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Effects of the Vestibular Caloric Stimulation with Ice Water on the Autonomic Nervous System

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Abstract

PURPOSE : The effect of the vestibular caloric stimulation with ice water on the autonomic nervous system was investigated using pulse oximetry.

METHOD : Thirty-four healthy men and women were subject to a 2-minute vestibular caloric stimulation with ice water, and autonomic nervous activities (low frequency, high frequency, and total power) were measured before and after the vestibular caloric stimulation. Data were analyzed separately for men and women.

RESULT : Low frequency, high frequency, and total power in the men and low frequency in the women were statistically significantly higher after vestibular caloric stimulation. High frequency and total power in the women were higher but not significantly different after vestibular caloric stimulation.

CONCLUSION : Vestibular caloric stimulation with ice water increases autonomic nervous activities, with the variation being within the normal range. The test can be considered safe for use.

Key Words : autonomic nervous system, caloric stimulation, ice water caloric test

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Ⅰ. INTRODUCTION

The autonomic nervous system maintains homeostasis against external and internal stress. The heart is controlled by the autonomic nervous system, and it dynamically responds to changes in the environment. Cardiovascular accidents increase when the functioning of the autonomic nervous system is irregular (Al-Qudah et al., 2015). Therefore, studies are performed to measure stress on the cardiovascular system in a variety of situations.

The vestibular caloric test, designed by Robert Barany, assesses the vestibulo-ocular reflex (Barany, 1907). By using quantitative stimulation by inducing temperature difference, the test determines morbidity related to equilibrium by measuring eye movements (Gonçalves et al., 2008). In this test, warm or cold water or air is irrigated into the external auditory canal. Some variants of the test are bithermal, monothermal, and ice water vestibular caloric test. The bithermal vestibular caloric test is the "gold standard" test of vestibular end-organ function (Cunha et al., 2010). On the other hand, ice water vestibular caloric test is an effective way to confirm complete loss of vestibular end-organ function (British Society of Audiology, 2010). But unlike the bithermal vestibular caloric test with cold water of 30°C, vestibular caloric test with ice water of 0°C can cause excessive dizziness (Proctor, 1992). Therefore, ice water vestibular caloric test should be performed with considerable care so as to not cause excessive vestibular stimulation.

The vestibular system and the autonomic nervous system interact with each other, and there could be autonomic nervous hyperactivity due to vestibular stimulation. Jauregui-Renaud et al.(2000) reported that vestibular caloric stimulation in bithermal vestibular caloric test affects the autonomic nervous system. However, no study has tested the effects of the ice water vestibular caloric test on the autonomic nervous system. Therefore, the purpose of this study was to investigate the effects of vestibular caloric stimulation with ice water on the autonomic nervous system and whether vestibular caloric stimulation with ice water is safe in the autonomic nervous system.

Ⅱ. METHOD

The study population included healthy men(n=19) and women(n=15) with no musculoskeletal, neurological, autonomic nervous system diseases. The mean ± SD values for age, weight, and height were 23.67 ± 1.27 years, 71.33 ± 9.20 kg, and 172.83 ± 3.29 cm for the men; the corresponding values for the women were 21.67 ± 0.49 years, 48.33 ± 2.44 kg, and 158.00 ± 2.93 cm (Table 1). All subjects provided their informed consent, after understanding the study's aims and methods. This study was approved by the Bioethics Committee of the Catholic University of Pusan (CUPIRB-2016-022).

Table 1. Subjects' characteristics

Group	Men (n=19)	Women (n=15)
Age (yrs)	23.67±1.27[a]	21.67±0.49
Weight (kg)	71.33±9.20	48.33±2.44
Height (cm)	172.83±3.29	158.00±2.93

