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Influence of Water Intake on Post-Exercise Heart Rate Variability Recovery

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ABSTRACT

Oliveira TP, Ferreira RB, Mattos RA, Silva JP, Lima JRP. Influence of Water Intake on Post-Exercise Heart Rate Variability Recovery. **JEPonline** 2011;14(4):97-105. The risk of severe cardiovascular events is increased soon after physical exertion. Interventions that could potentially improve post-exercise autonomic recovery could prevent cardiovascular events during this vulnerable period. Water intake during or after physical exertion is a widespread practice because it produces important hemodynamic and autonomic changes. The purpose of this study was to assess the influence of water intake on post-exercise autonomic recovery through the analysis of post-exercise heart rate variability (HRV) recovery. Ten healthy subjects, with a moderate level of physical activity were enrolled in this study. Following the recording of RR intervals at rest, the subjects exercised on cycle ergometer with water intake at the end of exercise during which the recording of recovery RR intervals was carried out. Heart rate variability was analyzed in time and frequency domains. The water intake led to higher HRV values throughout the recovery period measured ($P=0.05$). The findings suggest that post-exercise water intake enhances post-exercise autonomic recovery.

Key Words: Exercise, Heart Rate Variability, Autonomic Recovery

INTRODUCTION

The autonomic nervous system, through its sympathetic and vagal loops, modulates and maintains the physiological balance of the cardiovascular system both at rest and under different physiological conditions such as physical exertion and post-exercise recovery (22). During rest, cardiovagal activity predominates with consequent sinus bradychardia. Under the increased metabolic demands of physical exertion heart rate (HR) increases, due to reduced vagal activity and increased sympathetic activity. When physical exertion comes to an end, the immediate reduction of neuromuscular and metabolic activities contributes to HR recovery.

According to the rhythm of HR fall and its autonomic determinants, post-exercise autonomic recovery can be divided into two phases. The first phase is the fast phase (FP) of post-exercise autonomic recovery, which comprises the first 5 min following the end of exercise. This is a period during which the decrease in HR is fast, exponential, and chiefly mediated by parasympathetic reactivation. The second phase is the slow phase (SP) of post-exercise autonomic recovery in which the decrease in HR fall is slower and more prolonged. This phase is due to a combination of vagal reactivation and sympathetic withdrawal (1,5,10).

The risk of severe cardiovascular events is increased soon after physical exertion (2,14). Natural stress brought about by physical exertion leads to a transient autonomic disturbance along with an increase in cardiac risk. The decrease in cardiac parasympathetic tone and the increase in cardiac sympathetic tone seem to be the main cause of sudden death due to cardiovascular events soon after a session of physical exercises (2,13). Interventions that could potentially improve post-exercise autonomic recovery may help to prevent cardiovascular events during this vulnerable period.

Heart rate variability (HRV), the variation that occurs between successive sinus heart beats, is considered a non-invasive method to study cardiac autonomic modulation (22). Classical HRV analysis assumes the stationariness of the data; a situation typically found at rest or during the SP of post-exercise cardiac autonomic recovery (22). Alternative methods for assessing the cardiac autonomic modulation for non-stationary periods, such as during the study of post-exercise vagal reactivation have recently allowed for the investigation of HRV during the FP of post-exercise autonomic recovery (8,15).

Because dehydration is known to lead to untoward effects, hydration during or after physical exertion is a widespread practice (20). Water intake (WI) produces important hemodynamic and autonomic cardiovascular changes, promoting increased cardiac vagal modulation (4,19). Most studies on the influence of hydration over the cardiac autonomic control were undertaken at rest. Because there is increased risk of post-exercise cardiovascular events, investigating a putative benefit of WI on the cardiac autonomic modulation during recovery is important. Thus, the purpose of this study was to assess the influence of WI on HRV, measured during the FP and SP of post-exercise autonomic recovery.

METHODS

Subjects

Assuming a variation of 0.49 ± 0.17 ms in the natural logarithm of the quadratic mean root of the difference between successive post-exercise RR intervals (lnRMSSD) (1), we used the Statistica 6.0 software to determine that a 6-subject sample would be enough for 0.8 statistical power and 0.05 alpha. For better statistical power, 10 healthy subjects, with a moderate level of physical activity were enrolled (7 males and 3 females; 23.6 ± 4 yrs; 25.3 ± 3 kg/m^2). The participants were advised not to engage in physical exercises, and not to drink coffee or alcohol during the 24 hrs preceding the tests. They were also advised to keep their usual WI patterns on the eve of the tests and, in order to reach standardization, no WI was allowed during the 2 hrs immediately preceding the tests. The subjects provided voluntary written informed consent to participate in this study, which was approved by the University Human Ethics Review Board and followed the recommendations from the Declaration of Helsinki.

