

Original Article

Comparison of water and air caloric stimulation using videonystagmography

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Abstract: Introduction: The basic methods for assessing the vestibular system are the caloric tests, which can be performed using air or water stimulation. The aim of the study was to compare the parameters of nystagmus provoked during air caloric stimulation with the parameters obtained during water caloric stimulation in subjects with and without vertigo. Material and methods: The study included 102 subjects divided into two groups: Group I-patients with peripheral or mixed vertigo, Group II-healthy individuals without vertigo. Two caloric tests were carried out in all subjects: air stimulation (30 °C, 44 °C, application time: 45 seconds) and water stimulation (30 °C, 44 °C, application time: 30 seconds). The obtained parameters of nystagmus were analyzed using videonystagmography (VNG). Results: There were statistically significant differences concerning the angular velocity of the slow nystagmus phase as well as nystagmus frequency and excitability during water and air caloric stimulation in both groups. No significant difference in vestibular deficit was observed in relation to the applied stimulus. Conclusions: The results clearly show that water caloric stimulation produces considerably stronger reactions than air caloric stimulation. Despite significant differences in the values of individual parameters of nystagmus, both tests can be successfully used to evaluate vestibular system function.

Keywords: Water and air caloric stimulation, videonystagmography, vertigo

Introduction

Vertigo and balance disorders are major health problems. Based on the available literature data, it is estimated that they affect 17-30% of adults [1-3]. In approx. 88% of cases they are recurrent [4, 5], they are three times more common in the female population and more widely diagnosed in people over 65 years of age [6, 7]. The symptoms are often so severe that they limit daily functioning and greatly deteriorate the quality of life.

Diagnosis of vertigo is a multi-stage process comprising anamnesis, otoneurological examination, laboratory tests and diagnostic imaging. Caloric tests based on the phenomenon of thermal convection are commonly used in otoneurological diagnostics. Caloric stimulation, by provoking the vestibulo-ocular reflex, illustrates the excitability of individual labyrinths and allows evaluation of each one separately. The caloric test may be carried out using water

or air. Water caloric stimulation is contraindicated in patients with tympanic membrane perforation, "secondary tympanic membrane" or otitis externa and media; in such cases only air caloric stimulation may be used [8, 9].

The aim of the study was to compare the selected parameters of nystagmus (angular velocity of the slow nystagmus phase, nystagmus frequency, vestibular deficit, relative and absolute directional preponderance and excitability) provoked during water and air caloric stimulation of the vestibular system in subjects with peripheral or mixed vertigo and in healthy subjects.

Material and methods

The study included 102 subjects, either patients being treated at the Department of Otolaryngology, Laryngological Oncology, Audiology and Phoniatics of the Medical University due to vertigo, scheduled for surgery within the nose and paranasal sinuses, and students of

