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RESEARCH ARTICLE

Comparing mastoid and posterior cervical muscles vibration effects on eye movement in normal subjects

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Abstract

Background and Aim: Vibration is a method for stimulating the vestibular system. This method can unmask asymmetry between two vestibular systems (such as unilateral peripheral vestibular disorders). The occurrence of vibration-induced nystagmus (VIN) in healthy subjects can affect the diagnosis of patients with unilateral peripheral vestibular disorders. Thus, the evaluation of VIN in healthy subjects is critical to help the diagnosis of unilateral peripheral vestibular disorders.

Methods: This study was carried out on 72 healthy subjects (mean ± SD age: 27.12 ± 4.97 years) in the Auditory and Balance Clinic of Rofeideh Rehabilitation Hospital. Vibration stimulation with a frequency of 30 and 100 Hz was used on mastoid and posterior cervical muscles (PCMs) and simultaneously eye movements were recorded and analyzed using videonystagmography.

Results: The mastoid vibration with a frequency of 30 and 100 Hz, respectively produced VIN in 16.67% and 27.78% of subjects and VIN observed in PCMs vibration with a frequency of 30 and 100 Hz in 4.17% and 9.72% of the subjects.

Conclusion: The occurrence of VIN in healthy subjects was more probable with mastoid vibration in 100 Hz. In this study, VIN was predominantly horizontal, its direction was toward the stimulated side, and its slow phase velocity was lower than 5 deg/s. These criteria could be used for differentiation between normal and abnormal subjects.

Keywords: Vibration-induced nystagmus; vestibular vibration; mastoid, posterior cervical muscle; videonystagmography

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Introduction

Balance is defined as body stability in different positions [1] and needs the integrated function of visual, vestibular, and proprioceptive systems [2]. As 50% of the patients with balance disorder suffer from vestibular involvement [3], vestibular evaluation is an essential step in accurate diagnosis and treatment.

For vestibular evaluation, sensory receptors (or related neural fibers) of this system must be stimulated, and the consequent effects must be evaluated [4]. Caloric, vibration stimulation [5-7], head impulse, and galvanic stimulation can be used as the vestibular stimulations, and videonystagmography (VNG) can be used as an evaluation tool [4,8].

The most common stimulation for the vestibular system is caloric, but it has some potential limitations such as contraindication in patients with perforated tympanic membrane, middle ear pathologies, and external ear occlusion. This stimulation method is unbearable in some subjects and induces nausea and vomiting. Caloric stimulation evaluates vestibule-ocular reflex (VOR) at low frequency, but pathologies related to high frequency would remain undetected [9]. Considering these limitations, more studies on other stimulation methods for clinical use would be beneficial.

In this study, the vibration was selected, which is a non-invasive and straight forward stimulus, and it is more tolerable stimulus than caloric stimulation. This method does not have any significant side effect and induces less nausea (if any) than caloric [7,10-15]. In addition, vibration on mastoid, posterior cervical muscles (PCMs), vertex, and tendons induce high-frequency vestibular stimulation [5,6]. Furthermore, the cost of the equipment and the duration of the test are significantly lower than caloric. Considering these benefits, the clinical utilization of this method and investigation of its limitation and application seems vital.

One of the fundamental applications of this method is the determination of unilateral peripheral vestibular disorders. In these patients, vibration on mastoid results in vibration-induced nystagmus (VIN) [5-7]. VIN, mostly horizontal [6,16], can detect the side of the lesion. That is right beating nystagmus is representative of left peripheral loss. By applying vibration on either side, nystagmus always beats towards the unaffected side [5,7,17,18]. The neuronal base for VIN is as follows: the vibration applied on one labyrinth causes bilateral stimulation, and this leads to phase-locked action in irregular afferents in both labyrinths and nystagmus beats toward the unaffected side [5].

