

## EFFECTS OF INGESTING 250 AND 500 ML OF WATER ON INITIAL TRANSIENT HEART RATE AND HEART RATE VARIABILITY

### EFEITO DA INGESTÃO DE 250 E 500 ML DE ÁGUA SOBRE O TRANSIENTE INICIAL E A VARIABILIDADE DA FREQUÊNCIA CARDÍACA

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#### ABSTRACT

The purpose was to analyze the effect of the ingestion of two amounts of water in the autonomic modulation. A total of 26 men aged 18–30 years under went 2 days of intervention and evaluation with 24 hours in between. The protocol consisted of the intake of 250 or 500 mL of water in a random order. To assess the initial transient HR during dynamic exercise, the cardiac vagal index was obtained using a 4-second exercise test during the pre- and post-ingestion periods (5, 10, 20, and 30 minutes). To evaluate autonomic modulation at home, HRV value 30 minutes after water intake was used when HR at rest was registered. The results shows: Five minutes after the water intake, the initial transient HR was increased ( $p = 0.02$ ) with no difference in effect of the ingested volumes of water ( $p = 0.8$ ). In HRV, there was no difference between the intake volumes in the time or frequency domains. There were differences in HR rest after 20 minutes compared to at other times ( $p < 0.05$ ). In conclusion the results showed no difference in initial transient HR, HRV, or HR rest after the intake of 250 versus 500 mL of room temperature water in healthy individuals. However, resting initial transient HR and HR rest values differed among the analyzed times.

**Keywords:** Hydration. Heart rate. Autonomic nervous system.

#### RESUMO

O objetivo foi analisar o efeito da ingestão de duas quantidades de água na modulação autonômica. Participaram 26 homens, com idade entre 18 e 30 anos, foram submetidos a dois dias de intervenção e avaliação com intervalo de 24 horas. O protocolo consistiu na ingestão de 250 ou 500 mL de água, em ordem randômica. Para avaliar o TIFC no exercício dinâmico foi utilizado o índice vagal cardíaco (IVC) obtido por meio do Teste de Exercício de 4 segundos nos momentos pré e pós-ingestão (5°, 10°, 20° e 30° minutos). Para avaliar a modulação autonômica no repouso foi utilizada a VFC durante 30 minutos após a ingestão, quando foi registrado a FC de repouso. Os resultados apontam que após 5 minutos da ingestão de água houve um aumento do TIFC ( $p=0,02$ ), sem que houvesse diferença em função dos volumes de água ingeridos ( $p=0,8$ ). Na VFC não houve diferença entre os volumes ingeridos, tanto no domínio do tempo quanto no domínio da frequência. Em relação a FC de repouso, houve diferença no 20° minuto quando comparado aos demais momentos ( $p<0,05$ ). Conclui-se que os nossos resultados demonstraram que não houve diferença no TIFC, VFC e na FC de repouso quando foram comparadas a ingestão de 250 e 500 mL de água à temperatura ambiente em indivíduos saudáveis. Contudo, o TIFC e a FC de repouso demonstraram diferença entre os momentos analisados.

**Palavras-chave:** Hidratação. Frequência cardíaca. Sistema nervoso autonômico.

#### Introduction

The initial transient heart rate (HR) is mediated by the autonomic nervous system (ANS), primarily by the inhibition of cardiac vagal activity (CVA) in the first few seconds of dynamic exercise, which causes a sudden increase in HR<sup>1</sup>. Vagal dysfunction appears to be associated with the onset of cardiovascular disease<sup>2</sup> in addition to being an important predictor for sudden death<sup>2-5</sup>. Thus, several research groups have dedicated themselves to

investigating the effects of different variables on CVA, among which water intake is prominent<sup>6-8</sup>.

