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Original Article

# 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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**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 (5º, 10º, 20º e 30º 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 20º minuto quando comparado aos demais momentos (p<0,05). Conclui-se que os nossos resultados demostraram 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 demostraram diferença entre os momentos analisados.
**Palavras-chave**: Hidratação. Frequência cardíaca. Sistema nervoso autonômico.

**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.

## 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[1]. Vagal dysfunction appears to be associated with the onset of cardiovascular disease[2] in addition to being an important predictor for sudden death[2-5]. Thus, several research groups have dedicated themselves to investigating the effects of different variables on CVA, among which water intake is prominent[6-8].

Some evidence suggests that the simple act of ingesting water can promote important changes in the autonomic modulation and physiology of the cardiovascular system[9,10], for example, increased sympathetic nerve activity on muscle tissue[11], bradycardia[12], changes in blood pressure[13], alleviation of the symptoms of orthostatic hypotension[14], and increased peripheral vascular resistance[15]. A study by Routledge et al.[16] 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.[17] 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[18]. 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[16]. A previous study[19] 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[9,20] compared to a volume of 50 mL as the control[21-23]. 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[24].

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 $kg/m^2$. 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[25], and pharmacologically validated[26-27] test that proposes to separately evaluate the integrity of the parasympathetic branch of the autonomic nervous system to assess stroke[25]. The 4Set[26-28] 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).

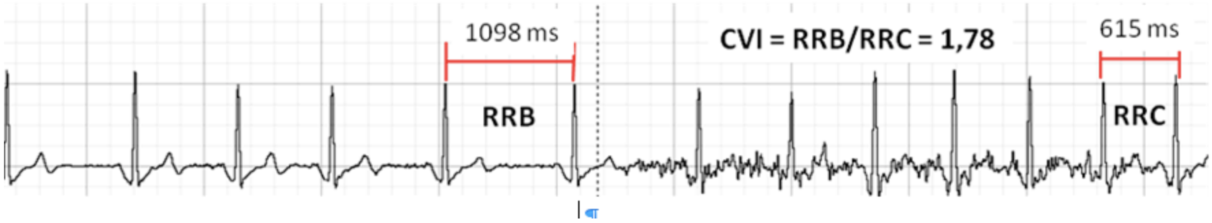


**Figure 1.** Identification and measurement of RRB, RRC, and cardiac vagal index calculation intervals.
**Source**: Authors

Note that the initial transient HR expressed by CVI is exclusively cardiac vagal withdrawal[(29)]. 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[30-31] for the ECG recording with *Powerlab (ADInstruments)* and the identification of RR intervals in the time and frequency domains[32-34].

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 ± 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 ± 2.46 (18-28) |
| Weight (kg) | 76.4 ± 9.60 (63-97) |
| Height (m) | 1.78 ± 0.07 (1.64-1.89) |
| Body mass index (kg/m$^2$) | 23.8 ± 2.14 (21-28) |