In spite of its advantages, VIN application for differential diagnosis faces an important limitation. This limitation would be the appearance of VIN in 20% of healthy subjects, and the only difference between normal and abnormal subjects is the direction of nystagmus [16]. In normal subjects, the nystagmus is mostly beating toward the vibration side. This means that vibration on the right mastoid produces right beating nystagmus and vice versa. The reason for this observation is not clearly defined [7,19]. So as there are some ambiguities in regards to the effects of the vibration on nystagmus in healthy subjects and this issue can affect the potential application of this stimulus in the evaluation of vestibular disorder, more comprehensive investigation in normal subjects is essential and is the aim of the present study.

In the present study, nystagmus induced by mastoid and PCMs vibration was investigated and compared with each other in normal subjects.

Methods

Eighty normal subjects in the age range of 18–35 years (mean ± SD age: 27.12 ± 4.97 years) were enrolled in the study after the University of Social Wellbeing and Rehabilitation Sciences (USWR) announcement. They all were referred to Auditory and Balance Clinic of Rofeideh Rehabilitation Hospital. They underwent auditory and vestibular evaluations. The inclusion criteria included lack of any history of vertigo, dizziness and disequilibrium, lack of family history of vestibular disorders, normal audiometry (no hearing loss or tinnitus), normal tympanometry (no middle ear involvement), presence of acoustic reflex, normal VNG, normal video head impulse test (vHIT), and lack of any ocular or neurologic disease (migraine, seizure and multiple sclerosis). Any abnormality in these test results, lack of interest in participation and lack of cooperation were considered as the exclusion criteria. This study was approved by the Ethics Committee of USWR with the registration number of IR.USWR.REC.1397.119.

Seventy two subjects met the inclusion criteria. During the examination, they were positioned in a chair in a dark room. Then binocular goggles of VNG were put on participants, and goggles cover was put in place to shield eyes from the

Table 1. Direction of vibration-induced nystagmus and the number of subjects with vibration-induced nystagmus by mastoidal and posterior cervical muscles vibration

Place and frequency of vibration	Side of vibration (n)	Absence of VIN	Horizontal VIN		Rotational VIN	
			Right beating	Left beating	Clockwise	Counter-clockwise
Mastoid vibration with frequency 30 Hz	Right side	60	7	2	2	1
	Left side (12 subjects)	1	0	10	0	1
Mastoid vibration with frequency 100 Hz	Right side	52	10	7	1	2
	Left side (20 subjects)	2	0	17	1	0
PCMs vibration with frequency 30 Hz	Right side	69	2	0	1	0
	Left side (3 subjects)	1	0	2	0	0
PCMs vibration with frequency 100 Hz	Right side	65	5	1	1	0
	Left side (7 subjects)	1	1	5	0	0

VIN; vibration-induced nystagmus, PCMs; posterior cervical muscles

light. The subjects were asked to keep their eyes open and look forward and minimize their blinking. This study had 5 stages:

Basic; spontaneous nystagmus was investigated, and subjects with spontaneous nystagmus were excluded.

1. 30-Hz mastoid vibration; vibrator (VVIB-3F, Synapsys, France) was set at 30 Hz and kept on the mastoid process for 20 seconds (its position is in line with the external auditory canal) [20].
2. 100-Hz mastoid vibration; the procedure was the same as stage 2 except for the vibration frequency.
3. 30-Hz vibration on PCMs; vibrator was set at 30 Hz and kept on trapezoid muscle (lower one-third of superior trapezius [20] for 20 seconds.
4. 100-Hz vibration on PCMs; the procedure was the same as stage 4 except for the vibration frequency.

Stages 2 to 5 were performed randomly on subjects by one examiner. The duration of vibration was 20 seconds. There was a one-minute rest between stages. All stages were applied to the right mastoid and PCMs. If there was a VIN in each stage, the opposite side was evaluated as well.