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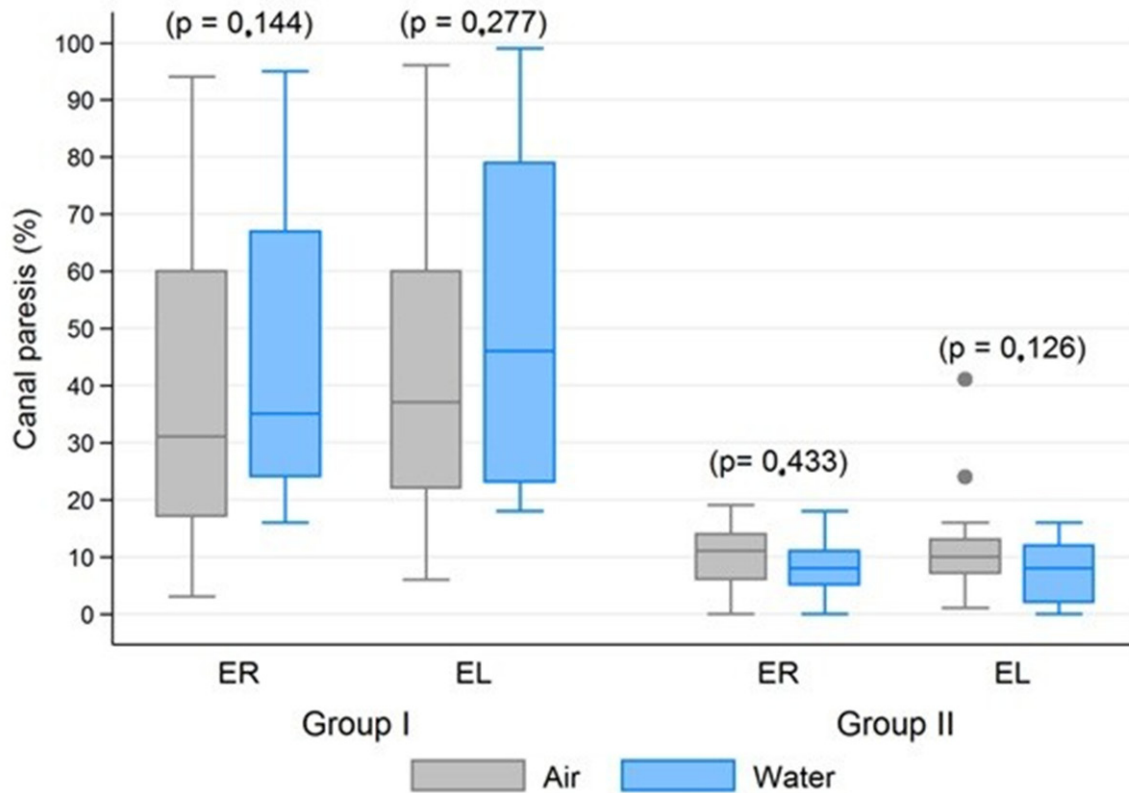


Figure 1. Velocity obtained during air caloric stimulation at an air temperature of 30°C and water temperature of 30°C.

Table 1. Velocity obtained during air caloric stimulation at 30°C and water caloric stimulation at 30°C

	Water stimulation		Air stimulation	
	RE	LE	RE	LE
Group I	10.33°/s	10.70°/s	3.09°/s	3.45°/s
Group II	15.91°/s	17.82°/s	5.44°/s	5.13°/s

the Medical University of Lodz without any balance disorders. The subjects were divided into two groups:

Group I: 51 subjects (35 women and 16 men) with peripheral or mixed vertigo, aged 21-82 years;

Group II: 51 subjects (31 women and 20 men) without balance disorders, aged 19-74 years.

The subjects were added to their group after an initial full videonystagmography using water caloric stimulation.

After obtaining written informed consent, the medical history was recorded and the subjects

underwent a physical examination, i.e. otorhinolaryngological and otoneurological investigations. After excluding diseases of the external auditory meatus and middle ear, double caloric tests using air and water stimulation were performed in each subject. In both tests, a cold impulse of 30°C and a warm impulse of 44°C were used. Application time of the stimulus was 45 seconds for air caloric stimulation and 30 seconds for water caloric stimulation. Caloric tests were carried out with an air calorimeter (HOMOTH) and a water calorimeter (OTOPRONT). Both calorimeters have the option of stimulus modulation by adjusting the temperature and time of application. To ensure the compliance of the vector of gravity with the vector of the lateral semicircular canal, all study subjects were positioned on a couch, with their heads bent to the chest at an angle of 30°. Qualitative and quantitative assessment of caloric-induced nystagmus was carried out using a videonystagmography system manufactured by Synapsis. The analysis of the tests included recording and analysis of the following nystagmus parameters: angular velocity of the

