Ice Water Ingestion and Sympatho-vagal Balance in Healthy Subjects: Importance of Time-Domain Heart Rate Variability

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ABSTRACT

Background: Literature has witnessed the recognition of a significant relationship between the autonomic nervous system and cardiovascular mortality. In patients with autonomic failure, water drinking has been shown to produce changes in hemodynamics in terms of high blood pressure and bradycardia. In healthy individuals, this has been not addressed. Therefore, this study is aimed to record the time domain parameters of heart rate variability (HRV) in healthy subjects after ice water ingestion.

Methods: This cross sectional study included a total of 60 healthy subjects between the age group of 18-24 years, randomly assigned into two groups. Study group ingested ice water and control group ingested normal room temperature water. Before and after water ingestion, time domain parameters of HRV were recorded. Statistical data was analyzed by Student's unpaired *t* test.

Results: The primary endpoints RRI, SDNN, RMSSD were significantly increased and mean HR was decreased after ice water ingestion, when compared with those after room temperature water ingestion indicating vagal activity. The results are consistent with previous studies. On the other hand, HRV parameters did not change significantly ($p > 0.05$) in control group before and after room temperature water ingestion.

Conclusion: Ice water ingestion can reduce heart rate by vagal modulation in healthy subjects assuming supine position. (J Clin Prev Cardiol. 2015;4(2):27-31)

Keywords: Ice water ingestion, heart rate variability, reduced heart rate, vagal modulation

Introduction

Drinking ice water is one of the most common daily activities, especially in hot weather. Many studies have shown bradycardia in response to immersion of face and hand in ice water (1-3). The last two decades have witnessed the recognition of a significant relationship between the autonomic nervous system and cardiovascular mortality, including sudden cardiac death. Experimental evidence for an association between a propensity for lethal arrhythmias and signs of either increased sympathetic or reduced vagal activity has encouraged the development of quantitative markers of autonomic activity (4). Ice fluid restriction was one of the standards of care in patients with acute myocardial infarction as a 'coronary precaution' in the 1960s. Though there was no evidence base, it was probably advocated considering the deleterious effects on heart rate (5). In humans, however, research on short-term cardiovascular effects of water drinking in healthy subjects has been neglected, and the issue has not been addressed in major physiology texts (6).

Heart rate variability (HRV) is a non-invasive and quantitative method that can be used to assess the autonomic nervous control of the heart rate (7). Measures of HRV in both, time and frequency domains, have been used successfully to index vagal activity. In the time domain, standard deviation of normal to normal R-to-R intervals (SDNN) and the root mean square of successive differences (RMSSD) have been shown to be useful indices of vagal activity (8).

This study investigated the HRV before and after cold water or room temperature water ingestion to delineate the effect of cold water ingestion on heart rate and the autonomic nervous modulation in the subjects. The primary hypothesis being that drinking ice water decreases heart rate through temperature stimulus-mediated vagal enhancement in healthy subjects.

Aims and Objectives

1. To record time domain HRV parameters in healthy

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subjects in basal state, after ingestion of water at room temperature (control group), and after ingestion of cold water (study group)

2. To compare percentage change in parameters between control group and study group

Methodology

The study was conducted in the department of Physiology, SDMCMS&H, Dharwad, Karnataka (India) from July to September 2014. For the study, a total of 60 healthy, both male and female (equal number), subjects between the age group of 18-24 years were selected from the same institution. The subjects were randomly assigned into two groups. Study group ingested cold water (7°C ± 0.5°C), and control group was given room temperature water. Sample size was 30 each in both the groups with age, sex and body mass index (BMI) matched. Exclusion criteria were subjects with cardiovascular disorder, respiratory disorder, neurological disorder, subjects taking any drug or medication, diabetes mellitus, hypertension and subjects having dental caries. Instrument used was INCO IV Channel Data Aquisition System to record HRV with computer to transfer the data. Prior to the commencement of the study, the institutional ethical clearance (IEC) was obtained. After taking an informed consent from each subject, the following anthropometric parameters were recorded:

1) Age (years)
2) Height (cms)
3) Weight (in kilograms)
4) BMI: Body mass index (kilogram/meter^2)

Parameters of Time Domain HRV recorded were:

- mean RRI (RR intervals)
- mean HR (mean heart rate)
- SDNN (standard deviation of all normal to normal interval)
- RMSSD (root mean square of successive differences between adjacent NN intervals)
- pNN50 (number of adjacent NN intervals differing by more than 50 ms divided by the total number of all NN intervals)
- HRV triangular index
- TINN (triangular interpolation of NN interval)

Procedure

- Recording of basal (supine rest for 5 minutes) HRV time domain parameters in all the subjects. Here ECG signals were picked by ECG monitor and transmitted to a computer for recording for 2 minutes.
- To observe autonomous reactions of water ingestion, HRV parameters were recorded in the control group for 5 minutes after ingestion of 250 ml of water at room temperature and after ingestion of 250 ml of cold water in study group.