Some evidence suggests that the simple act of ingesting water can promote important changes in the autonomic modulation and physiology of the cardiovascular system<sup>9,10</sup>, for example, increased sympathetic nerve activity on muscle tissue<sup>11</sup>, bradycardia<sup>12</sup>, changes in blood pressure<sup>13</sup>, alleviation of the symptoms of orthostatic hypotension<sup>14</sup>, and increased peripheral vascular resistance<sup>15</sup>. A study by Routledge et al.<sup>16</sup> demonstrated that, after the ingestion of 500 mL of water by healthy individuals, there was a significant reduction in HR and increased parasympathetic activity, the latter of which was identified by HR variability (HRV) analysis. Another study conducted by Callegaro et al.<sup>17</sup> observed that normotensive and hypertensive individuals may experience decreased HR and increased parasympathetic activity after the ingestion of 500 mL of water at rest. It is observed in elderly individuals and patients with autonomic failure, a substantial increase in blood pressure after the ingestion of 500 mL of water, which may become a strategy for a rapid relief of the symptoms resulting from cases of orthostatic hypotension or even a concern in these patients suffering from systemic arterial hypertension<sup>18</sup>. In young individuals, this effect is not observed, since the observed increase in the parasympathetic tonus is responsible for neutralizing the pressor effect after ingestion of the same amount of water<sup>16</sup>. A previous study<sup>19</sup> reported that, after dynamic exercise on a cycle ergometer, the intake of 500 mL of water did not cause a reduction in HR rest but promoted an increase in stroke when assessed with the 4-second exercise test (4sET).

Interestingly, studies that analyzed the effects of water intake on autonomic modulation used volumes equal to or near 500 mL<sup>9,20</sup> compared to a volume of 50 mL as the control<sup>21-23</sup>. However, it is likely that the sudden intake of 500 mL of water can generate stomach discomfort and relevant symptoms, such as nausea, which could influence the results. We hypothesized, therefore, that a volume of only 250 mL would be sufficient, since the changes observed on the ANS after water intake can be explained by changes in osmolality and not by gastric distension<sup>24</sup>.

Thus, the objective of this study was to analyze the effect of the ingestion of two amounts of water in the autonomic modulation.

## Methods

### Sample

A total of 26 men aged 18–28 years who met the following inclusion criteria were evaluated: absence of cardiovascular, respiratory and metabolic diseases known before the time of the study and without the use of medications that might have affected the cardiovascular and autonomic system; sinus rhythm cardiac rate; non-smoking; body mass index <30 kg/m<sup>2</sup>. Subjects were instructed not to ingest caffeinated and alcoholic beverages or perform strenuous exercise in the 24 hours prior to or ingest food or liquid in the 2 hours prior to testing.

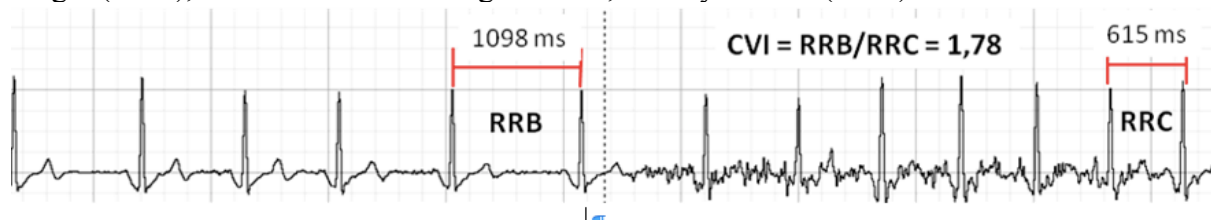
All subjects voluntary signed an informed consent form. The study protocol was approved by an institutional ethics committee (protocol number 020/2007) according to the Helsinki Declaration.

## Protocols

### 4-Second Exercise Test

We used the 4sET for initial transient HR, a simple, trusted<sup>25</sup>, and pharmacologically validated<sup>26-27</sup> test that proposes to separately evaluate the integrity of the parasympathetic branch of the autonomic nervous system to assess stroke<sup>25</sup>. The 4Set<sup>26-28</sup> requires subjects to pedal as fast as possible on an unloaded cycle ergometer from the 5th to 9th second of a maximum inspiratory apnea of 12 seconds. For the maneuver, they were given four verbal commands of the actions to be performed successively every 4 seconds: a) maximum and rapid inspiration, primarily by mouth; b) pedal as fast as possible; c) stop abruptly; and d) normal expiration. The 4sET was performed using a cycle ergometer for lower limbs (*Biocycle Plus Moviment, Brazil*).

