

Full Length Research Paper

Influence of the level of aquatic immersion on heart modulation of young adults

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Abstract

Little is known about the influence of different levels of immersion on autonomic modulation at rest. The objective of this study was to compare the effect of water immersion on two depth levels on heart rate variability (HRV) at rest in healthy young men. HRV at rest was assessed in 20 men (22 ± 2.9 years) immersed in water at the level of the anterior superior iliac spine (L_{ASIS}) and the xiphoid process (L_{XP}), with an interval of 24 hs between both. HRV was recorded by heart rate monitor, and considered the data rMSSD, pNN50, LF, HF and LF / HF ratio for 10 min at rest sitting in soil (T0), immersed in water (T1), and at 5 and 15min after returning to the soil (T2 and T3, respectively). No significant differences were observed between the moments of analysis in L_{ASIS} . In L_{XP} , there was an increase of rMSSD, pNN50 and HF from T0 to T1 and T2. Regarding BF, there was a significant increase only from T0 to T2. The analysis of LF / HF showed a reduction from T0 to T1 and T1 to T3. In T1 greater rMSSD, pNN50 and AF and lower LF / HF ratio were observed in L_{XP} , compared to L_{ASIS} . The relative changes (%) from T0 to T1 of all HRV indices were significantly higher in L_{XP} . The water immersion at the xiphoid process for 10 min promotes increase in vagal modulation of physically active young adults.

Keywords: Heart rate variability, immersion, levels of immersion, young men, autonomic modulation at rest.

ABBREVIATIONS

ANS; Autonomic nervous system, BMI; Body mass index, BP; Blood pressure, CO; Cardiac output, DBP; Diastolic blood pressure, HF; High frequency, HR; Heart rate, HRV; Heart rate variability, L_{ASIS} , Immersion at the antero-superior iliac spine (Depth 1), LF; Low frequency, LF / HF ratio; Sympathetic-vagal balance on heart, L_{XP} ; Immersion at the height of the xiphoid process (Depth 2), pNN50; Percentage of adjacent RR intervals with a difference of duration greater than 50ms, T0; 10 min at rest sitting in soil, T1; 10 min immersed in water, T2; 5 min after returning to the soil, T3; 10 min after returning to the soil, rMSSD; Square root of the mean squared differences between adjacent normal RR intervals in an interval of time, RR;

Respiratory rate.

INTRODUCTION

The cardiovascular system integrates the body as a unit and by the blood flow provides to body tissues continues current of nutrient and oxygen and removes the metabolism products (MacArdle et al., 1998). The blood flow happens, in turn, in synchrony with the cardiac cycle that represents the set of events that happen between

two heartbeats. The pressure exerted by the blood flow on the internal surface of the arteries is named blood pressure (BP), which is determinate by cardiac output (CO), expressed by the product of heart rate (HR) and stroke volume, and the total peripheral vascular resistance, which are coordinated by neural and humoral influences (Guyton et al., 2006).

The homeostasis of cardiovascular systems aims keeps BP into a relative close variation. This occurs by the constant regulation of HR and vascular tone with larger modulation by the autonomic nervous system (ANS) in its sympathetic and parasympathetic branches (Paschoal et al., 2006). The sympathetic branch increase the HR, resulting in shorter intervals between beats, while the parasympathetic branch, through the vagus nerve reduces HR, resulting in longer intervals between heartbeats. Changes in HR are normal and expected, indicating the ability of the heart to respond to multiple physiological and environmental stimuli, among them, breathing, exercise, mental stress, hemodynamic and metabolic changes, sleep and standing, as well as to compensate disorders induced by various health conditions (Ferreira et al., 2010).

The influences of the ANS in the cardiac cycle result in variability between consecutive beats of instantaneous HR (RR interval). The variation between successive RR intervals is called heart rate variability (HRV) (Vanderle et al., 2009; Longo et al., 1995; Task Force, 1996). Currently, HRV is used as a parameter to help determine the patient's cardiac status and assess individually the balance between sympathetic and parasympathetic ANS in various physiological situations and disease and their relations with other systems (Task Force, 1996).

One of the situations that can cause a series of physiological changes in blood flow, thermoregulation, metabolism, ANS, blood composition and glandular secretion is the immersion in water (Caromano et al., 2003). The change in resting HR in liquid medium depends on water temperature, body position, the depth of immersion, also the initial HR among others (Alberton et al., 2009; Müller et al., 2001).