For data analysis, ocular movements were recorded, and data were analyzed by SPSS 22. The percentage of subjects who showed VIN by 30- and 100-Hz vibration on mastoid and PCMs were described, and the exact characteristics of the nystagmus (type, direction, and strength) were analyzed based on the place and frequency of stimulation.

Results

Vibration-induced nystagmus (VIN) would occur more in mastoid vibration than PCMs. In 30- and 100-Hz mastoid vibration, VIN appeared in 12 (16.67%) and 20 (27.78%) subjects, respectively while for PCMs, VIN appeared in 3 (4.17%) and 7 (9.72%) subjects, respectively. In all cases, VIN started by the stimulation onset and ended by its offset. Horizontal VIN was the most common nystagmus with 75% and 85% occurrence rate for 30- and 100-Hz mastoid vibration and 66.67% and 85.71% occurrence rate for 30- and 100-Hz PCMs vibration, respectively.

Rotational VIN was also seen occasionally, but

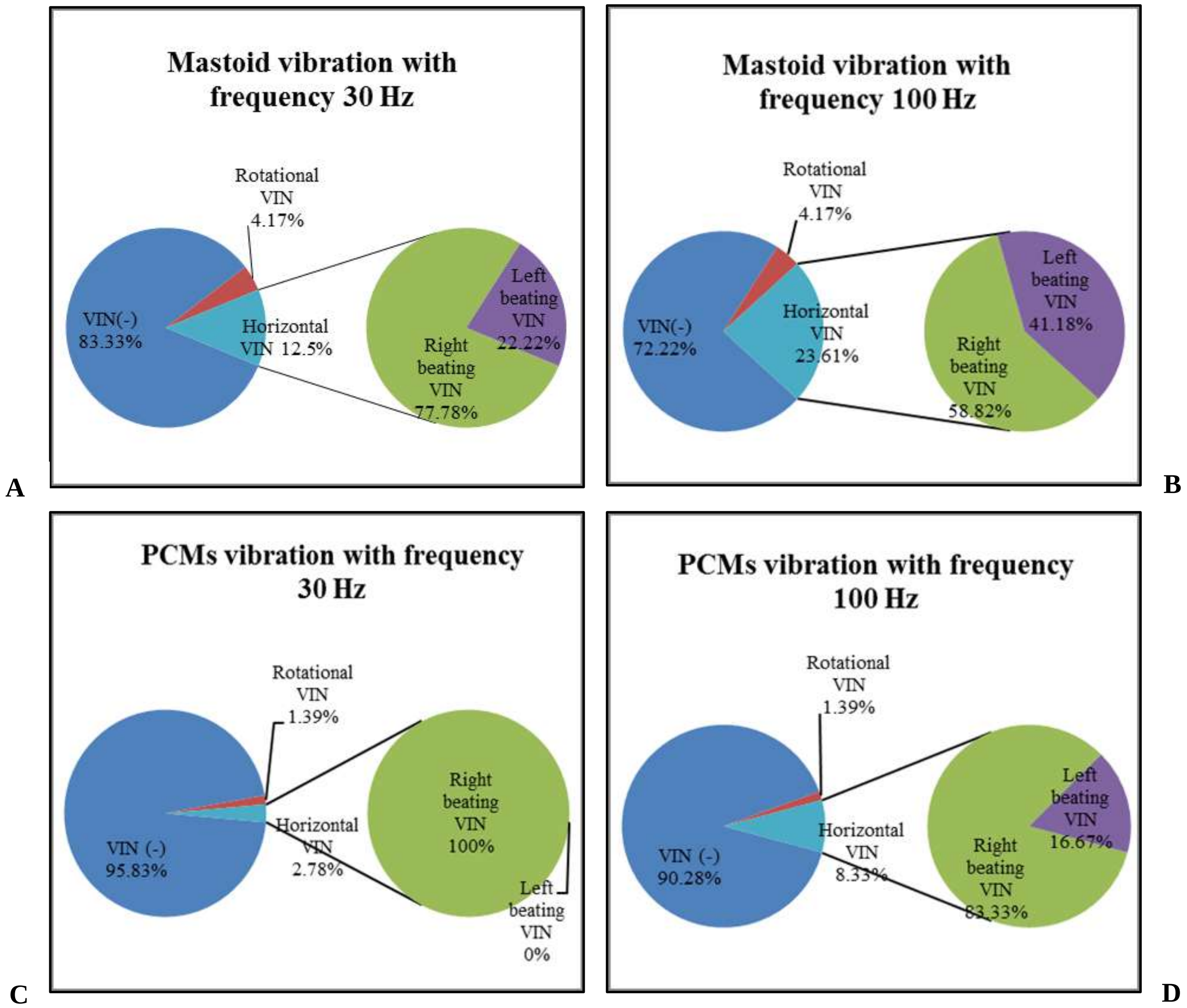

Fig. 1. Percentage of vibration-induced nystagmus based on place and frequency of vibration. The absence of vibration-induced nystagmus is represented by VIN (-). A) Mastoid vibration with frequency 30 Hz. B) Mastoid vibration with frequency 100 Hz. C) Posterior cervical muscles vibration with frequency 30 Hz. D) Posterior cervical muscles vibration with frequency 100 Hz.

vertical VIN did not appear in any of the locations or frequencies.

Beating direction was toward stimulated side, and right beating nystagmus was seen more frequently than left beating. In 7 out of 9 subjects (77.78%) and in 10 out of 17 subjects (58.82%) who had horizontal VIN for 30- and 100-Hz mastoid vibration, right beating nystagmus was apparent. In addition, for PCMs vibration, in 30-Hz vibration, all subjects (100%) and in 100-Hz vibration 5 out of 6 subjects (83.33%) had right beating nystagmus.