**Legend**: Mean ± 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).

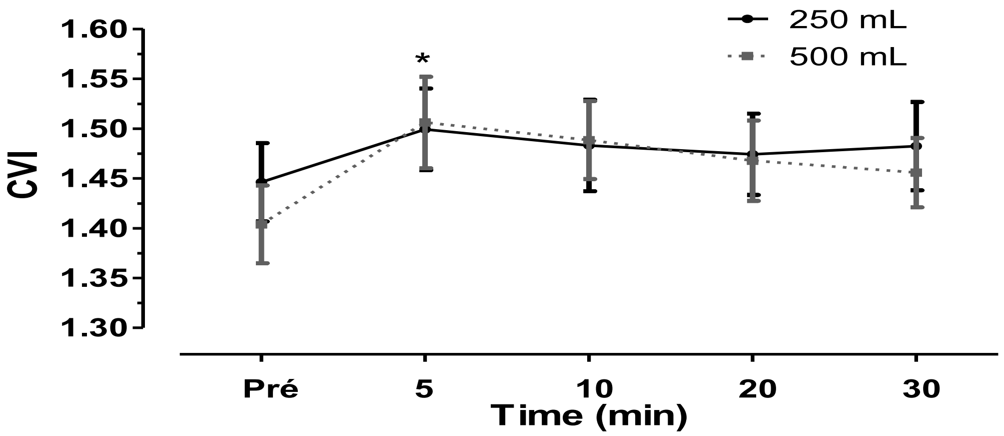


**Figure 2.** Initial transient heart rate by cardiac vagal index (CVI) by volume ingested (250 or 500 mL); *p < 0.05 compared to pre-ingestion
**Source**: Authors

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

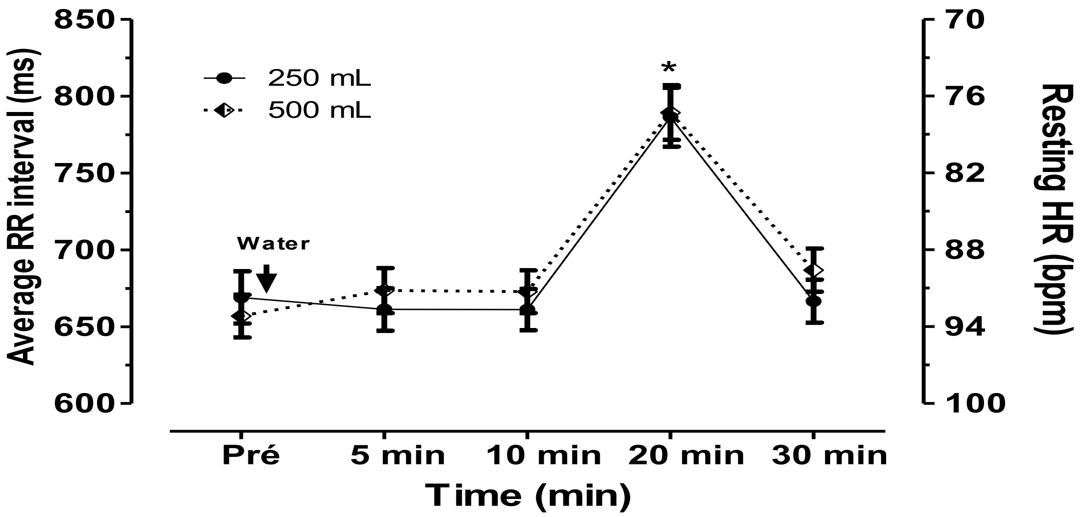


**Figure 3.** Average RR interval and resting heart rate by volume ingested (250 or 500 mL);
**Legend:** *p < 0.05 compared to pre-ingestion
**Source**: Authors