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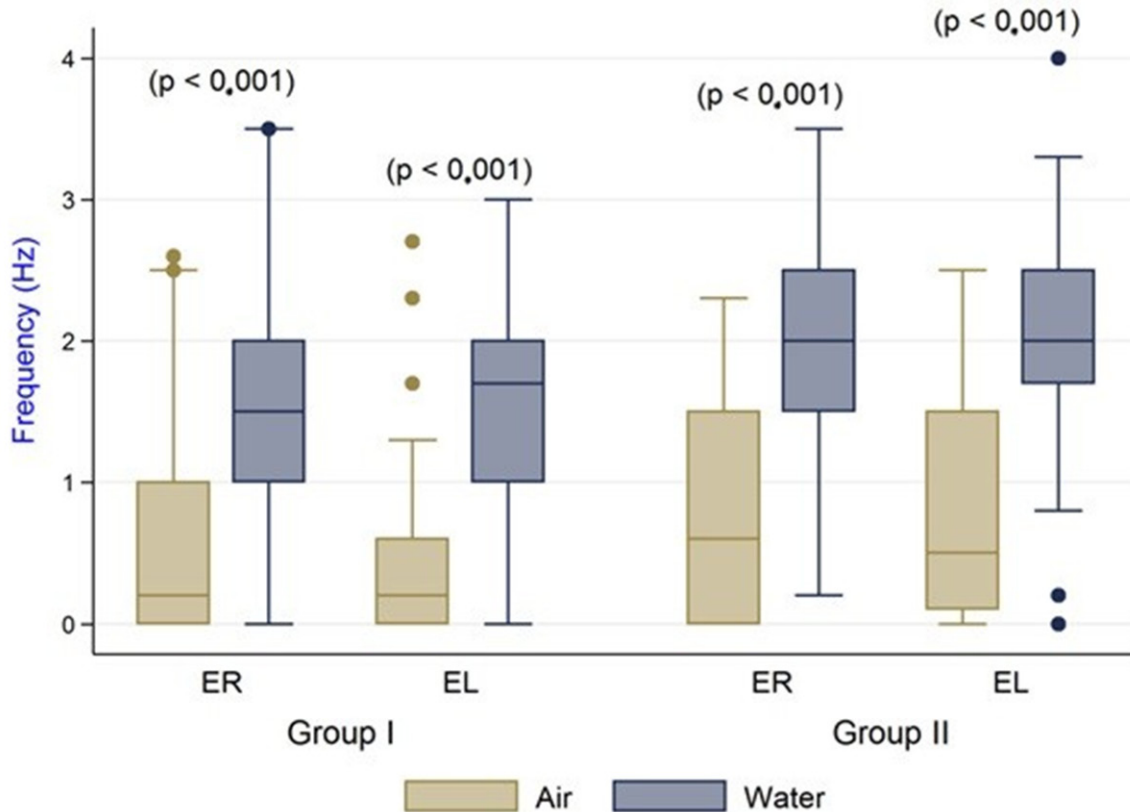


Figure 2. Velocity obtained during caloric stimulation at an air temperature of 44 °C and water temperature of 44 °C.

Table 2. Velocity obtained during air caloric stimulation at 44 °C and water caloric stimulation at 44 °C

	Water stimulation		Air stimulation	
	RE	LE	RE	LE
Group I	16.79°/s	18.62°/s	1.81°/s	1.95°/s
Group II	23.94°/s	26.15°/s	2.15°/s	2.17°/s

slow nystagmus phase, frequency of nystagmus, vestibular deficit, relative and absolute directional preponderance and excitability, for which the following reference values were adopted: vestibular deficit < 15%; relative directional preponderance < 11%; absolute directional preponderance < 2°/s; -excitability 6-80°/s.

The results were statistically analyzed based on the following tests of significance: chi-square test for independence, Shapiro-Wilk W test for normality, Grubbs' test, Levene's test for variance, analysis of variance (ANOVA) without repetitions, Mann-Whitney U test and Kruskal-Wallis H test.

Statistical significance of the results was assumed at P < 0.05. The Stata®/Special Edition version 12.1 (StataCorp LP, College Station, Texas, USA) software was used for statistical analysis.

The study was approved by the Bioethics Committee of the Medical University of Lodz, No. RNN/798/11/KB of 22.11.2011.

