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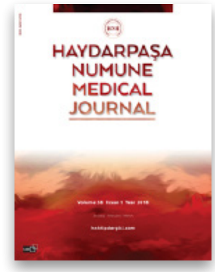

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ORIGINAL ARTICLE

Cervical Vestibular Evoked Myogenic Potentials in Children by Head Rotation Method: Normative Findings of Turkish Population

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Abstract

Introduction: To evaluate the normal values of vestibular-evoked myogenic potential (cVEMPs) in healthy children by the head rotation method.

Methods: 109 children ages 6–11 years with normal hearing underwent cVEMP testing with alternating clicks at intensities of 80, 85, 90, 95, and 100 dB levels by using averaged, unrectified electromyograms recorded by a surface electrode on the sternocleidomastoid muscle ipsilateral to the stimulus. The P1 output latency, peak latencies of P1 and N1, P1-N1 peak-to-peak amplitude, and asymmetry ratio were measured.

Results: There were no statistically significant differences between groups regarding interpeak amplitudes, P1 output latency, P1 latency ($p>0.05$). Whereas, the latency of N1 showed a statistically significant positive correlation with age (in group III, 25.04±2.34, in group II, 23.63±2.10, and in group III, 23.77±1.90, $p<0.01$). The amplitude asymmetry ratio also showed a statistically significant negative correlation with age (35.23±18.04, 26.26±18.21, and 19.58±14.69 I in groups, respectively, $p=0.008$). Furthermore, there was a statistically significant relationship between stimulus intensity and age. cVEMPs waves were obtained with higher stimulus intensity in early childhood, whereas lower stimulus intensity was sufficient to obtain cVEMPs waves in late childhood ($p=0.033$).

Discussion and Conclusion: cVEMP is an easily applicable, well-tolerated test for screening vestibular function with minimal test time and reproducible results. This is the first cVEMPs study to reveal the normative data of children by comparing latencies, amplitudes, and asymmetry ratios by the head rotation method.

Keywords: Amplitude; head rotation method; latency; threshold; vestibular evoked myogenic potential.

The human balance system is based on the co-processing of sensorimotor networks such as the visual, vestibular, somatosensory, and cerebellum systems[1]. In children, these complex systems are anatomically mature in early life, but the sensory systems are not completely responsive after birth. The coordination of postural responses develops in growing children and reaches adult-like values around 15 years of age[2].

Children often lack the appropriate vocabulary or experience to describe abnormal feelings of vertigo, dizziness, or imbalance[2]. Children's vertiginous complaints are often attributed to behavioral disorders or clumsiness[3]. Misdiagnosed vestibular diseases impact the future motor and psychological development of the child and may result in delayed postural control, episodic vertigo, or incoordination[4]. Although vestibular tests require cooperation, children can be difficult

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to test due to their short attention span. In several decades of research with children, a variety of techniques have been employed to explore and evaluate pediatric balance disorders. As usual, to assess the balance function, caloric, rotational, and postural tests can be used for children[5]. However, the poor tolerance of small children to the caloric test and the lack of a rotatory chair in each laboratory limit the use of caloric and rotational tests[6].