Procedures

Experimental Protocol

The experimental protocol was implemented in the afternoon, according to the following routine: 1) history-taking; 2) anthropometric measures (body mass and height); 3) recording of RR intervals at rest (rest RRi); 4) exercise on a cycle ergometer; 5) water intake or control session (randomized); and 6) recording of recovery RRi. The control session followed the same routine, with the exclusion of post-exercise WI. The interval between the control session and WI ranged from 2 to 7 days.

Rest iRR recording

A Polar RS800cx HR monitor was used for continuous recording of the rest iRR in the supine position for 10 min.

Physical exercise session

The 20-min exercise period was performed at a comfortable pace on an eletromagnetically-braked cycle ergometer loaded with 75 Watts for women and 100 Watts for men.

Water intake and control session

Immediately after the end of the exercise, the subjects drank 500 ml of water at room temperature. The entire amount was drunk in less than 30 sec, after which the subjects were prepared for recording of the recovery iRR. In addition, a control session (CON), similar to the experimental one except for the absence of WI, was performed on another day.

Recording of recovery iRR

After the WI or CON, the subjects laid on a stretcher, where they remained in the supine position for 10 min with continuous iRR recording (POLAR RS800cx).

Data transmission and signal procession

After the RRi recording, the data acquired by the HR monitor were transmitted to a computer, through an interface with an infrared device and the Polar Precision Performance software. The data were subsequently sent to the Kubios HRV (v. 2.0) software for error correction and calculation of the HRV indices.

HRV analysis

Rest HRV was analyzed in time and frequency domains. The last 5 min of the recorded signal were used for calculation of the following time-domain indices: SDNN (iRR standard deviation), RMSSD (root mean square of RRi successive differences) and pNN50 (percentage of successive iRR with differences greater than 50 ms). Analysis at the frequency domain involved prior smoothing, data resampling at 4 Hz, and performance of the Fast Fourier Transform-based algorithm. From the estimate of the power spectrum, the low-frequency (LF: 0.04-0.15 Hz) and high-frequency (HF: 0.15-0.4 Hz) components were calculated.

For analysis of the FP of the HRV, the first 5 min of the recorded signal during recovery were used. Because of the stationariness of the signal, a 30-sec window for the temporal series was used to calculate the RMSSD index for each window formed ($RMSSD_{30s}$), as proposed by Goldberger et al. (8). For analysis of the SP of the HRV, the period of time corresponding to the 5th to the 10th-min were used. The same indices used for rest HRV were calculated here.

Statistical Analyses

The data were presented as mean ± standard deviation. Because the Kolmogorov-Smirnov test showed that the LF, HF and $RMSSD_{30s}$ indices did not have a normal distribution, a logarithmic transformation of these indices (lnLF and lnHF) was performed. The paired Student`s t-test (significance set at P=0.05) was performed for comparison of the effect of WI on the HRV values during recovery.

RESULTS

Heart rate variability at rest

Table 1 indicates there were no significant differences in the rest HRV values, both in the time and frequency domains between the two conditions.

Table 1. Comparison of the rest HRV between the water intake (WI) and control (CON) conditions.

	WI	CON	*P*
SDNN (ms)	71.0±33.5	61.1± 5.6	ns
RMSSD (ms)	79.8±53.1	60.9±33.3	ns
pNN50 (ms)	37.7±25.6	29.9±22.3	ns
Ln LF (ms^2)	7.4±1.0	7.3±0.9	ns
Ln HF (ms^2)	7.1±1.6	6.8±1.6	ns
LF (nu)	51.5±5.0	52.4±5.2	ns
HF (nu)	48.5±5.0	47.6±5.2	ns