Results

In both groups, there was a significant statistical difference in the angular velocity of the slow nystagmus phase related to the applied stimulus. Similar results were obtained for the left and right ear. In Groups I and II, the average velocity values for an impulse of 30°C were three times higher for water caloric stimulation than air caloric stimulation (Figure 1; Table 1).

For the stimulus of 44°C, the mean velocity values in Group I were approx. nine times higher, and in Group II approx. ten times higher for water simulation than air stimulation (Figure 2; Table 2).

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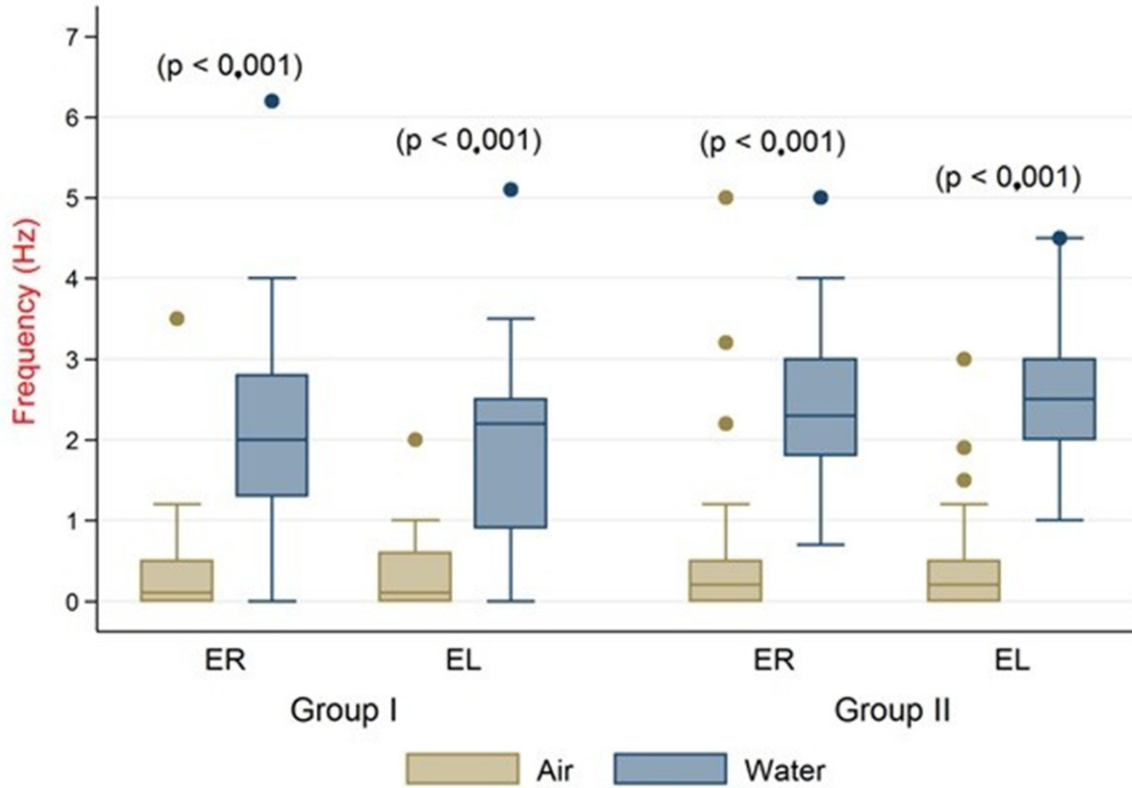


Figure 3. Frequency during caloric stimulation at an air temperature of 30 °C and water temperature of 30 °C.

Table 3. Frequency during air caloric stimulation at 30 °C and water caloric stimulation at 30 °C

	Water stimulation		Air stimulation	
	RE	LE	RE	LE
Group I	1.51 Hz	1.50 Hz	0.55 Hz	0.40 Hz
Group II	1.92 Hz	2.1 Hz	0.83 Hz	0.76 Hz

A statistically significant difference in nystagmus frequency was also found in both groups depending on the caloric test. Results for the right and left ear were not significantly different. In both groups, the average frequency values for the cold stimulus were approx. three times higher during the water stimulation (Figure 3; Table 3).