The vestibular-evoked myogenic potential (cVEMP) described by Colebatch et al.[7] is a non-invasive and easily applicable test that evaluates the dynamic otolithic function, sacculo-collic reflex, and utriculo-ocular reflexes in adults and children[8]. By stimulating the ear with air-conducted sound or bone-conducted vibration, VEMP can be recorded and termed cervical VEMP (cVEMP) and ocular VEMP (oVEMP), respectively[9]. The reflex originates in the sacculus and transmits to neurons in the ganglion of Scarpa, proceeds through the inferior vestibular nerve, vestibular nuclei, and vestibular spinal tract, and then terminates in the motor neurons for the sternocleidomastoid (SCM) muscle[10]. Bickford, Jacobson, and Cody in 1964 first described that both head elevation and head rotation methods cause a myogenic amplitude response with an auditory stimulation[11]. In the head elevation method, false-negative VEMPs are sometimes encountered, especially in children, the aged, and pregnant or debilitated persons, because they are unable to sustain SCM muscle contraction[12,13]. Therefore, although the response rates have been shown to be higher with the head elevation method than with the head rotation method, easy application of the head rotation method may serve as an alternative for eliciting VEMPs in those who cannot sustain SCM muscle contraction by the head elevation method[12,13]. Brix et al.[13] collected normative VEMP data for adolescents in a study and assessed their results with a meta-analysis of 14 published studies. They found that head position (elevation or rotation), stimulus type (click or tone-burst), placement of electrodes on the SCM muscle, and stimulus rise time were all factors of importance when interpreting latencies[13]. Hereby, they suggested thatseparate normative cVEMP data should be established for head elevation and head rotation[13].

Normal standard values in adults have been widely revealed, whereas there are only a limited number of published data for the child population in a few countries[14-17]. Therefore, we aimed to study the normal values for cVEMP responses in 6–11-year-old healthy children by the head rotation method.

Materials and Methods

Study Population

The study included a total of 109 healthy children (218 ears) ages 6–11. All children were subjected to full-history taking, including prenatal, perinatal, natal, and postnatal histories in addition to developmental histories and family histories of hearing loss. None of the participants had auditory symptoms. The informed consent of the individuals was obtained before the procedure.

To confirm the participants had no hearing loss, a pure-tone audiometric examination was performed. And, to rule out middle ear conductive alterations, an otoscopic examination of the tympanic membrane and a middle ear impedance measurement were performed.

The subjects were divided into three groups according to their age. Groups I, II, and III included subjects aged 6–7 years, 8–9 years, and 10–11 years for analysis, respectively.

The study protocol was approved by the research ethical committee of Umraniye Education and Research Hospital as a study (date: March 14, 2017, protocol number: B.10.1TKH.4.34.HGP.0.01/18).

cVEMP Procedure

The subjects were admitted to a quiet and comfortable room and seated on a chair in a sitting position. All participants were asked to bend their heads by 30° and turn them toward the opposite side of the stimulated ear for SCM muscle contraction[17]. Cervical vestibular-evoked myogenic potentials were recorded by the Interacoustic Eclipse EP 25 (Interacoustics Inc., Denmark) device. After cleaning the skin, electrodes (ECG Conductive Adhesive Medi-trace, Kendall) were attached. The active electrode was placed on the center point of the same side SCM muscle; one reference electrode was positioned on the suprasternal notch; and one ground electrode was situated on the forehead. Skin impedances were <10 kΩ. Surface electromyographic (EMG) activity between 150 and 250 μV was mandatory for each measurement, and the maintenance of the desired muscle tension was monitored by providing visual and auditory feedback. If muscle tensions were below or above the preset margins, children were kindly asked to increase or decrease muscle tension. The EMG signal was amplified and band-pass filtered (10–1000 Hz). Alternating clicksat intensities at 80, 85, 90, 95, and 100, dB normalized hearing levels were presented through a headphone to test each ear. The stimulation rate was 5 Hz, and the analysis time for each stimulus was 80 ms. To obtain cVEMP waveforms, 200 trials were averaged, and two traces from each side were obtained to assess reproducibility.

The positive (P1) output latency (ms), positive (P1) and negative (N1) peak latencies (ms), P1-N1 peak-to-peak amplitude (μV), and amplitude asymmetry ratio (%) were measured.

Table 1. Demographic parameters of the groups (n:109)

Gender	Groups			p
	Group I	Group II	Group III	
Male				
n	25	25	16	[a]0.63
%	64.1	62.5	53.3	
Female				
n	14	15	14	
%	35.9	37.5	46.7	

[a]Pearson Chi-square $p<0.05$ Group I: 6–7 years, Group II: 8–9 years, Group III: 10–11 years.