By applying vibration on left mastoid or PCMs in subjects who showed VIN in right stimulation, nystagmus mostly had left beating direction (83.33% and 76.47% in 30- and 100-Hz mastoid vibration and 100% and 83.33% in 30- and 100-Hz PCMs vibration) (Table 1 and Fig. 1).

The degree of nystagmus was not higher than 5 deg/s in none of the stimulation locations and frequencies. The strongest nystagmus was seen in 100-Hz mastoid vibration. The strongest horizontal nystagmus was 5 deg/s, and rotational

Table 2. Intensity of vibration-induced nystagmus (slow-phase velocity) in normal subjects. Horizontal nystagmus is represented by one component (X) and Rotational nystagmus is represented by two components (X, Y). (The negative sign (-) indicated right-beating direction in horizontal nystagmi and up-beating direction in vertical nystagmi)

Place and frequency vibration	Side vibration (n)	Horizontal nystagmus		Rotational nystagmus	
		Mean SPV	Maximum SPV	Mean SPV	Maximum SPV
Mastoid vibration with frequency 30 Hz	**Right side**	-2.11	-4	(-3, -1.33)	(-3, -2)
	Left side (12 subjects)	1.9	3	(1, 1)	(1, 1)
Mastoid vibration with frequency 100 Hz	**Right side**	-2.17	-5	(2, -2)	(3, -3)
	Left side (20 subjects)	2.06	4	(-2, 1)	(-2, 1)
PCMs vibration with frequency 30 Hz	**Right side**	-0.5	-1	(-1, -1)	(-1, -1)
	Left side (3 subjects)	0.5	1	0	0
PCMs vibration with frequency 100 Hz	**Right side**	-1.83	-5	(-1, -2)	(-1, -2)
	Left side (7 subjects)	1.5	3	0	0

SPV; Slow-phase velocity, PCMs; posterior cervical muscles

nystagmus, regardless of the rotation direction, was [3,3] deg/s. Rotational nystagmus is displayed by horizontal (X) and vertical (Y) vectors (X,Y). The strength of nystagmus in other stimulation locations and frequencies was lower than the mentioned values (Table 2).