However, the behavior of HRV to the changes caused by exposure to different mediums (soil and water) at different depths is not yet well understood. In this context, the objective of this study was to analyze the effect of water immersion on HRV at rest, on two depth levels in physically active young adults.

METHODS

This study was approved by the Ethics Committee of the Federal University of the Valleys Jequitinhonha and Mucuri (UFVJM), where after informed about the

procedures of the study, all subjects signed a consent form.

Sample

For the selection and characterization of the sample, the volunteers answered a questionnaire structured by the researchers in order to identify possible risk factors for cardiovascular or cardiopulmonary, metabolic or systemic diseases that contraindicate participation in the study. We included male subjects, aged between 18 and 30 years; physically active, according to the International Physical Activity Questionnaire (IPAQ) (Dishman et al 1994); nonsmokers and nonusers of drugs that interfere with the regulation of HR and other hemodynamic conditions. We excluded individuals with alterations in the skin's surface and hydrophobics.

Procedures

Physical examination

The subjects were instructed before evaluation sessions not to use alcohol and / or stimulant drinks for at least 12 h, did not perform vigorous physical activity for at least 24 h, in addition to including light meals and a night's sleep of at least 8 hs.

BP measurements were made by the auscultatory method, using a sphygmomanometer aneroid and following the VI Brazilian Guidelines of Hypertension (2010). The measured weight and height were obtained through properly calibrated scales (Libra Leader - LD 1050), according to recommendations of the Technical Standards and Manuals from the Ministry of Health (Fagundes et al., 2004). Later, the body mass index (BMI) was calculated as the ratio $\text{weight}/\text{height}^2$, being body mass in kilograms (kg) and height in meters (m). The waist-hip ratio was evaluated with tape. It was recorded HR and HRV using a heart rate monitor (Polar® S810, Polar Electro Oy, Kempele, Finland) (Gamelin et al., 2006), and the data subsequently transferred to a computer.

Data Collection

Data were collected in a closed environment with temperature monitoring through digital thermostat (Incoterm®), ranging between 22.5 °C and 26.5 °C (Cai Y et al, 2000). During the collection in a therapeutic pool, the water temperature was kept between 31 °C and 33 °C (Müller et al., 2001). The study was divided into two

implementation phases, as follows:

Depth 1 (L_{ASIS}) - Immersion at the anterior superior iliac spine

Initially the volunteer remained at rest on the ground for 5 min, sitting in mobile chair beside the pool to stabilize and record the values of respiratory rate (RR), HR and BP. In this and in other situations the volunteer remained sitting upright, back straight, hips and knees flexed at 90 degrees. After resting HR monitor was attached to the record of HRV for 10 min, followed by a new record of RR and BP (T0). Then the volunteers were transported in the pool chair and immersed in the height of the anterior superior iliac spines where they remained for 5 min at rest. After that HRV was similarly recorded for 10 min (T1), followed by a new collection of RR and BP. Continuing, the volunteers were transported in chair to the ground, where they remained at rest for 15 min, and HRV recorded on the 5th (T2) and 15th min (T3), followed by monitoring of vital signs.

Depth 2 (L_{XP}) - Immersion at the height of the xiphoid process

After 24 hours of collection in L_{ASIS} the same procedures were performed at this time at the height of xiphoid process.

Analysis of Heart Rate Variability

The RR intervals recorded by HR monitor were stored on a computer for analysis using specific software (Polar Precision Performance SW, version 4.03.040). Were removed from the records of premature ectopic beats or artifacts that could interfere with HRV analysis by digital filtering method found in the software itself (Casonatto et al., 2011; Godoy et al., 2005). For HRV analysis indices were obtained by linear methods (Vanderlei et al., 2009). In the time domain parameters were evaluated: rMSSD (square root of the mean squared differences between adjacent normal RR intervals in an interval of time), expressed in milliseconds, and pNN50 (percentage of adjacent RR intervals with a difference of duration greater than 50ms), expressed as a percentage. In the frequency domain variables were considered: low frequency (LF), ranging between 0.04 and 0.15 Hz, resulting from the action of the vagal and sympathetic components of the heart with sympathetic predominance, high frequency (HF), ranging from 0.15 to 0.4 Hz, corresponding to the respiratory modulation is an indicator of vagal activity on the heart; LF / HF ratio, which reflects the absolute and relative changes between the sympathetic and

parasympathetic components of the ANS, featuring the sympathetic-vagal balance on heart (Task Force, 1996; Rassi, 2011).