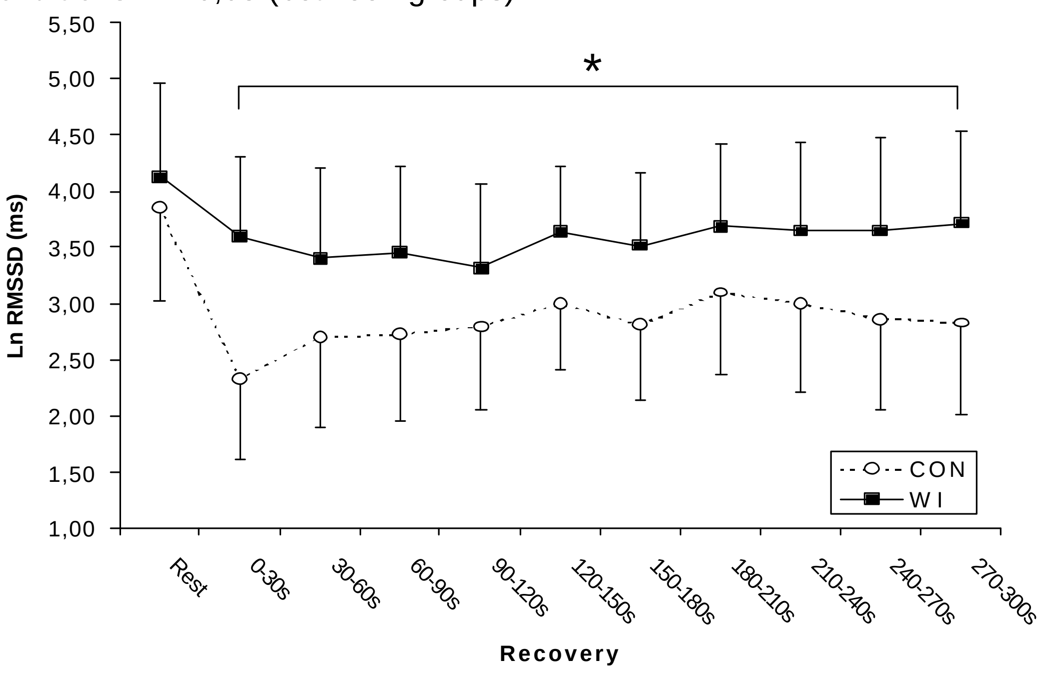
Exercise

Exercise HR values were 127.2 (±11.3) and 129.7 (± 14.6) beats·min^{-1} for the “control” and “water intake” conditions, respectively. The differences were not statistically significant, which guarantees the same relative intensity during the two days of the study.

Influence of WI on the HRV measured during the FP of the post-exercise autonomic recovery

WI positively affected the HRV measured during the FP (Figure 1). The $RMSSD_{30s}$ values with WI were statistically higher during the whole recovery (P=0.05).

Figure 1. Comparison of the FP of HRV recovery between water intake (WI) and control (CON) conditions. *P=0,05 (between groups)



Influence of WI on the HRV measured during the SP of post-exercise autonomic recovery

Time and frequency domains HRV indices, expressed in absolute units, during the SP, were statistically higher with WI, compared with controls, during the 5 to 10-min recovery period (Table 2; Figure 2).

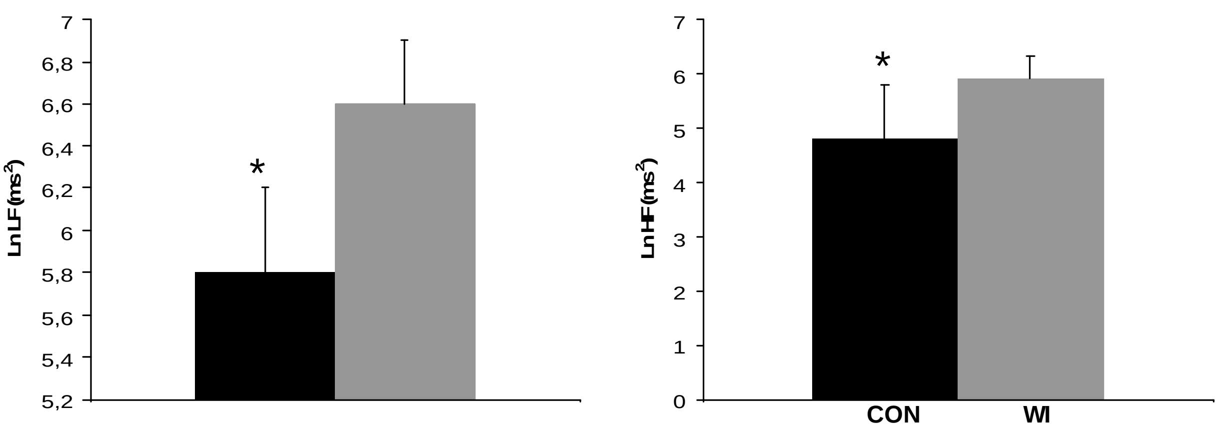
Table 2. Comparison of the time and frequency domains (normalized units) of the SP of the HRV recovery between water intake (WI) and control (CON) conditions.

	WI	CON	P
SDNN (ms)	44.7±20.2	32.5±24.3	= 0.05
RMSSD (ms)	43.6±24.8	28.8±24.6	= 0.05
pNN50 (ms)	21.9±18 0	11.3±16.1	= 0.05
LF (nu)	64.4 ± 23.2	69.0 ± 26.4	ns
HF (nu)	35.6 ± 23.2	31.0 ± 26.4	ns

DISCUSSION

Water intake has been associated with increases in blood pressure, (11,12), muscle sympathetic activity (11), and cardiac vagal modulation at rest (19). Our study aimed to assess the influence of WI on the post-exercise autonomic recovery, analyzed through measurements of HRV during the fast and slow phases of post-exercise autonomic recovery. Compared with controls, WI led to higher HRV values in both phases.