Discussion

This study was conducted on 72 healthy subjects to examine characteristics of VIN. We used 30- and 100-Hz vibration in two stimulation locations (mastoid and PCM). Type, direction, and strength of nystagmus were studied via VNG.

Vibration stimulation is a clinical approach for the evaluation of vestibular asymmetry, which is the most common vestibular disorder [21]. The sensitivity and specificity of this test are 81% and 100%, respectively [5] and it elicits nystagmus in patients with vestibular asymmetry [5-7]. Studies have shown that the presence and direction of VIN in patients with vestibular disorder are highly correlated with unilateral weakness in the caloric test [22]. In addition, it can be a good complementary test for caloric test because caloric test evaluates vestibular system at low frequencies, but vibration is a high-frequency stimulus. Therefore these two stimuli together provide comprehensive information about vestibular system condition [5]. In addition to patients with unilateral vestibular involvement, VIN is also seen in 27.78% of healthy subjects. This nystagmus in normal subjects has special characteristics which can help interpretation of the results of unilateral peripheral vestibular disorder. The first characteristic is the direction of nystagmus, which is mostly towards the stimulated side in healthy subjects. Dumas et al. stated that VIN was not typically seen in healthy subjects or if present, it lacked a fixed direction. Mastoid and PCMs vibration caused nystagmus toward the vibration side [19]. The findings of the present study are in agreement with their study. Park et al. suggested that VIN elicited by sternocleidomastoid (SCM) vibration beat toward the non-stimulated side [6]. The present study result is not in agreement with their results which might be due to this fact that SCM vibration is interpreted centrally as a head turn toward the opposite side while PCM vibration is interpreted as a head turn toward the vibration side. Therefore for SCM stimulation, slow phase of eye movement is toward the vibration side, and the fast phase is toward the opposite side [23,24]. The second characteristic of VIN in healthy subjects is nystagmus strength. There are few studies on the strength of VIN in healthy subjects. Most studies have just reported the existence of horizontal nystagmus. Studies have not shown any rotational nystagmus. The present study showed that the strength of nystagmus is dependent on the location and frequency of stimulation. The strongest was seen for 100-Hzmastoid stimulation. The maximum eye movement velocity in both locations and for both frequencies was not beyond 5 deg/s.

Dumas et al. suggested that 100-Hz stimulation had more effects on the strength of nystagmus because it applied more energy to the labyrinth (101 dB SPL) and could potentially stimulate all labyrinth structures, but 30 Hz had lower energy (95 dB SPL) [25]. Besides, the 100-Hz frequency could stimulate both semicircular canals and otolithic organs [19]. The optimum frequency for otolith stimulation is a little lower than 100 Hz to 2000 Hz and for semicircular canals is 100 Hz to 200–300 Hz [26,27]. The present study showed that the probability of nystagmus occurrence and its strength for mastoid vibration was more than PCMs. This finding is in agreement with Magnusson et al. study results. They suggested that vibration transmission was easier and stronger through hard mediums compared to the soft materials. Therefore, mastoid is a better conductive material for transmitting vibration to cerebral fluids and makes stronger eye movements with higher amplitudes [28]. Kelders et al. mentioned that applying vibration on the trapezoid muscle indirectly activated the primary end of muscle spindles which brain considers this as cervical muscle tension and head turn so that it would trigger cervico-ocular reflex (COR) and eye movements [29]. On the other hand, mastoid vibration activates both labyrinths directly and makes phase-locked activity in their related irregular afferents and initiates VOR [22]. It must be considered that COR gain is very low in healthy subjects. Therefore, VOR has much more gain than COR, and VIN for mastoid vibration is more than PCMs. Considering VIN characteristics in healthy subjects, VIN is a valuable diagnostic tool. Conducting similar studies on patients suffering from various vestibular deficits is recommended for validating and completing the present study.

