	109.98 (62.79)	44.67 (143.80)	0.863	0.388
OP1	14.90 (2.20)	15.07 (3.35)	0.354	0.724
OP1N1	5.00 (1.59)	4.43 (1.46)	0.173	0.863
O amplitude	9.89 (1.00)	10.31 (2.71)	0.997	0.319
	5.26 (7)	7.51 (08)	1.046	0.296
<b>Left</b>				
CP1	19.08 (3.68)	20.92 (4)	0.124	0.901
CN1	26.93 ± 2.38	26.69 ± 4.19	*0.259	*0.797
CP1N1	7.48 ± 1.44	9.38 ± 3.34	*0.482	*0.632
C amplitude	136.92 ± 72.71	102.45 ± 51.90	*2.044	*0.045
OP1	14.40 (1.00)	14.57 (1.33)	0.551	0.582
ON1	9.89 (1.23)	9.73 (0.92)	0.703	0.482
OP1N1	5.00 (0)	4.68 (1.67)	0.982	0.326
O amplitude	7.00 (5.00)	6.56 (4.21)	0.669	0.503

-Independent two sample t test and Mann Whitney U nonparametric test were used.

Table 5: The comparison of VEMP values between control and migraine patients

VEMP values			Statistical Test	
Right	Migraine (n=49) Mean± SD Median (IQR)	Meniere (n=27) Mean± SD Median (IQR)	*t, Z	p
CP1	20.00 (3.76)	19.00 (4.00)	1.040	0.298
CN1	27.00 (3.17)	26.00 (4.00)	1.728	0.084
CP1N1	8.04 (3.82)	8.00(3.00)	0.911	0.362
C amplitude	106.42 ± 63.35	87.21 ± 74.83	1.041	0.302
OP1	14.90 (1.40)	15.00 (2.00)	1.039	0.299
ON1	10.19± 1.84	10.03 ± 2.41	0.404	0.687
OP1N1	5.00 (1.34)	5.00 (1.00)	0.969	0.332
O amplitude	7.08 (4.21)	4.02 (6.00)	1.860	0.063
<b>Left</b>				
CP1	20.92 (5.43)	19.08 (3.85)	2.237	0.025
CN1	28.43 (4.26)	26.59 (4.17)	1.378	0.168
CP1N1	10.19 (3.34)	7.01 (3.02)	0.338	0.735
C amplitude	62.75 (97.29)	75.93 (81.00)	2.548	0.011
OP1	15.57 (1.96)	14.57 (1.40)	0.586	0.558
ON1	9.73 (0.92)	10.00 (1.00)	1.789	0.074
OP1N1	4.68 (1.17)	5.00 (1.00)	0.827	0.409

Independent two sample t test and Mann Whitney U nonparametric test were use.

**Table 6:** The comparison of VEMP values between migraine and meniere patients

VEMP values	Control (n=29) Median (IQR)	Meniere (n=27) Median (IQR)	Statistical Test Z	p
Right				
CP1	20.00 (4.82)	18.58 (4.88)	0.704	0.481
CN1	26.71 (3.04)	26.00 (4.00)	1.049	0.294
CP1N1	7.09 (3.99)	8.00 (3.00)	0.601	0.548
C amplitude	109.98 (62.79)	80.00 (71.00)	1.850	0.064
OP1	14.90 (2.30)	15.00 (2.00)	0.815	0.415
ON1	9.89 (1.00)	9.89 (1.00)	0.585	0.558
OP1N1	5.00 (1.80)	5.00 (1.00)	0.447	0.655
O amplitude	5.26 (7)	4.02 (7)	1.395	0.163
<b>Left</b>				
CP1	19.08 (4.00)	18.08 (3.00)	1.888	0.059
CN1	26.59 (2.80)	26.26 (4.20)	1.258	0.208
CP1N1	7.52 (1.84)	7.00 (4.00)	0.011	0.991
C amplitude	122.00 (100.34)	60.50 (73.25)	3.255	0.001
OP1	14.40 (1.00)	14.57 (1.40)	0.552	0.581
ON1	9.89 (1.23)	10.00 (1.17)	1.440	0.150
OP1N1	5.00 (0.00)	5.00 (1.00)	0.968	0.333
O amplitude	7.00 (5.00)	5.00 (6.00)	1.074	0.283

- Mann Whitney U nonparametric test was used.