Figure 2. Comparison of the SP of the HRV recovery (frequency domain, absolute units), between the water intake (WI) and control (CON) conditions. *P=0.05 (between groups)



Influence of WI on HRV during the FP of post-exercise autonomic recovery

This study found a beneficial effect of WI on the HRV measured during the FP. The FP of post-exercise autonomic recovery comprises the first 5-min after exercise interruption. Because of immediate reduction of the metabolic activity during this phase, there is a rapid and exponential fall of the HR, chiefly due to resumed cardiac vagal activity (3,5,10). The non-linear characteristic of the HR precludes the use of traditional techniques for HRV analysis. This is why a 30-sec window for signal recording was used for analysis of the iRR temporal series, the RMSSD index being calculated for each window (8). This approach is relatively recent (8) and, therefore, there are few studies using it. This might explain why we could not find any other study on the influence of WI on the HRV measured soon after exercise interruption. The present study is then an original contribution, as a beneficial effect of WI on the FP of the HRV could be determined.

Influence of WI on HRV during the SP of post-exercise autonomic recovery

The SP of post-exercise autonomic recovery is characterized by a slow and gradual fall of the HR (3,5,9) due to a combination of vagal reactivation and sympathetic withdrawal. Because of the relative stationariness of the data during this phase, traditional HRV indices can be calculated, as carried out in this study during the 5 to 10-min period. This is why most studies on HRV during post-exercise autonomic recovery have analyzed the SP (7,21,25). Yet, literature review found only 1 study that assessed the WI effect on the autonomic recovery during the SP. In agreement with our findings, Vianna et al. (24), observed enhanced post-exercise vagal reactivation after WI (500 ml at room temperature). Notwithstanding, the authors observed the cited effect only 30 min after exercise interruption, using the cardiac vagal index (24). Findings in the present study, based on the analysis of HRV indices, complement the earlier reported data, and may be a springboard for additional studies on the influence of WI over the cardiac autonomic modulation during recovery.

Physiological rationale for the influence of WI on cardiac autonomic modulation

In spite of the scarcity of evidence about the influence of WI on post-exercise recovery, some studies have assessed rest cardiac vagal modulation after WI, with results that agree with the present study. Routledge et al. (19) observed higher HRV vagal indices in healthy subjects, after a 500 ml WI. The authors suggested that increased vagal activation after WI blunts the increased vasoconstrictive sympathetic activity due to WI (19).

Water intake is associated with increased blood pressure in subjects with autonomic dysfunction or who are elderly (11,12). Increased muscle sympathetic activity seems to be responsible for this heightened pressure response associated with WI (11). In healthy subjects, however, besides increased muscle sympathetic activity, there seems to be concomitant increase in cardiac vagal activity, blunting this tendency towards a blood pressure increase (19).

The mechanisms underlying the increase of the WI-associated muscle sympathetic activity and concomitant increase of cardiac vagal activity remain elusive. Two explanations for the increased WI-related sympathetic activity have been proposed: 1) gastric distension (18,23); and 2) factors related to blood osmolarity (4). As for the former, studies with animal models suggest that stimulation of mechanoreceptors in the stomach would lead to increased sympathetic activity (16,17). As for the latter, water`s hypo-osmolarity might stimulate osmolarity-sensitive receptors in the portal circulation and intestine, thus leading to a reflex increase in sympathetic activity (4). Concerning the mechanisms responsible for the commonly observed increased cardiac vagal activity, it is suggested that increased blood pressure would stimulate arterial baroreceptors, which in turn, would reduce HR through increased cardiac vagal tone (19). The increased systolic volume observed by Brown et al., (4) after WI seems to explain the reduced HR through a reflex increase in the vagal modulation aimed at keeping cardiac output. Yet, there is still controversy surrounding the cited mechanisms (6), and deeper analyses are beyond the scope of this study.

Practical implications and future investigations

The findings in the present study point to post-exercise WI as a resource to enhance post-exercise HRV. The literature shows that there is increased risk of severe cardiovascular events after exercise, autonomic imbalance seeming to be the underlying issue (2,14). It may then be suggested that WI might protect against post-exercise cardiovascular events. Notwithstanding, the relation between WI and the rate of cardiovascular events should be investigated. Precise identification of the mechanisms responsible for the observed responses and the influence of water temperature and volume on the cardiovascular responses should be further investigated. Different liquids might also produce different responses.

CONCLUSION

This study found a positive influence of WI on recovery HRV both during the fast and slow phases.

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