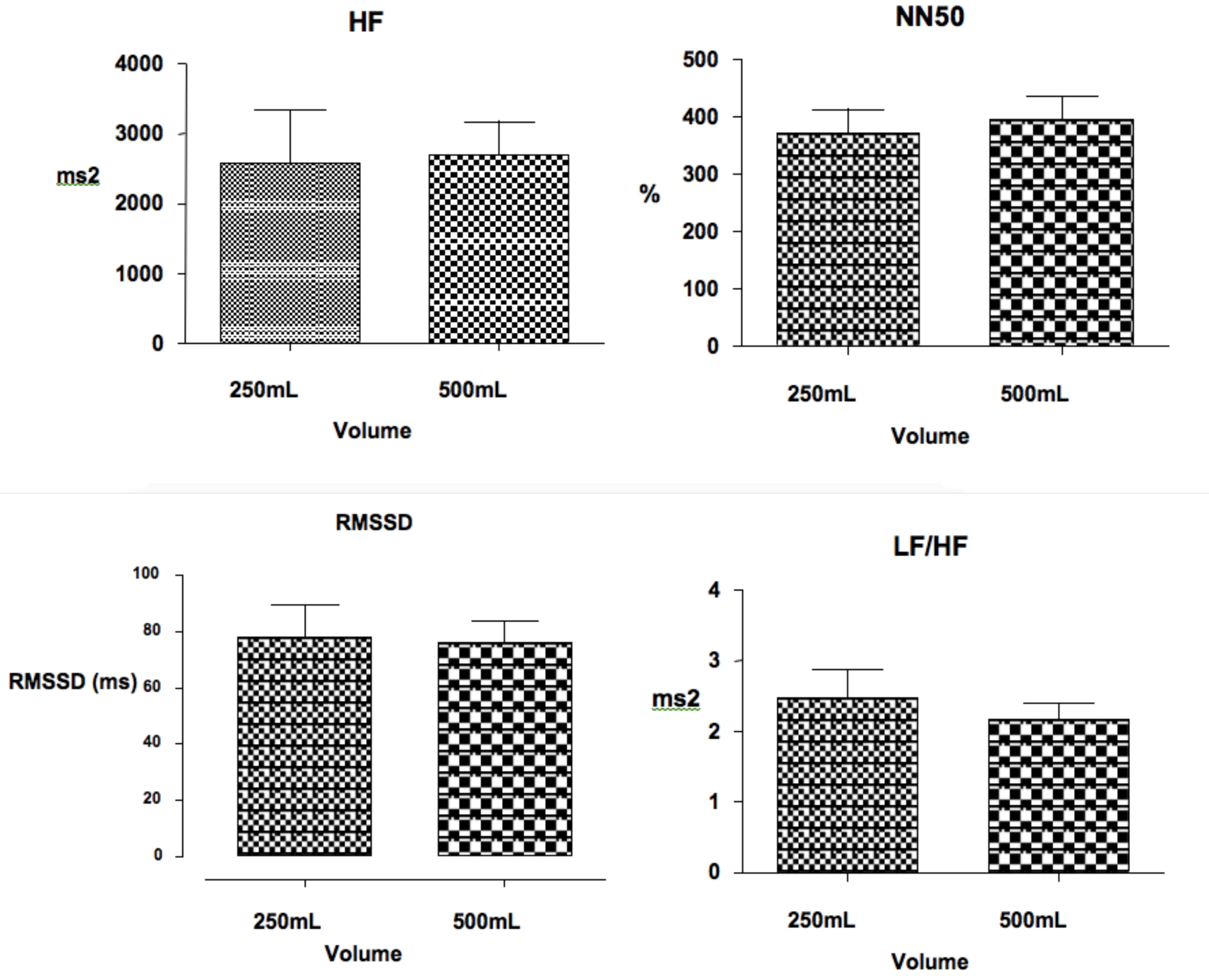


**Figure 4.** AF intervals, percentage of normal RR intervals that differ by more than 50 mS (pNN50), root mean square of successive differences (RMSSD), and LF/AF measured 30 minutes after the intake of 250 or 500 mL of water ($p > 0.05$)
**Source**: Authors

## 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[16-18]. The theory of osmolality[24] 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[35-36] located in the liver and portal circulation[37-38]. 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[39] and increasing plasma norepinephrine such as observed with some substances such as nicotine and caffeine[18]. Thus, the increase in parasympathetic activity can be understood to counteract these stimuli[16].

To determine which mechanism is responsible for cardiovascular responses, Brown et al.[24] 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[19]. 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[16,18,19] 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[40]. It should be noted that the baseline volume of the stomach hovered at small values of approximately 100 mL[41]; as such, the possibility that gastric distension can cause significant physiological changes cannot be excluded[42,43]. 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[44]. Mechanoreceptors present in the stomach cause increased muscle sympathetic nerve activity, which is mediated largely through afferent fibers of the splanchnic nerve[42].