**Table 7:** The comparison of VEMP values between meniere and control group

MD as well. Vasospasm related to migraine may cause endolymphatic hydrops [10,12]. Vasospasm of the internal auditory artery was followed by the implication of the trigemino-vascular system in VM [13,14]. Ischemia has also been proposed as an underlying mechanism for MD [15]. Studies have shown that vasoactive neuropeptides are present in the inner ear and vestibular sensor fibers of the trigeminal nerve and the local extravasation of the basilar and that the anterior inferior cerebellar artery plasma would lead to the excitation of the trigeminal nerve. [16,17]. In an attempt to differentiate MD from VM, different objective test methods have been used, one of which is VEMP testing. In a limited number of studies, it was proposed that patients with VM showed smaller cVEMP amplitudes in comparison with healthy control subjects. It was reported that VEMP responses

were symmetrically reduced on both sides in migraine, suggesting an otolith dysfunction due to migraine-induced ischemia [13]. However, the other studies reported conflicting results. No differences were found between patients with MD, those with migraine, and healthy controls regarding their cVEMP and oVEMP parameters except for reduced cVEMP latency [14]. In two studies, no difference in latencies or amplitudes between MD and VM were found with cVEMP. [10,18]. However, Taylor et al. [19] showed that cVEMP asymmetry ratios for 500 Hz tone bursts were significantly higher for MD than VM and the cVEMP amplitude was significantly lower for MD than for VM or controls ears. Murofushi et al. [12] reported that cVEMP amplitudes were significantly smaller on the affected side of MD. Zuniga et al. [20] showed longer oVEMP latencies and lower amplitudes in MD.

VEMP Values	Group		Statistical test	
Right	Control(n=29) Median (IQR)	VestibularMigraine (n=34) Median (IQR)	Z	P
CP1	20.00 (4.82)	18.58 (4.43)	0.076	0.939
CN1	26.71 (3.04)	27.60 (4.34)	0.709	0.479
CP1N1	7.09 (3.99)	8.02 (3.93)	1.721	0.085
C amplitude	109.98 (62.79)	101.56 (86.67)	0.497	0.619
OP1	14.90 (2.20)	14.90 (1.50)	0.304	0.761
ON1	9.89 (1.00)	9.73 (1)	0.192	0.848
OP1N1	5.00 (1.59)	4.68 (1.01)	0.439	0.661
O amplitude	5.26 (7)	7.51 (6)	0.738	0.460
<b>Left</b>				
CP1	19.08 (3.68)	20.08 (4)	0.359	0.719
CN1	26.59 (2.84)	26.59 (3.7)	0.175	0.861
CP1N1	7.52 (1.84)	7.85 (3.17)	0.447	0.655
C amplitude	122.00 (100.34)	106.20 (83.74)	1.465	0.143
OP1	14.40 (1.00)	14.73 (1.33)	0.536	0.592
ON1	9.89 (1.23)	9.73 (1.17)	0.686	0.493
OP1N1	5.00 (0)	4.68 (1.30)	1.363	0.173
O amplitude	7.00 (5.00)	6.01 (4.16)	1.329	0.184