A sampling rate of 500 Hz was used. The fiducial point of the R wave was identified by an algorithm of parabolic interpolation and a derivative plus threshold algorithm to locate a stable and noise-independent reference point. The last 512 stationary RRI were obtained for HRV analysis. If the percentage of deletion was more than 5%, then the subject was excluded from the study. The power spectrum of 512 RRI was obtained by means of fast Fourier transformation. The percentage change in HRV parameters in both the groups were determined to avoid deviation of parameters value from normal distribution and is given by the formula (1):

100 × (HRV after water ingestion – HRV before water ingestion) / HRV before water ingestion.

Statistical Analysis

Recorded data analysis was done using SPSS window version 20. The clinical parameters included age, body height, body weight, and BMI and HRV measures were presented as mean ± standard deviation. Paired *t* test was used to compare the HRV data before and after water ingestion in both the groups of subjects. The Student's unpaired *t* test was used to compare the normally distributed and equal variance data, i.e., age, body height, body weight and BMI, and to compare values between two groups. While the Mann–Whitney rank sum test was used to compare the percentage change in HRV measures between two groups of subjects. p value < 0.05 was considered as statistically significant. To compare the responses to water ingested at different temperatures, the percentage change in HRV measures (100 × [HRV after water ingestion - HRV before water ingestion]/ HRV before water ingestion) in both room temperature and ice water ingestion groups was calculated.

Results

Table 1 depicts subjects' characteristics. No significant (p > 0.05) differences in age, gender, body height, body weight and BMI were found between two groups. No significant difference (p > 0.05) was found between the two groups before (basal) water ingestion in HRV time domain parameters as shown in Table 2. HRV parameters did not change significantly (p > 0.05) in control group before and after room temperature water ingestion (data not shown).

Table 1. Baseline characteristics of the subjects.

Features	Control group (N= 30)	Study group (N= 30)	p value
Age (years)	19.433±0.504	19.84±0.78	0.718
Gender (M/F)	15 /15[a]	15 /15[a]	0.611
Body height (cms)	162.70±8.101	168.58±9.91	0.167
Body weight (kg)	58.133±6.099	59.10±10.11	0.300
BMI (kg/m^2)	22.11±3.7	22.7±2.8	0.572

All values except a are expressed in Mean ± Standard Deviation. p value < 0.05 is statistically significant

However, mean RRI (743.60 ± 170.12 vs. 793.2 ± 80.21, p value 0.001), SDNN (58.23 ± 1.42 vs. 64.72 ± 0.32, p value 0.002) and RMSSD (41.11 ± 2.33 vs. 48.48 ± 0.43, p value 0.01) were significantly increased and mean HR was decreased (80.02 ± 2.42 vs. 72.22 ± 4.13, p value 0.001) after ice water ingestion compared to before water ingestion in study group. pNN50, HRV triangular and TINN parameters were statistically non significant (Table 3).

Table 2. Basal (before water ingestion) HRV time domain parameter of both groups.

HRV parameters	Control group (N= 30)	Study group (N= 30)	p value
Mean RRI (ms)	759.01±187.6	743.6±170.12	0.797
Mean HR (bpm)	78.22±7.21	80.02±2.42	0.641
SDNN (ms)	59.33±4.21	58. 23±1.42	0.522
RMSSD (ms)	43.41±4.82	41.11±2.33	0.518
pNN50 (%)	44. 51±9.22	42.78±1.87	0.233
HRV Triangular	8.32±4.22	8.03±2.0	0.346
TINN (ms)	140.2±8.34	141.3±6.1	0.491

mean RRI: mean RR intervals; mean HR: mean Heart Rate; SDNN: standard deviation of all NN interval; RMSSD: Standard deviation of differences between adjacent; NN: Square root of the mean of the sum of the square of the differences between adjacent NN intervals; pNN50: number of adjacent NN intervals differing by more than 50 ms divided by the total number of all NN intervals; HRV triangular index; TINN: triangular interpolation of NN interval.

Table 3. HRV Time Domain parameters of Study group.

HRV parameters	Study group (ice water ingestion)		p value
	Before	After	
Mean RRI (ms)	743.6±170.12	793.2±80.21	0.001
Mean HR (bpm)	80.02±2.42	72.22±4.13	0.001
SDNN (ms)	58. 23±1.42	64.72±0.32	0.002
RMSSD (ms)	41.11±2.33	48.48±0.43	0.01
pNN50 (%)	42.78±1.87	44.23±5.20	0.06
HRV Triangular	8.03±2.0	8.83±4.11	0.06
TINN (ms)	141.3±6.1	139.7±6.2	0.54

mean RRI: mean RR intervals;mean HR: mean Heart Rate;SDNN: standard deviation of all NN interval;RMSSD: Standard deviation of differences between adjacent; NN: Square root of the mean of the sum of the square of the differences between adjacent NN intervals; pNN50: number of adjacent NN intervals differing by more than 50 ms divided by the total number of all NN intervals; HRV triangular index; TINN: triangular interpolation of NN interval.