Statistical Analysis

Statistical analyses were performed using the Statistical Package for the Social Sciences version 20 for Windows statistical software (SPSS Inc., Chicago, IL). Descriptive statistical data were calculated. The relevance of the variables to the normal distribution was analyzed through analytical methods (Kolmogorov–Smirnov and Shapiro-Wilk tests). The Kruskal–Wallis test was used to compare the continuous variables between the three groups. The Mann-Whitney U test was used to compare the continuous variables between the two groups. The Type-1 error level was identified as 5% for statistical significance.

Results

Demographic Data

All participants completed cVEMP without any complaint for both ears. They easily followed all the instructions. The demographic data of groups I, II, and III are demonstrated in Table 1, with no significant difference among groups regarding age or gender. Group I, Group II, and Group III consisted of 39 patients (mean ages 6.49±0.51), 40 patients (mean ages 8.47±0.51), and 30 patients (mean ages 10.47±0.51), respectively.

Latency and Interpeak Amplitude

We evaluated the relationship between three age groups and cVEMP parameters (Table 2). There was no statistically significant difference between groups regarding interpeak amplitudes ($p>0.05$). In addition, compar-

Table 2. Comparison of latencies and interpeak amplitudes of the groups

Number of Subjects	Groups			p
	Group I n=64	Group II n=60	Group III n=50	
P1 Output Latency (ms)				
Mean±SD	9.87±1.35	9.46±1.26	9.90±1.43	0.181
Median (Range)	9.67 (7.00–14.33)	9.50 (7.00 – 12.67)	9.67 (7.00 – 13.33)	
P1 Peak Latency (ms)				
Mean±SD	15.14±1.36	15.21±1.19	15.64±1.45	0.129
Median (Range)	15.00 (12.67–19.00)	15.00 (13.33–19.00)	15.67 (13.00–21.33)	
N1 Peak Latency (ms)				
Mean±SD	23.63±2.10	23.77±1.90	25.04±2.34	0.001*
Median (Range)	23.84 (19.67–29.33)	24.00 (20.00–28.67)	25.00 (20.67–34.00)	
Amplitude Asymmetry Ratio (%)				
Mean±SD	35.23±18.04	26.26±18.21	19.58±14.69	0.008*
Median (Range)	33.56 (1.19–70.62)	25.13 (0.05–69.20)	17.43 (0.68–60.79)	
Number of Subject	**Groups**			**p**
	Group I n=78	**Group II n=80**	**Group III n=60**	
P1-N1 Peak to peak Amplitude (μV)				
Mean±SD	112.01±93,36	108.15±82.35	112.44±95.09	0.975
Median (Range)	95.11 (0.00–412.50)	111.80 (0.00–279.80)	100.09 (0.00–413.40)	

Kruskal-Wallis test, *$p<0.05$ Group I: 6–7 year, Group II: 8–9 year, Group III: 10–11 year.

isons of P1 output latency and P1 peak latency didn't reveal any statistically significant differences among the groups. In group III, there was a significantly prolonged initial N1 peak latency (25.04±2.34) when compared with the groups II and III N1 peak latencies (23.63±2.10, 23.77±1.90, respectively) ($p<0.01$). Furthermore, the amplitude asymmetry ratio showed a statistically significant negative correlation with increasing age (35.23±18.04 in group I, 26.26±18.21 in group II, 19.58±14.69 I in group III, $p=0.008$) (Table 2 and Fig. 1).

Thresholds Values

cVEMP threshold values for all three age groups are evaluated in Table 3. When threshold levels were compared between the groups, a 100 dB threshold level was mostly obtained in group I (56.2%), 90dB threshold level was mostly obtained in group II (44.2%), and 80 dB threshold level was mostly obtained in group III (46.2%). It was statistically significant that cVEMP waves were obtained with higher stimulus intensity in the early childhood period; on the other hand, lower stimulus intensity was sufficient to obtain cVEMP waves in the late childhood period ($p=0.033$).