-Mann Whitney U nonparametric test was used

**Table 8:** The comparison of right and left VEMP values between vestibular migraine and control groups

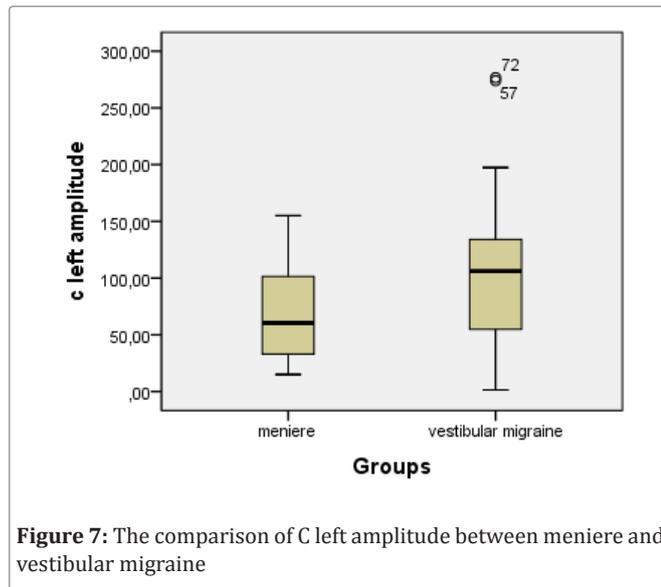
VEMP Values	Group		Statistical test	
Right	VestibularMigraine (n=34) Median(IQR)	Meniere (n=27) Median (IQR)	Z	p
CP1	18.58 (4.43)	19.00 (4.00)	0.348	0.728
CN1	27.60 (4.34)	26.00 (4.00)	1.466	0.143
CP1N1	8.02 (3.93)	8.00 (3.00)	1.973	0.048
C amplitude	101.56 (86.67)	80.00 (71.00)	1.254	0.210
OP1	14.90 (1.50)	15.00 (2.00)	1.346	0.178
ON1	9.73 (1.00)	9.89 (1.00)	0.784	0.433
OP1N1	4.68 (1.01)	5.00 (1.00)	1.413	0.158
O amplitude	7.51 (6.00)	4.02 (7.00)	1.956	0.050
<b>Left</b>				
CP1	20.08 (4.00)	18.08 (3.00)	1.487	0.137
CN1	26.59 (3.70)	26.26 (4.20)	0.994	0.320
CP1N1	7.85(3.17)	7.00 (4.00)	0.389	0.697
C amplitude	106.20 (83.74)	60.50 (73.25)	2.010	0.044
OP1	14.73 (1.33)	15.00 (2.00)	0.462	0.644
ON1	9.73 (1.17)	10.00 (1.00)	1.033	0.301
OP1N1	4.68 (1.30)	5.00 (1.00)	0.189	0.850
O amplitude	6.01 (4.16)	5.00 (6.00)	0.222	0.824

**Table 9:** The comparison of VEMP values between vestibular migraine and meniere groups

In our study we found that in MD, the left cVEMP and the right oVEMP amplitudes were significantly lower as compared with VM and healthy controls. There was no difference for latencies. It shows that there is not a structural damage, such as demyelination but it is difficult to explain why the right oVEMP amplitude and the left cVEMP amplitude were lower. A central abnormality might explain the high prevalence of bilaterally reduced VEMP responses. It was reported that absence of a cVEMP response had been found in one or both ears in 44% (16/37) of patients with VM and in 3% (1/30) of controls, yielding a sensitivity of 43% (95% CI 27.5%–60.3%) and a specificity of 97% (95% CI 80.9%–99.8%) [20]. In another study, cVEMP measurements found a sensitivity of 31% using absence of a response as an indicator of VM. This lack of response, however, is not diagnostic of VM, and the study authors made no assertion that

cVEMP is helpful in distinguishing patients with VM from controls [21]. In our study we found no statistically significant difference between the right and left VEMP values between patients with VM and control group. When we compared whole migraine patients with MD, we found that the left cVEMP amplitude was significantly lower in MD. When comparing the VEMP values with migraine, VM and MD, we found lower sensitivity and specificity.

Based on our study, there were conflicting results for VEMP testing as the other past studies. cVEMP and oVEMP responses might be helpful in the differential diagnosis of migraine, VM and MD. We proved the evidence of peripheral vestibular abnormalities occurring not only in the vestibulospinal tract, but also in the vestibulo-ocular pathway, as shown by reduced cVEMP and oVEMP amplitudes in



**Figure 7:** The comparison of C left amplitude between meniere and vestibular migraine

MD compared to VM. However, we could not compare the affected and non-affected sides of MD patients with the VM patients as the MD patient numbers were small. In patients with migraine and MD, it is possible that asymmetric amplitude is more common than in controls, but in no study was VEMP useful in establishing a VM or MD diagnosis. VM is a clinical diagnosis with established clinical criteria. No vestibular test makes the diagnosis of VM, but vestibular tests, including VEMP, may clarify the status of vestibular function when we need to exclude other conditions such as MD. More standardization is needed for recording methods, normal and pathologic ranges of the amplitudes and latencies, if cVEMP and oVEMP were to be used more effectively in clinical practice. This requires for each laboratory needs to determine its own normal and pathologic ranges for each test for younger and older patients. Human studies are needed to confirm that cVEMP and oVEMP are indicative of saccular and utricular function, vestibular disorders and neurologic disorders. In conclusion, the diagnoses of VM and MD could be made based on clinical findings. oVEMP testing might also help to differentiate them in the future. We need more studies about oVEMP testing for MD and VM as well as to determine whether VM is a disorder with a central or peripheral pathology. Patients with MD and VM are treated differently; therefore, improving the diagnosis of these two pathologies could avoid the mistakes in management.

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