For the warm impulse, the average frequency values in both groups were approx. six times higher for water stimulation than air stimulation (Figure 4; Table 4).

In both groups, a statistically significant difference in excitability depending on the applied impulse was observed. The average excitability

values in Group I were approx. eight times higher for water simulation than air stimulation. In Group II, the mean excitability values were approx. five times higher for water simulation (Figure 5; Table 5).

There were no significant differences in the vestibular deficit depending on the type of caloric test. In both groups, similar values of vestibular deficit were obtained for both types of stimulation (Figure 6; Table 6).

In Group I, non-compliance of the results regarding the side of damage was observed in seven patients for both tests.

In Group II, abnormal results for the vestibular deficit were obtained in three subjects during air caloric stimulation, while the values for water stimulation were within normal limits.

The last parameter of nystagmus assessed during the study was directional preponderance. Table 7 shows the average values of relative and absolute directional preponderance obtained for stimulations in both groups.

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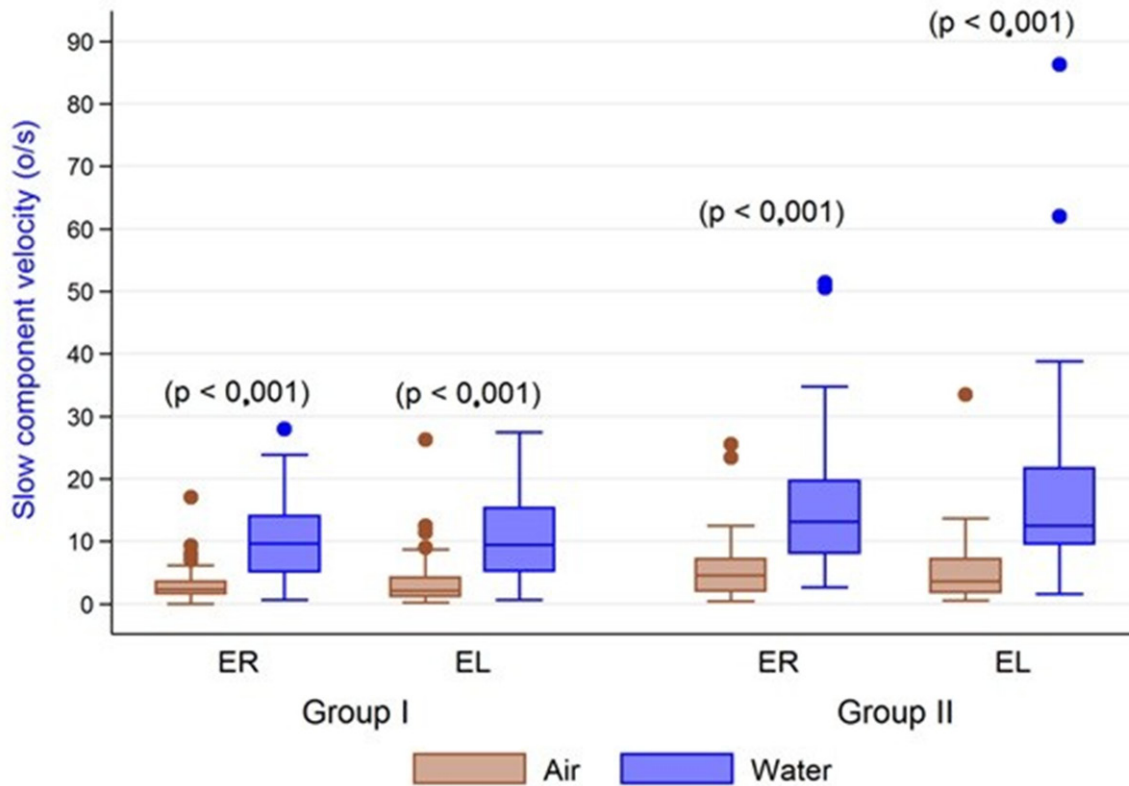


Figure 4. Frequency during caloric stimulation with air at an temperature of 44 °C and water of 44 °C.