Statistical Analysis

The sample size calculation was performed taking as outcome variable changes in the expected variations of HRV in the time domain and frequency. It was deemed a confidence level of 95% and 95% significance ($p = 0.05$), resulting in a total number of 18 subjects, increased by 10% to compensate for possible losses.

Was used SPSS program version 17.0, with significant $p < 0.05$. Descriptive characteristics of variables with normal distribution are presented as mean \pm standard error and non-normal distribution expressed as median and interquartile range, according to the Kolmogorov-Smirnov test.

Comparison of HRV indices among the four moments of analysis (T0 to T3) at each level of immersion (intragroup) was performed by analysis of variance for repeated measures (ANOVA) followed by Tukey test when multiple comparisons were required (Post Hoc). Comparison between levels of immersion (intergroup), rates obtained (rMSSD, pNN50, LF, HF, LF / HF) as well as their relative change (%) of soil for immersion (T0 to T1) were compared using the paired T test or Wilcoxon depending on the distribution normal or not normal data, respectively.

RESULTS

The study included 20 subjects, classified according to the IPAQ: very active 40% (N = 8), active 55% (N = 11) and irregularly active 5% (N = 1). General characteristics of the sample are presented in Table 1 while the results concerning the influence of water immersion on HRV indices are shown in Table 2 and Figure 1.

In L_{ASIS}, there was no difference between the 4 time points assessed for any of the variables. During the L_{XP} was noted in rMSSD, pNN50 and AF significant increase from T0 to T1 and T2. In relation to the index BF, there was a significant increase only from T0 to T2. The LF / HF ratio showed a reduction from T0 to T1, and from T1 to T3. Comparing L_{ASIS} and L_{XP} there were no differences between depths for any variable at T0. It was noted in L_{XP}, higher values of rMSSD, pNN50 and HF, and lower LF / HF ratio in T1, no significant differences for the other moments. When comparing the relative variations of HRV indexes from T0 to T1 between the two levels of immersion, there was greater variation of all HRV indices in L_{XP}. The same result was found from T1 to T3, except BF, whose variation was similar between L_{ASIS} and L_{XP} (Figure 1 and Table 3).

Table 1. General characteristics of the subjects (N = 20)

Variable	
Age (years)	22 ± 2,9
Height (cm)	175 ± 5,0
BMI (kg/m ²)	24,8 ± 2,8
HR (bpm)	69,9 ± 10,7
SBP (mmHg)	116,0 ± 9,1
DBS (mmHg)	76,7 ± 7,5
WHR	0,8 ± 0,0
IPAQ (n)	8/11/1

Values are expressed as mean and standard deviation or n. BMI = body mass index; HR = heart rate; bpm = beats per minute; SBP = systolic blood pressure; DBP = diastolic blood pressure; WHR = waist-hip ratio; IPAQ = Very Active / Active / Active Erratically; n = number of voluntaries

Table 2. Effect of water immersion on the HRV indices at two depths

Variable	T0	T1	T2	T3	p3
<i>L</i> _{ASIS}					
rMSSD (ms)	52,4 (38,1 a 77,5)	60,3 (40,5 a 92,5)	67,5(47,5 a 131,3)	54,7(44,5 a 91,5)	0,325
pNN50 (%)	12,5 (7,0 a 17,3)	16,7(8,7 a 21,2)	19,1 (13,2 a 24,0)	15,7(10,5 a 24,1)	0,664
LF (ms ²)	2949,9(1565,0 a 3587,2)	3217,7(891,5 a 6904,4)	4089,2 (2298,3 a 7014,3)	2907,9(1945,4 a 4984,0)	0,074
HF (ms ²)	1104,9 (504,9 a 1977,0)	1199,2 (281,5 a 7602,3)	1619,1(878,4 a 5755,6)	985,8(703,4 a 3154,8)	0,311
LF/HF (%)	277,5 (168,5 a 343,7)	215,3(84,5 a 453,89)	199,4 (136,5-281,9)	231,1 (143,1 a 303,4)	0,339
<i>L</i> _{XP}					
rMSSD (ms)	45,4 (32,8 a 71,9)	81,2 #(65,9 a 104,6)	75,8 (66,7 a 108,8)	58,1 (53,3 a 77,2)	0,001 †
pNN50 (%)	11,0 (7,7)	18,9 #(7,4)	17,9 (5,8)	15,7 (6,7)	0,003*†
LF (ms ²)	1579,3(1020,8 a 3742,3)	3415,3 (2085,3 a 4779,1)	4280,9(3170,5 a 7410,9)	3289,0 (2506,5 a 4787,7)	0,010†
HF (ms ²)	843,5 (328,5 a 1690,8)	2241,8 #(1548,3 a 3538,5)	2597,6(1497,2 a 4115,8)	1400,2(934,8 a 2250,6)	0,001*†
LF/AF (%)	227,0(176,6 a 365,9)	171,2 #(99,6 a 210,0)	208,0 (148,8 a 284,1)	237,0 (185,5 a 325,7)	0,011*+