Conclusion

Presenting VIN in healthy subjects by applying mastoid stimulation, especially for 100 Hz, is more probable than 30 Hz vibratory frequency and PCMs location. In these cases, VIN beats toward the stimulated side with the strength of less than 5 deg/s. This clue can be diagnostic criteria for differentiating normal from abnormal subjects. Application of vibration and examining VIN as a diagnostic tool is promising.

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Conflict of interest

The authors declared no conflicts of interest.

References

1. Sparto PJ, Redfern MS, Jasko JG, Casselbrant ML, Mandel EM, Furman JM. The influence of dynamic visual cues for postural control in children aged 7-12 years. Exp Brain Res. 2006;168(4):505-16. doi: 10.1007/s00221-005-0109-8
2. Mickle KJ, Munro BJ, Steele JR. Gender and age affect balance performance in primary school-aged children. J Sci Med Sport. 2011;14(3):243-8. doi: 10.1016/j.jsams.2010.11.002
3. Macedo C, Gazzola JM, Ricci NA, Doná F, Ganança FF. Influence of sensory information on static balance in older patients with vestibular disorder. Braz J Otorhinolaryngol. 2015;81(1):50-7. doi: 10.1016/j.bjorl.2014.11.004
4. Walther LE. Current diagnostic procedures for diagnosing vertigo and dizziness. GMS Curr Top Otorhinolaryngol Head Neck Surg. 2017;16:Doc02. doi: 10.3205/cto000141
5. Xie S, Guo J, Wu Z, Qiang D, Huang J, Zheng Y, et al. Vibration-induced nystagmus in patients with unilateral peripheral vestibular disorders. Indian J Otolaryngol Head Neck Surg. 2013;65(4):333-8. doi: 10.1007/s12070-013-0638-6
6. Park H, Shin J, Shim D. Mechanisms of vibration-

induced nystagmus in normal subjects and patients with vestibular neuritis. Audiol Neurootol. 2007;12(3):189-97. doi: 10.1159/000099023