To quantify the initial transient HR, we used the cardiac vagal index (CVI), a dimensionless value that is obtained by dividing the last two RR intervals on the electrocardiogram (ECG) tracing: the first immediately before or of the exercise, whichever is longer (RRB), and the shortest during exercise, usually the last (RRC).



**Figure 1.** Identification and measurement of RRB, RRC, and cardiac vagal index calculation intervals.  
Source: Authors

Note that the initial transient HR expressed by CVI is exclusively cardiac vagal withdrawal<sup>(29)</sup>. The continuous record of RR intervals was made by the *Powerlab (4/25T; ADInstruments, Australia)* biological signal converter with a resolution of 1 ms. The data were analyzed using *LabChart 5 (ADInstruments)*.

### HRV and HR Rest

The individuals were seated on a cycle ergometer for 30 minutes<sup>30-31</sup> for the ECG recording with *Powerlab (ADInstruments)* and the identification of RR intervals in the time and frequency domains<sup>32-34</sup>.

In the time domain analysis, the cardiac vagal modulation was evaluated using the percentage of normal RR intervals that differ by more than 50 mS (pNN50) and the root mean square of successive differences (RMSSD) indexes. In the frequency domain analysis, levels of high frequency (HF) and low frequency (LF) were determined and the correlation between them was calculated. The analysis was performed with *LabChart 5 (ADInstruments)*.

### Procedures for Data Collection

The subjects made two visits on different days, with a minimum interval of 24 hours in the afternoon, and the amount of water intake was 250 or 500 mL, defined by randomization for visits 1 and 2.

### Visits 1 and 2

A medical history was initially completed to obtain the following records: name, age, date of birth, occupation, medication use, physical activity, smoking, alcohol consumption, and time of the last meal. We then measured the weight and height of each individual using a model PL 200 stadiometer (*Filizola, Brazil*) with a precision of 0.05 kg and 0.005 m,

respectively. Disposable electrodes were affixed to each individual's chest on a single CC5 or CM5 lead to obtain the ECG.

The subjects performed the 4sET (pre-ingestion) and remained comfortably seated on the cycle ergometer for 5 minutes while ingesting 250 or 500 mL of room temperature water. The volunteers had 60 seconds to ingest the volume, which was predetermined randomly. After ingestion, the 4sET was repeated four times (after 5, 10, 20, and 30 minutes). Throughout the procedure, the individuals remained seated on the cycle ergometer under continuous ECG recording, and these data were used to assess the HR rest values and mean RR intervals.

### Statistical Analysis

Initially, the normality of the distribution and the homoscedasticity was tested by validating the use of parametric statistics. Data were presented as mean  $\pm$  SD for descriptive statistics. To compare the effect of ingesting 250 or 500 mL of water in the different times studied, two-way repeated-measures analysis of variance was used. The same analysis was used to compare mean RR intervals with respect to time and the volume investigated. The post-hoc Bonferroni test was utilized when required.

The analysis of HRV indexes (AF, AF/BF RMSSD, and pNN50) as a function of the ingested volumes of water was performed using the paired t-test considering the 30-minute period after the water intake for analysis. All analyses were performed using SPSS (version 17; Chicago, IL, USA) with a 5% significance level.

### Results

A descriptive analysis of the sample is shown in Table 1.