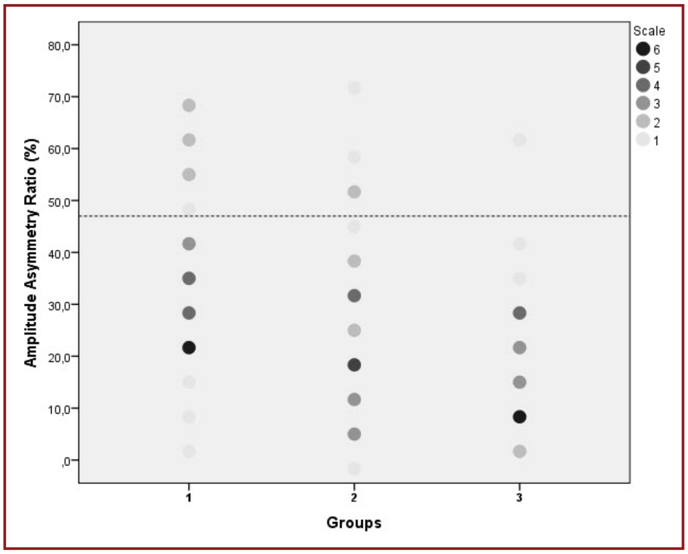

Figure 1. Scatter plot of amplitude asymmetry ratio (%) and age groups. (Group I: 6–7 years, Group II: 8–9 years, Group III: 10–11 years).

Table 3. Comparison of threshold values of the groups

Groups	Threshold					p
	100 (dB) N	95 (dB) N	90 (dB) N	85 (dB) N	80 (dB) N	
Group I	9 56.2%	20 57.1%	13 25.0%	15 33.3%	7 26.9%	0.033*
Group II	4 25.0%	7 20.0%	23 44.2%	19 42.2%	7 26.9%	
Group III	3 18.8%	8 22.9%	16 30.8%	11 24.4%	12 46.2%	

Pearson Chi-square *$p<0.05$, Group I: 6–7 years, Group II: 8–9 years, Group III: 10–11 years.

Discussion

cVEMP is a relatively new test in the diagnosis of various peripheral and central vestibular diseases that is still in the process of validation in studies with patients with specific vestibular disorders. In clinical practice, a delay in reflex, a decrease in amplitude, and the absence of reflexes are accepted as pathological[18]. Normal cVEMP standards in adults have been widely revealed, whereas the standard normative values for children have no formal guide. The protocol for the present study on cVEMP was determined based on studies addressing the normalization of responses in school-aged children.

In this study, we performed screening pure tone audiometry and middle ear impedance measurements on all subjects to rule out any hearing loss or middle ear pressure disturbance. And also, all children were examined by an ENT specialist to rule out any otitis media with effusion, which can possibly cause balance disturbances and affect vestibular test results[19]. A difference between air and bone thresholds of 10 dB or more at 1000 Hz has been found to be associated with a reduction in P1-N1 peak-to-peak amplitudes of click-evoked responses[7]. Therefore, only healthy participants without any audiologic, neurologic, or vestibular disorders were accepted for the study.

Recently, VEMP has been used as a supplementary tool to rotational and caloric tests to help the diagnose of many vestibular diseases such as acoustic neuroma,[20] vestibular neuritis,[21] Ménière's disease,[22] delayed endolymphatic hydrops,[23] multiple sclerosis[24] and superior semicircular canal dehiscence syndrome[25]. Despite its clinical usefulness, several factors may influence VEMP parameters such as effort, attention, fatigue,[2] tonicity of the cervical muscles[10] and age[18,26]. To maintain the tonicity of the cervical muscle, the head rotation method is preferred for juvenile and old patients because of its simplicity in maintaining that position[12,13,16,27]. Previous studies using the head rotation method in a healthy pediatric population put forth that the mean latency of P1 ranged between 11.3 and 15.4 ms, the mean latency of N2 ranged between 18.2 and 23.7 ms, and the mean total amplitude ranged from 126.7 to 160.5 µV, with asymmetry indices between 16 and 20%[13,16,28,29]. In this study, we also used the head rotation method for SCM muscle contraction. According to our evaluation, the mean latency of P1 ranged between 15,14 and 15.64 ms, the mean latency of N1 ranged from 23,63 to 25,04 ms, and the mean interpeak amplitude ranged from 108,15 to 112,44μV. The amplitude asymmetry ratio showed a statistically significant negative correlation with increasing age, and in accordance with literature, the ratio was 19.58±14.69 in group III. The differences observed among studies are probably explained by the use of different devices. Therefore, the significance of standardizing the reference values according to the equipment type is obvious.