The mean ± SD[a], SD: standard deviation

The laboratory was set to a temperature of 22 °C and humidity of 65 %, with measures taken to block external noise. During the 48 hours before the experiment, exercise, overeating, and drinking were controlled. During the 4

hours before the experiment, smoking and caffeine intake were controlled. Subjects were asked to wear comfortable clothes and rest by supine on a table for 10 minutes. Vestibular caloric stimulation was applied in head flexed 30° forward in upright position using a syringe: 5 ml of ice water (0 ℃), and was irrigated into the right external auditory canal (Park, 2012). The stimulation lasted for 2 minutes. The activity of the autonomic nervous system was measured before and after caloric stimulation by using pulse oximetry. Low frequency, high frequency, and total power were measured. The measurement duration was 70 seconds, and measurement was repeated five times; average of the values was taken for analysis. Statistical analyses were conducted using the SPSS version 12.0 software. A paired t-test was used to compare the values before and after vestibular caloric stimulation; the significance level was set at 0.05.

Ⅲ. RESULT

Low frequency, high frequency, and total power in the men and low frequency in the women were statistically significantly higher after the vestibular caloric stimulation with ice water when compared with the values before the vestibular caloric stimulation ($p<0.05$). High frequency and total power in the women were higher but not significantly different after the vestibular caloric stimulation when compared with the values before vestibular caloric stimulation (Table 2).

Table 2. Changes in autonomic nervous activities after vestibular caloric stimulation with ice water

Group	Men (n=19)		Women (n=15)	
	Before VCS	After VCS	Before VCS	After VCS
Low frequency (ms^2)	5.84±1.02	6.33±1.06*	4.91±1.11	5.59±0.92*
High frequency (ms^2)	5.05±1.02	5.59±0.95*	4.94±0.62	5.17±0.59
Total power (ms^2)	6.78±1.01	7.22±0.88*	6.23±0.82	6.56±0.78

*$p<0.05$, Signifiant differences were compared with Before VCS.
VCS: vestibular caloric stimulation

Ⅳ. DISCUSSION

Stimulation of the vestibular system causes autonomic symptoms such as nausea and/or vomiting, indicating that the vestibular system and the autonomic nervous system interact anatomically and physiologically. Animal studies, through inducing injury or irritation of the vestibular organ, have also shown interaction between the two systems (Oh et al., 1999; Park et al., 2002). In particular, Oh et al.(1999) reported that stimulation of the peripheral vestibular organ by inducing temperature difference increases the low frequency and high frequency of autonomic nervous system activity. In this animal model as well, caloric stimulation influences the autonomic nervous system.

Jauregui-Renaud et al.(2000) studied the effects of bithermal vestibular caloric stimulation on the heart rate and blood pressure variability in human subjects and found that vestibular caloric stimulation increased the activity of the autonomic nervous system. Proctor(1992) also studied the effects of vestibular caloric stimulation using ice water by using the electronystagmogram and reported that vestibular caloric stimulation using ice water provide a greater stimulus than that of cold water. In the present study, vestibular caloric stimulation was provided using ice water,

and low frequency, high frequency, and total power were found to increase after the vestibular caloric stimulation. Although high frequency and total power in women group did not show a statistically significantly, there were increased after vestibular caloric stimulation. Low frequency reflects sympathetic nervous system activity, high frequency reflects parasympathetic activity, and total power reflects the overall activity of the autonomic nervous system. Thus, our study showed that vestibular caloric stimulation with ice water increases the activity of the autonomic nervous system in human subjects, a finding which is in agreement with Jauregui-Renaud et al.(2000)'s study results.

However, a concern with vestibular caloric stimulation with ice water is that, that it would cause imbalance of the autonomic nervous system. However, a study by Nunan et al.(2010) showed short-term heart rate variability but within the normal range in healthy adults. It is believed that the changes in the autonomic nervous activity caused by ice water vestibular caloric test may not be significant to cause side effects. A limitation of this study is that its results are limited to healthy subjects, as only healthy subjects were enrolled. In cases of vestibular disorders, the autonomic nervous system activity patterns may differ. In future therefore, we will study the safety of ice water vestibular caloric test on the autonomic nervous system in patients with vestibular disorder.

Ⅴ. CONCLUSION

Vestibular caloric stimulation with ice water increases autonomic nervous activities, with the variation being within the normal range. The test can be considered safe for use.

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