Data are expressed as median (interquartile range). T0 = resting on the ground; T1 = 10min immersion T2 = 5 min recovery in the soil; T3 = 15 min recovery in the soil; *L*_{ASIS} = depth of immersion in height iliac spine; *L*_{XP} = depth of immersion time in the process xiphoid; rMSSD = square root of the mean squared differences between adjacent normal RR intervals; pNN50 = percentage of adjacent RR intervals with a difference of duration greater than 50ms, LF = low frequency; HF = high frequency; LF / HF = ratio of low High frequency by frequency. One way Anova: * difference between T0 and T1; † difference between T0 and T2 + difference between T1 and T3; paired t test or Wilcoxon: # difference (p < 0.05) compared to PQ

DISCUSSION

This study demonstrated that in thermoneutral temperature for the same body position at rest (sitting), healthy young men showed different responses in HRV when immersed in two depths in water. A vagal response, with gradual return of HRV indexes for initial condition (resting on ground), 15 min after the start of the aquatic environment, was noted when the body was immersed in the xiphoid process level (*L*_{XP}).

The effects of immersion in hemodynamic variables have been described in different studies and in pregnant women (Finkelstein et al., 2004), the elderly (Itoh et al.,

2007), hypertension (Coruzzi et al., 2003), patients with heart failure (Grüner Sveälv B et al., 2009), as well as acute cardiovascular events (Ivanov et al., 1990) and in young healthy (Keller et al., 2011).

Changes in peripheral vascular resistance, triggered by high temperature or hydrostatic pressure, can promote increased of venous return (VR), which interferes with atrial distension, increased blood volume within the heart chambers, increasing the pulmonary circulation and increased CO given mainly by variations in the stroke volume (Smith et al., 1998). The vascular expansion leads to increased vagal afferents coming from pressoreceptors aortic and carotid, which excite the