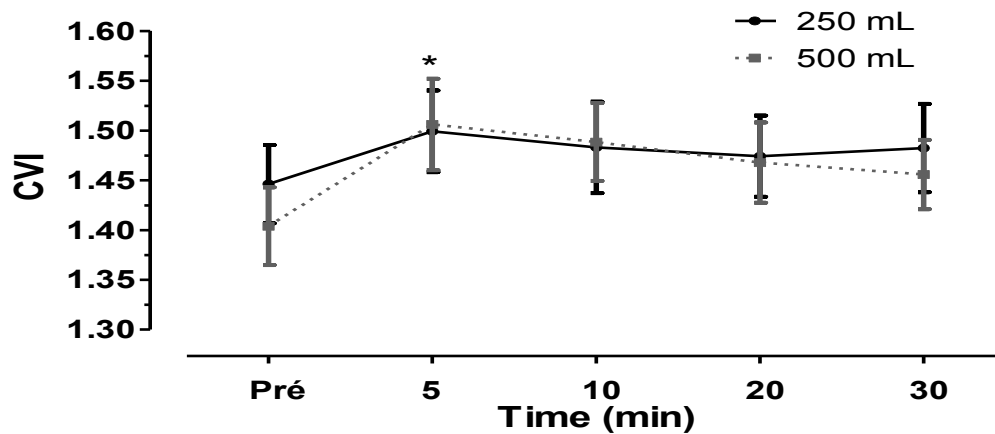
**Table 1.** Demographic characteristics of individuals in the sample (n = 26)

Variable	Value
Age (years)	22 $\pm$ 2.46 (18-28)
Weight (kg)	76.4 $\pm$ 9.60 (63-97)
Height (m)	1.78 $\pm$ 0.07 (1.64-1.89)
Body mass index (kg/m <sup>2</sup> )	23.8 $\pm$ 2.14 (21-28)

**Legend:** Mean  $\pm$  standard deviation (range)

**Source:** Authors

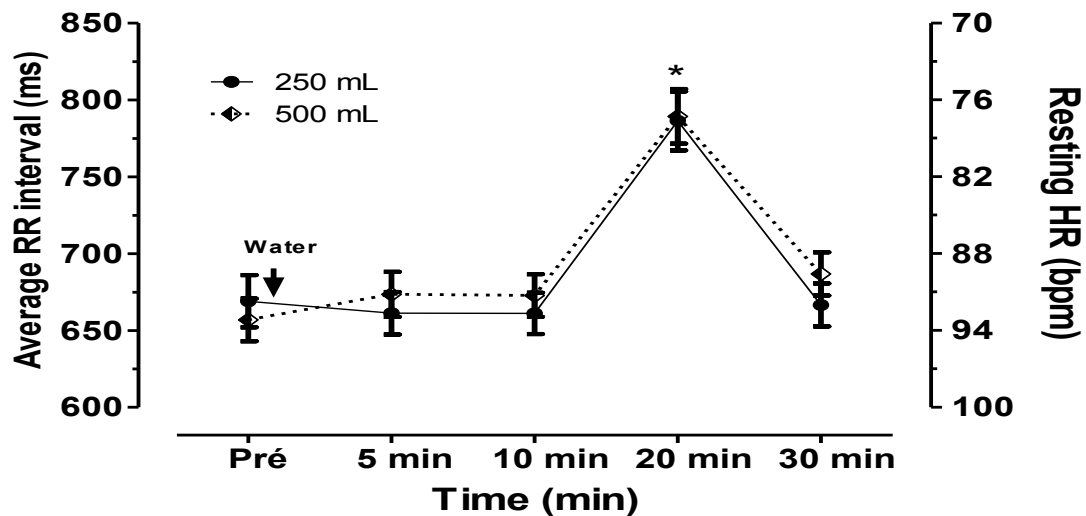
The initial transient HR increased significantly when the CVI results were compared before and 5 minutes after water intake ( $p = 0.002$ ) (Figure 2), but no differences were seen between the two volumes ( $p = 0.801$ ).