Table 4. Frequency during air caloric stimulation at 44 °C and water caloric stimulation at 44 °C

	Water stimulation		Air stimulation	
	RE	LE	RE	LE
Group I	2.04 Hz	1.83 Hz	0.32 Hz	0.31 Hz
Group II	2.30 Hz	2.56 Hz	0.41 Hz	0.37 Hz

Discussion

Vertigo and balance disorders affect a considerable part of the Polish population. A large variety of symptoms behind the broad concept of vertigo as well as the underlying causes pose both diagnostic and therapeutic challenges. Diagnostic difficulties also stem from the fact that the process of balance and spatial orientation is controlled by the systems of the sense organs, of which the vestibular system plays a significant role. An examination technique that quantitatively and qualitatively assesses the vestibular function is the evaluation of caloric nystagmus. The basic parameter of nystagmus defining the function of the peripheral portion

of the balance system is angular velocity of the slow nystagmus phase (SPV). The SPV value is proportional to the angular deflection of the cupula in the lateral semicircular canal from its resting position [10].

In the presented study, a stronger response was observed during water caloric stimulation of the vestibular system compared to air stimulation. In both groups, significantly higher values of the angular velocity of the slow nystagmus phase were obtained during both cold and warm water stimulation.

Zangemeister et al. [11] compared air stimulation (29°C, 45°C, application time: 60 s) with water stimulation (30°C, 44°C, application time: 30 s), obtaining statistically significant differences in SPV values depending on the applied stimulus. The maximum value of the angular velocity of the slow nystagmus phase was almost two times higher for water stimulation than air stimulation.

Similar results were also obtained in children. In this population, the maximum SPV values for

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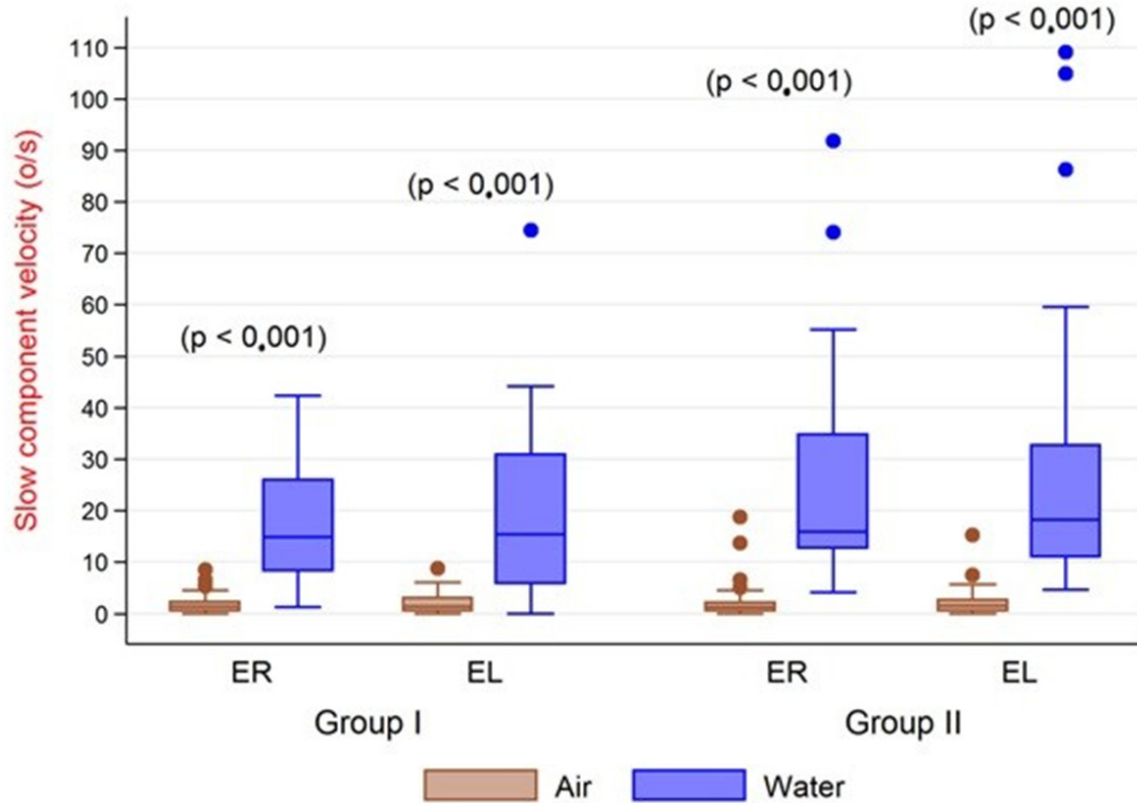