Auditory brain stem response (ABR) is a reliable test to evaluate maturational changes in auditory and brain stem function. In the literature, when researchers assess ABR, some studies put forward that auditory pathways mature until up to 12 years of age, whereas others suggest maturation develops at 3 years of age[29]. Furthermore, Chu et al.[30] confirmed data of an age-related increase in the latency of brainstem auditory evoked potentials. Myelination of the vestibular nerve fibers begins at the 20th fetal week, and the vestibular nerves are myelinated at birth. After birth, myelination within the brain proceeds rapidly until approximately 2 years of age and is completed at the time of puberty[31]. As a child grows, the increase in neck length and head size strongly correlate with the increase in path length of the afferent and efferent nerve fibers in the sacculo-collic reflex[32]. Therefore, cVemp latencies correlate positively to neck length in adults and children,[13,33] and if the neck length is >15.3 cm in adolescents, the adult range of VEMP latencies can be anticipated[32]. In previous VEMP studies in healthy children, neck length was not taken into account[14,15,17]. The reason why neck length was not taken into consideration in our study was that the study population consisted of children before puberty who were not in a rapid growth period and had similar racial characteristics. In addition, the fact that the age groups subsume only consecutive two ages increases the similarity of the children within the groups.

In our study, there was no significant difference in latency for P1 and interpeak amplitude among the three groups categorized by age. On the contrary, N1 latency was statistically significantly prolonged in accordance with the increasing age, and the amplitude asymmetry ratio decreased significantly with increasing age. On the other hand, Picciotti et al.[17] investigated the cVEMP values of normal-hearing children aged between 3 and 15 years with the head elevation method in two groups (preschool and scholar). They reported that the latency and amplitude values of P1 and N1 in scholars and pre-scholar children were similar to the adult normative cVEMP values.

Previous studies documented that there is a positive correlation between age in older adulthood and cVEMP threshold values. These findings are attributed to increased stiffness in the otolith structures related to aging, so stimulus intensity needs to increase to stimulate the organs[34]. Maes et al.[35] reported a significant negative correlation for the threshold values between healthy children and adults. In previous studies, although children and adults were compared within themselves, there was not enough data about threshold parameters for different pediatric age groups. In our study, although cVEMP waves were obtained with higher stimulus intensity in early childhood, lower stimulus intensity was sufficient to obtain them in a late childhood period. These differences in thresholds between age groups and age-related prolongation of cVEMP latencies are probably related to structural changes during the growth period, such as neck length and head size[32].

Conclusion

In the last decade, cVEMP has gained popularity as a non-invasive, low-cost diagnostic tool in the pediatric population. However, among the many factors that can affect VEMP results are stimulus intensity, response laterality, muscular tonicity, condition of the middle ear cavity, patient age, neck length, and head position. It is obvious that standardization of the cVEMP parameters will provide more widely usage in the evaluation of the vestibular system in children as age-related normative values are determined. In the future, it will be appropriate to determine the normative VEMP values for a wider pediatric population and children with different racial characteristics and body development.

Ethics Committee Approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committees and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study protocol was approved by the research ethical committee of Umraniye Education and Research Hospital as a study (date: March 14, 2017, protocol number: B.10.1TKH.4.34.HGP.0.01/18).

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Conflict of Interest: None declared.

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