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[14,17,18,45,46].

## 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.

## References

1. Araujo C. Fast" ON" and" OFF" heart rate transients at different bicycle exercise levels. Int J Sports Med 1985;6(2):68-73. DOI: 10.1055/s-2008-1025815
2. Thayer JF, Lane RD. The role of vagal function in the risk for cardiovascular disease and mortality. Biol Psychol 2007;74(2):224-42. DOI: 10.1016/j.biopsycho.2005.11.013
3. Jouven X, Empana JP, Schwartz PJ, Desnos M, Courbon D, Ducimetiere P. Heart-rate profile during exercise as a predictor of sudden death. N Engl J Med 2005;352:1951-1958. DOI: 10.1056/NEJMoa043012
4. Buch AN, Coote JH, Townend JN. Mortality, cardiac vagal control and physical training--what's the link? Exp Physiol 2002;87(4):423-35

5. Cole CR, Blackstone EH, Pashkow FJ, Snader CE, Lauer MS. Heart-rate recovery immediately after exercise as a predictor of mortality. N Engl J Med 1999; 341:1351-1357. DOI: 10.1056/NEJM199910283411804
6. Chen CL, Lin HH, Orr WC, Yang CC, Kuo TB. Transfer function analysis of heart rate variability in response to water intake: correlation with gastric myoelectrical activity. J Appl Physiol 2004;96(6):2226-30. DOI: 10.1152/japplphysiol.01037.2003
7. Girona M, Grasser EK, Dulloo AG, Montani JP. Cardiovascular and metabolic responses to tap water ingestion in young humans: does the water temperature matter? Acta Physiol 2014;211(2):358-70. DOI: 10.1111/apha.12290
8. Pecanha T, Paula-Ribeiro M, Campana-Rezende E, Bartels R, Marins JC, de Lima JR. Water intake accelerates parasympathetic reactivation after high-intensity exercise. Int J Sport Nutr Exerc Metab 2014;24(5):489-96. DOI: 10.1123/ijsnem.2013-0122
9. Young TM, Mathias CJ. The effects of water ingestion on orthostatic hypotension in two groups of chronic autonomic failure: multiple system atrophy and pure autonomic failure. J Neurol Neurosurg Psychiatry 2004;75(12):1737-41. DOI: 10.1136/jnnp.2004.038471
10. Deguchi K, Ikeda K, Sasaki I, Shimamura M, Urai Y, Tsukaguchi M, et al. Effects of daily water drinking on orthostatic and postprandial hypotension in patients with multiple system atrophy. J Neurol 2007 ;254(6):735-40. DOI: 10.1007/s00415-006-0425-3
11. Scott EM, Greenwood JP, Gilbey SG, Stoker JB, Mary DA. Water ingestion increases sympathetic vasoconstrictor discharge in normal human subjects. Clin Sci 2001;100(3):335-42.
12. Chiang CT, Chiu TW, Jong YS, Chen GY, Kuo CD. The effect of ice water ingestion on autonomic modulation in healthy subjects. Clin Auton Res 2010 ;20(6):375-80. DOI: 10.1007/s10286-010-0077-3
13. Schroeder C, Bush VE, Norcliffe LJ, Luft FC, Tank J, Jordan J, et al. Water drinking acutely improves orthostatic tolerance in healthy subjects. Circulation. 2002 Nov 26;106(22):2806-11.