Figure 5. Excitability measured during air and water caloric stimulation.

Table 5. Excitability measured during air and water caloric stimulation

	Water stimulation	Air stimulation
Group I	39.53°/s	5.62°/s
Group II	45.67°/s	8.29°/s

water caloric stimulation using the cold stimulus of 31°C and warm stimulus of 31°C were about two times higher than values for air caloric stimulation using the stimuli of 25°C and 49°C. The air stimulation test was much better tolerated by children [12-15].

Tole [16] used air stimuli at the same temperature as water stimuli, i.e. 30°C and 44°C. Other authors used more extreme temperatures for air caloric stimulation (24°C and 50°C) compared to water stimulation (30°C and 44°C) [17].

Suter et al. [18] obtained similar SPV results for stimulation with water at 30°C and air at 24°C, and found a significantly stronger response after using the air stimulus at a temperature of 50°C compared to the water stimulus of 44°C.

Munro et al. [19] obtained similar values of the angular velocity of the slow nystagmus phase for air stimulation at 30°C and water stimulation at 21°C.

On the other hand, Rydzewski [20] obtained similar values of caloric nystagmus parameters after using air stimuli at 26°C and 48°C, and water stimuli at 30°C and 44°C; the stimulus application time was 80 seconds.

The present study demonstrated no statistically significant differences in SPV values for the left and right ear depending on the stimulus temperature and type of stimulation. Similar results were also obtained by other authors, who used similar or more extreme temperatures [21-23].

The present study also demonstrated a statistically significant difference in the nystagmus frequency depending on the applied stimulus. In both groups, the mean frequency values were higher for water than air stimulation for both cold and warm stimuli. Results for the right and left ear did not differ significantly.