**Figure 2.** Initial transient heart rate by cardiac vagal index (CVI) by volume ingested (250 or 500 mL); \*p < 0.05 compared to pre-ingestion

Source: Authors

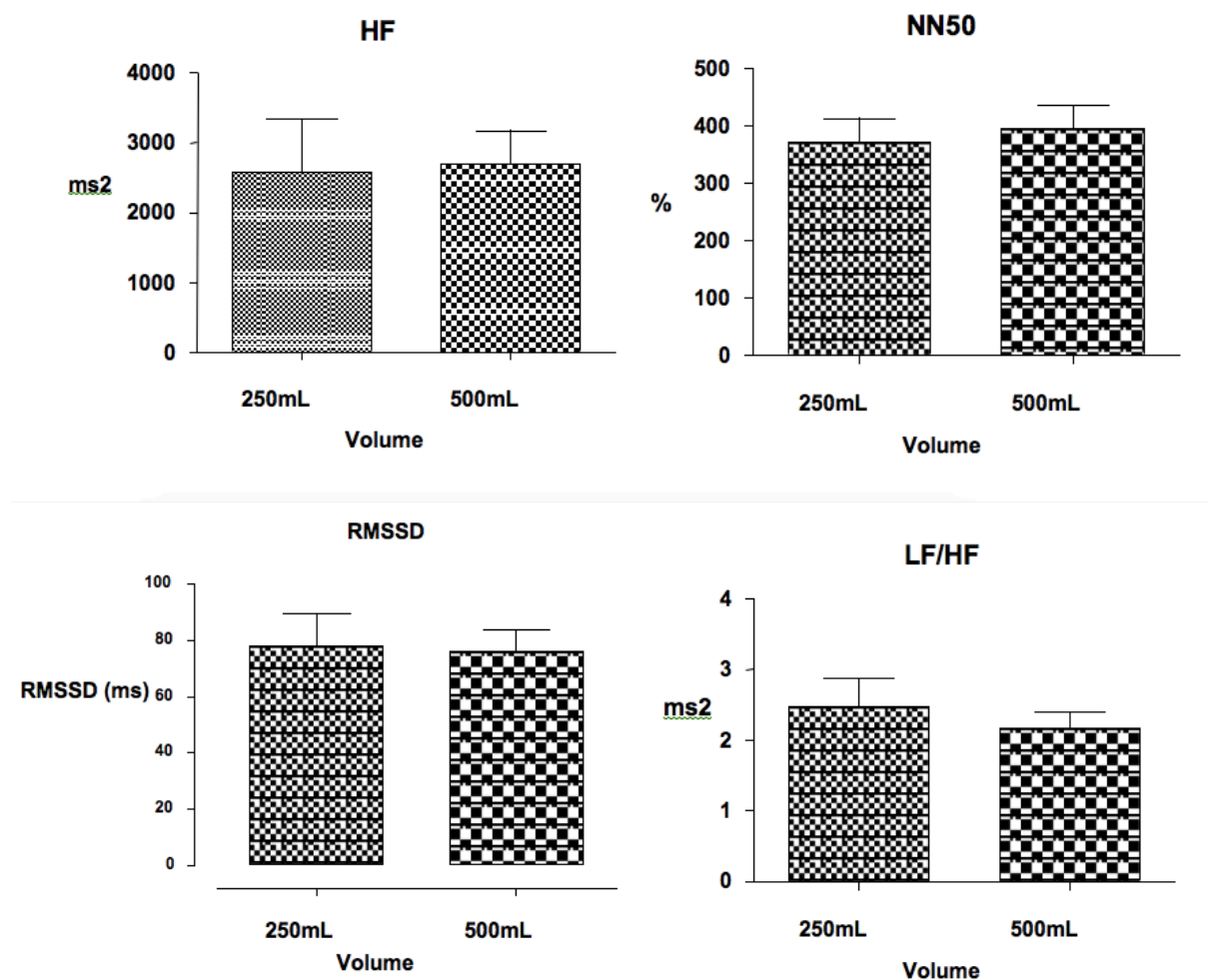
Regarding the average duration of RR interval, there was a significant increase in the duration of these intervals in the 20<sup>th</sup> minute at rest (Figure 3). However, analysis of the various indicators obtained by HRV showed no difference between the two consumed volumes (Figure 4).