7. Park HJ, Shin JE, Lim YC, Shin HA. Clinical significance of vibration-induced nystagmus. Audiol Neurootol. 2008;13(3):182-6. doi: 10.1159/000113508
8. Kheradmand A, Zee DS. The bedside examination of the vestibulo-ocular reflex (VOR): an update. Rev Neurol (Paris). 2012;168(10):710-9. doi: 10.1016/j.neurol.2012.07.011
9. McGarvie LA, Curthoys IS, MacDougall HG, Halmagyi GM. What does the dissociation between the results of video head impulse versus caloric testing reveal about the vestibular dysfunction in Ménière's disease? Acta Otolaryngol. 2015;135(9):859-65. doi: 10.3109/00016489.2015.1015606
10. Dumas G, De CW, Hamann KF, Cohen B, Negrevergne M, Ulmer E, et al., editors. Skull vibration induced nystagmus test. Ann Otolaryngol Chir Cervicofac. 2007;124(4):173-83. doi: 10.1016/j.aorl.2007.05.001
11. Hamann KF, Schuster EM. Vibration-induced nystagmus - A sign of unilateral vestibular deficit. ORL J Otorhinolaryngol Relat Spec. 1999;61(2):74-9. doi: 10.1159/000027645
12. Ohki M, Murofushi T, Nakahara H, Sugasawa K. Vibration-induced nystagmus in patients with vestibular disorders. Otolaryngol Head Neck Surg. 2003;129(3):255-8. doi: 10.1016/S0194-5998(03)00529-1
13. Perez N. Vibration induced nystagmus in normal subjects and in patients with dizziness. A videonystagmography study. Rev Laryngol Otol Rhinol (Bord). 2003;124(2):85-90.
14. Colombé C, Dumas G, Troussier J, Schmerber S. Assessement of the vibration-induced nystagmus test (Dumas' test) in deaf children: preliminary results. J Hear Sci. 2018;8(2);289
15. Dumas G, Karkas A, Perrin P, Chahine K, Schmerber S. High-frequency skull vibration-induced nystagmus test in partial vestibular lesions. Otol Neurotol. 2011;32(8):1291-301. doi: 10.1097/MAO.0b013e31822f0b6b
16. Zamora EG, Araújo PE, Guillén VP, Gamarra MFV, Ferrer VF, Rauch MC, et al. Parameters of skull vibration-induced nystagmus in normal subjects. Eur Arch Otorhinolaryngol. 2018;275(8):1955-1961. doi: 10.1007/s00405-018-5020-6
17. Park H, Hong SC, Shin J. Clinical significance of vibration-induced nystagmus and head-shaking nystagmus through follow-up examinations in patients with vestibular neuritis. Otol Neurotol. 2008;29(3):375-9. doi: 10.1097/MAO.0b013e318169281f
18. Lee SU, Kee HJ, Sheen SS, Choi BY, Koo JW, Kim JS. Head-shaking and vibration-induced nystagmus during and between the attacks of unilateral ménière's disease. Otol Neurotol. 2015;36(5):865-72. doi: 10.1097/MAO.0000000000000743
19. Dumas G, Curthoys IS, Lion A, Perrin P, Schmerber S. The skull vibration-induced nystagmus test of vestibular function-a review. Front Neurol. 2017;8:41. doi: 10.3389/fneur.2017.00041
20. Dumas G, Lion A, Gauchard GC, Herpin G, Magnusson M, Perrin PP. Clinical interest of postural and vestibulo-ocular reflex changes induced by cervical muscles and skull vibration in compensated unilateral vestibular lesion patients. J Vestib Res. 2013;23(1):41-9. doi: 10.3233/VES-130468
21. Grill E, Heuberger M, Strobl R, Saglam M, Holle R, Linkohr B, et al. Prevalence, Determinants, and consequences of vestibular hypofunction. results from the KORA-FF4 survey. Front Neurol. 2018;9:1076. doi: 10.3389/fneur.2018.01076
22. Mayoux-Benhamou MA, Revel M, Vallee C. Selective electromyography of dorsal neck muscles in humans. Exp Brain Res. 1997;113(2):353-60.
23. Conley MS, Meyer RA, Bloomberg JJ, Feeback DL, Dudley GA. Noninvasive analysis of human neck muscle function. Spine (Phila Pa 1976). 1995;20(23):2505-12.
24. Dumas G, Perrin P, Ouedraogo E, Schmerber S. How to perform the skull vibration-induced nystagmus test (SVINT). Eur Ann Otorhinolaryngol Head Neck Dis. 2016;133(5):343-348. doi: 10.1016/j.anorl.2016.04.002
25. Curthoys IS, Vulovic V, Burgess AM, Sokolic L, Goonetilleke SC. The response of guinea pig primary utricular and saccular irregular neurons to bone-conducted vibration (BCV) and air-conducted sound (ACS). Hear Res. 2016;331:131-43. doi: 10.1016/j.heares.2015.10.019
26. Hartmann R, Klinke R. Discharge properties of afferent fibres of the goldfish semicircular canal with high frequency stimulation. Pflugers Arch. 1980;388(2):111-21.
27. Magnusson M, Andersson G, Gomez S, Johansson R, Mårtensson A, Karlberg M, et al. Cervical muscle afferents play a dominant role over vestibular afferents during bilateral vibration of neck muscles. J Vestib Res. 2006;16(3):127-36.
28. Kelders WP, Kleinrensink GJ, van der Geest JN, Feenstra L, de Zeeuw CI, Frens MA. Compensatory increase of the cervico-ocular reflex with age in healthy humans. J Physiol. 2003;553(Pt 1):311-7. doi: 10.1113/jphysiol.2003.049338
29. Hain T, Helminsky J. Anatomy and Physiology of the Normal Vestibular System. In: herdman S, editor. Vestibular rehabilitation. 4th ed. Philadelphia: FA Davis Company; 2007. p. 617-12.