When HRV parameters of both the groups were compared after water ingestion, mean RRI, SDNN, RMSSD were statistically higher, while the mean HR was significantly lower in the study group. pNN50, HRV Triangular and TINN parameters were statistically non significant with p value less than 0.05 (Table 4).

Table 4. HRV time domain parameters of both the groups after water ingestion.

HRV parameters	Control group (N= 30)	Study group (N= 30)	p value
Mean RRI (ms)	762.0±120.6	793.2±80.2	0.001
Mean HR (bpm)	76.22±4.11	72.22±4.13	0.01
SDNN (ms)	61.30±2.24	64.72±0.32	0.02
RMSSD (ms)	45.13±4.72	48.48±0.43	0.002
pNN50 (%)	42.91±7.21	44.23±5.20	0.12
HRV Triangular	8.72±4.32	8.43±4.11	0.32
TINN (ms)	141.7±4.31	139.7±6.2	0.41

mean RRI: mean RR intervals; mean HR: mean Heart Rate; SDNN: standard deviation of all NN interval; RMSSD: Standard deviation of differences between adjacent; NN: Square root of the mean of the sum of the square of the differences between adjacent NN intervals; pNN50: number of adjacent NN intervals differing by more than 50 ms divided by the total number of all NN intervals; HRV triangular index; TINN: triangular interpolation of NN interval

After ice water ingestion, the percentage change in mean RRI, SDNN, RMSSD were higher, while the percentage change in mean HR was lower when compared with those after the room temperature water ingestion (Table 5).

Table 5. Percentage change in HRV parameters of both the groups after water ingestion.

HRV parameters	Control group (N= 30)	Study group (N= 30)	p value
Mean RRI (ms)	−2±4	4±3	0.001
Mean HR (bpm)	0.7±2	−4.2±8	0.001
SDNN (ms)	10±22	19±32	0.01
RMSSD (ms)	5±9	7±11	0.01
pNN50 (%)	2±10	3±13	0.32
HRV Triangular	3±41	4±32	0.51
TINN (ms)	2±1	1±9	0.62

mean RRI: mean RR intervals;mean HR: mean Heart Rate; SDNN: standard deviation of all NN interval; RMSSD: Standard deviation of differences between adjacent; NN: Square root of the mean of the sum of the square of the differences between adjacent NN intervals; pNN50: number of adjacent NN intervals differing by more than 50 ms divided by the total number of all NN intervals; HRV triangular index; TINN: triangular interpolation of NN interval.

Discussion

The present study was conducted to find out the effect of ice water ingestion on autonomic system in healthy subjects. The primary endpoints RRI, SDNN, RMSSD were increased and mean HR was decreased after ice water ingestion, when compared with those after room temperature water ingestion indicating vagal activity. The results are consistent with previous studies. Previously, in a study, it was concluded that after ice water ingestion, the percentage change in mean RRI, and standard deviation of RRI were higher, while percentage change in HR was lower, when compared with those after the room temperature water ingestion (5). Further studies (9) have shown that the reduction in HR in response to ice water ingestion depends on position of the subject and volume of ice water. Recumbent position or larger volume up to 600 to 800 ml of ice water has a greater effect than those of upright position or smaller volume. Ellis (10) studied ice-water induced arrhythmias in a patient with ischemic heart disease and concluded that it is the ice water induced arrythmia rather than the act of swallowing and it is a vagally mediated phenomenon.

Although the mechanism of cardiovagal activation after ice water ingestion is not clear at present, previously in many studies it was shown that when cold stimuli was applied to the forehead and maxillary region in healthy subjects, (the cold face test) HR can be reduced due to cardiovagal activation (1-3). The cold stimulation on the oral cavity and receptors in the esophagus after ice water ingestion might have the same results to that of cold test. There is a evidence for presence of vagal receptors in esophagus in animal studies (11). Thus the ice water ingestion reduced the HR compared to room temperature water probably via vagal receptors in the esophagus. Opposing views have been reported in a study by Jordon *et al* (12) that water drinking increases sympathetic activity. Raised blood pressure was noted in older healthy subjects and in autonomic failure patients, but no effect on blood pressure or HR on healthy young subjects.

Limitations

The effect of position and volume of water could not investigated as it was a small sample size.

Conclusion

Ice water ingestion can enhance the vagal modulation and cause reduction in HR i.e., increase in mean RRI, SDNN and RMSSD in healthy subjects assuming supine position. The study highlights the advantages of ice water ingestion. In future, the study can be extended to know the gender difference and correlation between HRV parameters and BMI with large sample.

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Conflicts of interest: None

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