**Figure 3.** Average RR interval and resting heart rate by volume ingested (250 or 500 mL);

Legend: \*p < 0.05 compared to pre-ingestion

Source: Authors



**Figure 4.** AF intervals, percentage of normal RR intervals that differ by more than 50 ms (pNN50), root mean square of successive differences (RMSSD), and LF/HF measured 30 minutes after the intake of 250 or 500 mL of water ( $p > 0.05$ )

Source: Authors

## Discussion

We hypothesize that it would be sufficient to ingest 250 mL instead of 500 mL of room temperature water as carried out in previous studies to influence autonomic modulation since this volume is most often associated with gastric distress. Thus, the present study observed the effects of the intake of 250 and 500 mL of water on autonomic modulation by evaluating initial transient HR and HRV and noted that the two volumes of water intake caused similar effects on the variables investigated in healthy young people.

In the initial transient HR, a difference was only observed between pre-intake versus 5 minutes in both ingested volumes. The physiological explanation for the increase in parasympathetic activity after water intake can be understood as an integrated response for the purpose of counteracting sympathetic stimuli<sup>16-18</sup>. The theory of osmolality<sup>24</sup> can be used as an example of this explanation, which may have assumed an important role in the results expressed in this study due to its stimulation of the TRPV4 receptor<sup>35-36</sup> located in the liver and portal circulation<sup>37-38</sup>. However, the entire population of receptors and transduction mechanisms remains poorly understood. Thus, the stimulation of osmoreceptor nerve fibers sensitive to a drop in osmolality results in a reflexive increase in the sympathetic nerve

activity in the muscle tissues by stimulating the postganglionic adrenergic activity<sup>39</sup> and increasing plasma norepinephrine such as observed with some substances such as nicotine and caffeine<sup>18</sup>. Thus, the increase in parasympathetic activity can be understood to counteract these stimuli<sup>16</sup>.

To determine which mechanism is responsible for cardiovascular responses, Brown et al.<sup>24</sup> observed the ingestion of water versus saline in young individuals and noted a significant decrease in HR, increased peripheral vascular resistance, and high frequency only for the group that drank water, thus corroborating the hypothesis that osmolality can contribute to autonomic modulation after water intake.

In a previous study aimed at evaluating vagal reactivation with 500 mL of water after the completion of 30 minutes of exercise, an increase in parasympathetic activity through initial transient HR was also observed<sup>19</sup>. However, a greater response time was found than that in the present study, which can probably be explained by a difference in the methods used.

Analysis of the RR interval length revealed an increase in the average after 20 minutes. These results confirm those of previously published studies<sup>16,18,19</sup> considering that approximately 21 minutes is required to empty 800 mL of water from the stomach as seen in a study using magnetic resonance imaging<sup>40</sup>. It should be noted that the baseline volume of the stomach hovered at small values of approximately 100 mL<sup>41</sup>; as such, the possibility that gastric distension can cause significant physiological changes cannot be excluded<sup>42,43</sup>. During the digestion process, the flow of blood in the mesenteric artery increases, and to prevent a sudden decrease in blood pressure after a meal, an increase in the peripheral vascular resistance is necessary to maintain cardiac output<sup>44</sup>. Mechanoreceptors present in the stomach cause increased muscle sympathetic nerve activity, which is mediated largely through afferent fibers of the splanchnic nerve<sup>42</sup>.

It is important to highlight that, during the experimental procedure, the assessed volunteers reported some discomfort in drinking 500 mL of room temperature water in 60 seconds. Therefore, we believe that subsequent studies evaluating these variables would require individuals to ingest only 250 mL of water since there was no significant difference in initial transient HR expressed by CVI or HRV upon the ingestion of different volumes. A favorable point of this research is its sample size since past studies covering this topic included substantially fewer individuals<sup>14,17,18,45,46</sup>.

## Conclusion

Given these findings, we can conclude that there was no difference in initial transient HR and HRV after the ingestion of 250 versus 500 mL of room temperature water by healthy subjects. However, the initial transient HR and HR rest differed among the various analyzed times.

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