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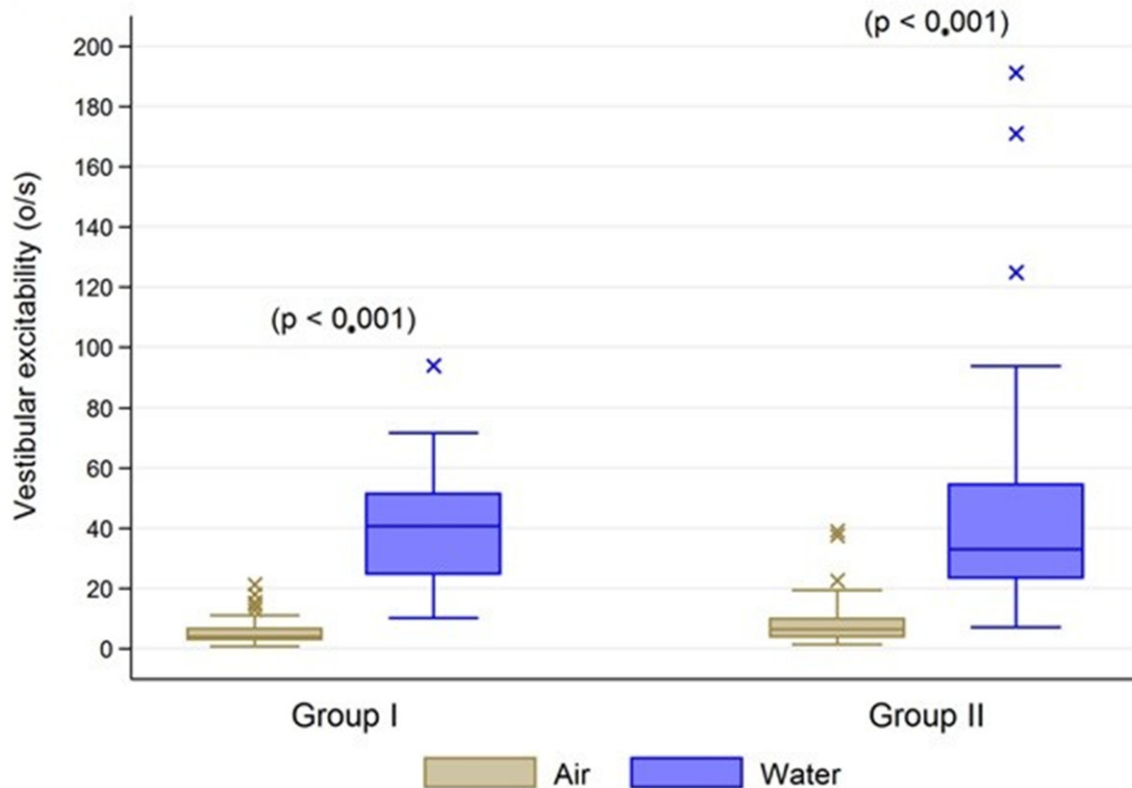


Figure 6. Vestibular deficit observed during air and water caloric stimulation.

Table 6. Vestibular deficit observed during air and water caloric stimulation

	Water stimulation		Air stimulation	
	RE	LE	RE	LE
Group I	44.60%	50.80%	34.50%	41.79%
Group II	8.83%	7.32%	9.78%	10.86%

Other authors also obtained higher frequency values for water stimulation, but they did not observe an effect of temperature on the results [24, 25].

The present study also assessed the relative and absolute directional preponderance. In Group II, for air caloric stimulation, the mean values of relative directional preponderance were almost double the normal limit, while the average values of the absolute directional preponderance were correct. In the same group, during water stimulation, the mean values of the relative and absolute directional preponderance were correct.

Taking into account the weaker response of the vestibular system to air stimulation, it can be assumed that some of the artifacts were interpreted and analyzed by the computer system

as nystagmus. The described phenomenon can be explained by the abnormal values of relative directional preponderance obtained during the air test in the groups of individuals without vestibular system disorders.

A statistically significant difference in excitability depending on the applied caloric stimulus was also observed. In both groups, higher excitability values were obtained during the water test.

Other studies demonstrated similar excitability values for both tests using air stimuli at a temperature of 24°C and 50°C, and water stimuli at 33°C and 44°C [23].

However, no statistically significant differences were observed for the vestibular deficit depending on the applied stimulus. In both study groups, similar values of vestibular deficit were obtained for both types of stimulation.

Conclusions

Water caloric stimulation produced a stronger response, which allowed for easier analysis of the vestibular system functioning.

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Table 7. Relative and absolute directional preponderance during water and air caloric stimulation

	Water stimulation		Air stimulation	
	Relative directional preponderance	Absolute directional preponderance	Relative directional preponderance	Absolute directional preponderance
Group I	27.43%	2.27 °/s	31.14%	0.91 °/s
Group II	9.9%	1.75 °/s	24.39%	0.58 °/s

Despite significantly lower values for nystagmus obtained during air stimulation, statistically, the final vestibular deficit value for both types of caloric stimulation was not significantly different.

In the case of contraindications for water stimulation, air caloric stimulation should be the primary test.

Caloric stimulation may also be recommended for individuals who are intolerant of water caloric stimulation.

Acknowledgements

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Disclosure of conflict of interest

None.

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