14. Olatunji LA, Aaron AO, Micheal OS, Oyeyipo IP. Water ingestion affects orthostatic challenge-induced blood pressure and heart rate responses in young healthy subjects: gender implications. Niger J Physiol Sci 2011;26(1):11-8.
15. Lu CC, Li MH, Lin TC, Chen TL, Chen RM, Tung CS, et al. Water ingestion reduces skin blood flow through sympathetic vasoconstriction. Clin Auton Res 2012;22(2):63-9. DOI: 10.1007/s10286-011-0142-6
16. Routledge HC, Chowdhary S, Coote JH, Townend JN. Cardiac vagal response to water ingestion in normal human subjects. Clin Sci 2002;103(2):157-62. DOI: 10.1042
17. Callegaro CC, Moraes RS, Negrao CE, Trombetta IC, Rondon MU, Teixeira MS, et al. Acute water ingestion increases arterial blood pressure in hypertensive and normotensive subjects. J Hum Hypertens 2007;21(7):564-70. DOI: 10.1038/sj.jhh.1002188
18. Jordan J, Shannon JR, Black BK, Ali Y, Farley M, Costa F, et al. The pressor response to water drinking in humans : a sympathetic reflex? Circulation 2000;101(5):504-9.
19. Vianna LC, Oliveira RB, Silva BM, Ricardo DR, Araujo CG. Water intake accelerates post-exercise cardiac vagal reactivation in humans. Eur J Appl Physiol 2008;102(3):283-8. DOI: 10.1007/s00421-007-0584-7
20. Mathias CJ, Young TM. Water drinking in the management of orthostatic intolerance due to orthostatic hypotension, vasovagal syncope and the postural tachycardia syndrome. Eur J Neurol 2004;11(9):613-9. DOI: 10.1111/j.1468-1331.2004.00840.x
21. Mendonca GV, Teixeira MS, Heffernan KS, Fernhall B. Chronotropic and pressor effects of water ingestion at rest and in response to incremental dynamic exercise. Exp Physiol 2013;98(6):1133-43. DOI: 10.1113/expphysiol.2013.071886
22. Mendonca GV, Teixeira MS, Pereira FD. Cardiovascular responses to water ingestion at rest and during isometric handgrip exercise. Eur J Appl Physiol 2012 ;112(7):2495-501. DOI: 10.1007/s00421-011-2223-6
23. Boschmann M, Steiniger J, Franke G, Birkenfeld AL, Luft FC, Jordan J. Water drinking induces thermogenesis through osmosensitive mechanisms. J Clin Endocrinol Metab 2007 ;92(8):3334-7. DOI: 10.1210/jc.2006-1438
24. Brown CM, Barberini L, Dulloo AG, Montani JP. Cardiovascular responses to water drinking: does osmolality play a role? Am J Physiol Regul Integr Comp Physiol 2005;289(6):R1687-92. DOI: 10.1152/ajpregu.00205.2005
25. Araujo CG, Ricardo DR, Almeida MB. Intra and interdays reliability of the 4-second exercise test. Rev Bras Med Esporte 2003;9(5):299-303. http://dx.doi.org/10.1590/S1517-86922003000500005
26. Araujo CG, Nobrega AC, Castro CL. Heart rate responses to deep breathing and 4-seconds of exercise before and after pharmacological blockade with atropine and propranolol. Clin Auton Res 1992 ;2(1):35-40.
27. Nobrega AC, Castro CL, Araujo CG. Relative roles of the sympathetic and parasympathetic systems in the 4-s exercise test. Braz J Med Biol Res 1990;23(12):1259-62

28. Ricardo DR, de Almeida MB, Franklin BA, Araujo CG. Initial and final exercise heart rate transients: influence of gender, aerobic fitness, and clinical status. Chest 2005;127(1):318-27. DOI: 10.1378/chest.127.1.318
29. Araujo CG. Fast "ON" and "OFF" heart rate transients at different bicycle exercise levels. Int J Sports Med. 1985;6(2):68-73. DOI: 10.1055/s-2008-1025815
30. Koenig J, Jarczok MN, Warth M, Ellis RJ, Bach C, Hillecke TK, et al. Body mass index is related to autonomic nervous system activity as measured by heart rate variability - a replication using short term measurements. J Nutr Health Aging 2014;18(3):300-2. DOI: 10.1007/s12603-014-0022-6
31. Caruso FCR, Reis MS, Siqueira ACB, Gardim M, Catai AM, Borghi-Silva A. Determining anaerobic threshold through heart rate variability in patients with COPD during cycloergometer exercise. Fisioter mov 2012;25(4):717-25. http://dx.doi.org/10.1590/S0103-51502012000400004
32. Heart rate variability: standards of measurement, physiological interpretation and clinical use. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. Circulation 1996 1;93(5):1043-65
33. Heart rate variability. Standards of measurement, physiological interpretation, and clinical use. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. Eur Heart J 1996;17(3):354-81
34. Vanderlei LCM, Pastre CM, Hoshi RA, Carvalho TDd, Godoy MFd. Noções básicas de variabilidade da frequência cardíaca e sua aplicabilidade clínica. Rev Bras Cir Cardiovasc 2009;24(2):205-17. http://dx.doi.org/10.1590/S0102-76382009000200018
35. Liedtke W, Choe Y, Marti-Renom MA, Bell AM, Denis CS, Sali A, et al. Vanilloid receptor-related osmotically activated channel (VR-OAC), a candidate vertebrate osmoreceptor. Cell. 2000 27;103(3):525-35.
36. Liedtke W, Friedman JM. Abnormal osmotic regulation in trpv4-/- mice. Proc Natl Acad Sci U S A 2003 11;100(23):13698-703. DOI: 10.1073/pnas.1735416100
37. Kobashi M, Adachi A. Effect of hepatic portal infusion of water on water intake by water-deprived rats. Physiol Behav 1992;52(5):885-8.
38. Osaka T, Kobayashi A, Inoue S. Thermogenesis induced by osmotic stimulation of the intestines in the rat. J Physiol 2001 ;532:261-9. doi: 10.1111/j.1469-7793.2001.0261g.x
39. May M, Jordan J. The osmopressor response to water drinking. Am J Physiol Regul Integr Comp Physiol 2011 ;300(1):R40-6. DOI: 10.1152/ajpregu.00544.2010
40. Ploutz-Snyder L, Foley J, Ploutz-Snyder R, Kanaley J, Sagendorf K, Meyer R. Gastric gas and fluid emptying assessed by magnetic resonance imaging. Eur J Appl Physiol Occup Physiol 1999;79(3):212-20. DOI: 10.1152/ajpregu.00544.2010
41. Kuiken SD, Samsom M, Camilleri M, Mullan BP, Burton DD, Kost LJ, et al. Development of a test to measure gastric accommodation in humans. Am J Physiol 1999;277:G1217-21.
42. Nosaka S, Murase S, Murata K. Arterial baroreflex inhibition by gastric distension in rats: mediation by splanchnic afferents. Am J Physiol 1991;260:R985-94. DOI: 10.1152/ajpregu.1991.260.5.R985
43. Rossi P, Andriesse GI, Oey PL, Wieneke GH, Roelofs JM, Akkermans LM. Stomach distension increases efferent muscle sympathetic nerve activity and blood pressure in healthy humans. J Neurol Sci 1998;161(2):148-55.
44. Fujimura J, Camilleri M, Low PA, Novak V, Novak P, Opfer-Gehrking TL. Effect of perturbations and a meal on superior mesenteric artery flow in patients with orthostatic hypotension. J Auton Nerv Syst 1997 3;67(1-2):15-23.
45. Li MH, Chen PH, Ho ST, Tung CS, Lin TC, Tseng CJ, et al. Lower body negative pressure-induced vagal reaction: role for the osmopressor response? Am J Hypertens 2013 ;26(1):5-12. DOI: 10.1093/ajh/hps027
46. Mendonca GV, Teixeira MS, Pereira FD, Fernhall B. Cardiovascular and autonomic effects of water ingestion during postexercise circulatory occlusion. Appl Physiol Nutr Metab. 2012;37(6):1153-63. DOI: 10.1139/h2012-106

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