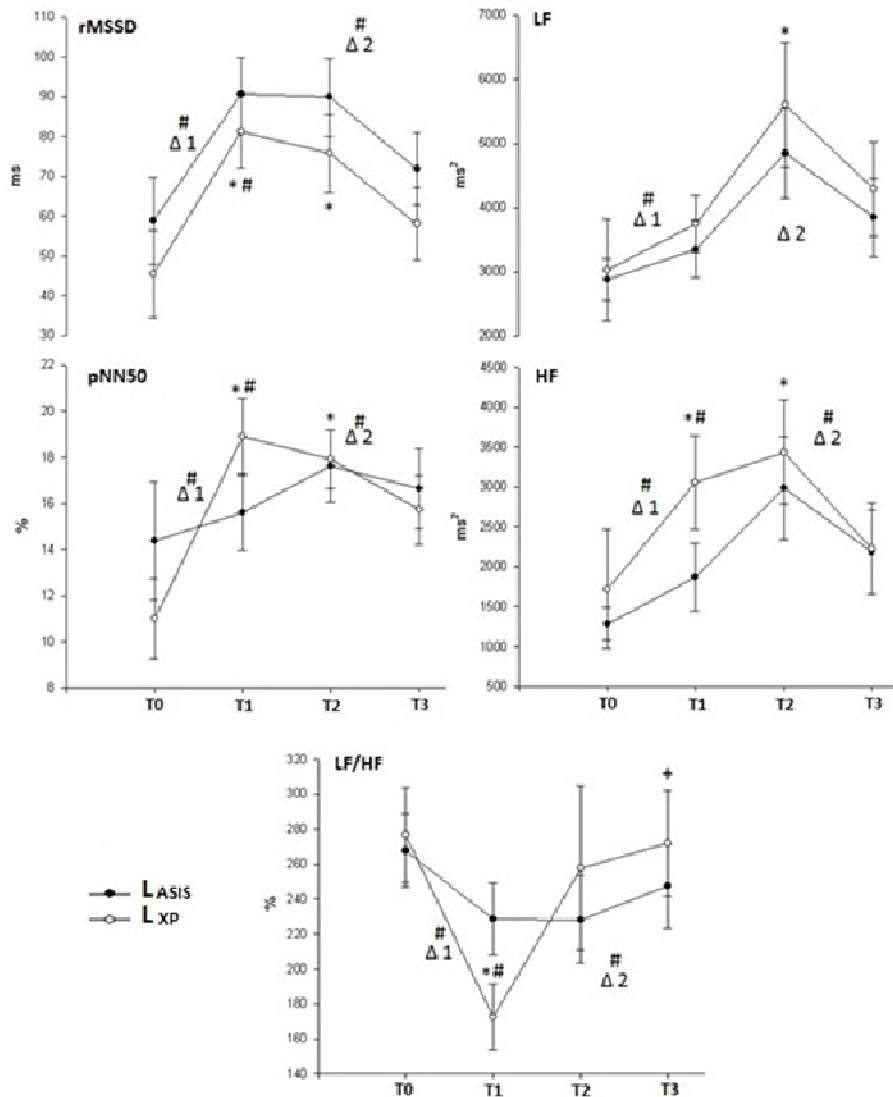


Figure 1. Behavior of heart rate variability during water immersion at two depths; Behavior of heart rate variability during water immersion at two depths. Data are expressed as mean \pm standard error. T0 = resting on the ground; T1 = 10min immersion T2 = 5 min recovery in the soil; T3 = 15 min recovery in the soil; L_{ASIS} = depth of immersion in height iliac spine; L_{XP} = depth of immersion time in the process xiphoid; rMSSD = square root of the mean squared differences between adjacent normal RR intervals; pNN50 = percentage of adjacent RR intervals with a difference of duration greater than 50ms, LF = low frequency, HF = high frequency; LF / HF = ratio of low High frequency by frequency; $\Delta 1$ = percentage change from T0 to T1; $\Delta 2$ = percentage change from T1 to T3. * Statistical difference (p < 0.05) compared T0; + statistical difference (p < 0.05) compared to T1; # statistically significant difference (p < 0.05) compared to L_{ASIS}

nucleus of the solitary tract, stimulating the vagal nucleus and reducing sympathetic tone, resulting in inhibition of vasomotor activity (Rasia et al., 2004).

Stimulation of cardiopulmonary reflexes, triggered by the elevation of VR and pulmonary circulation, resulting in inhibition of peripheral sympathetic, vasodilation and bradycardia (Bezold-Jarish reflex) (Rasia et al., 2004). In

addition, the atrial distension promotes increased release of natriuretic peptide that reduces renal sympathetic activity with inhibition of the rennin-angiotensin-aldosterone system, increasing diuresis and natriuresis (Larsen et al., 1994; Hammerum et al., 1998). In this regard, the increased axial and central blood volume, with consequent increase in VR, the distention of the

Table 3. Variation of relative indices of heart rate variability during immersion in two levels deep

Variable	$\Delta 1$	$\Delta 2$
L_{ASIS}		
rMSSD (%)	18,5 ± 32,8	4,5 ± 20,7
PNN50 (%)	35,8 (-87,9 a 262,1)	6,6 (-33,8 a 170,0)
HF (%)	48,9 ± 90,8	18,5 ± 46,7
LF (%)	20,6 ± 46,9	17,4 ± 31,5
LF/HF (%)	12,3 ± 34,7	7,1 (-48,2 a 89,9)
L_{XP}		
rMSSD (%)	84,1 ± 74,1#	-21,1 ± 17,2#
PNN50 (%)	80,5 (-33,6 a 764,3) #	-15,5 (-56,7 a 400) #
HF (%)	247,3 ± 251,6#	-28,4 ± 34,9#
LF (%)	79,0 ± 90,3#	11,7 ± 38,1
LF/HF (%)	-32,5 ± 33,5#	54,9 (-16,4 a 218,2) #

L_{ASIS} = immersion depth at the height of the iliac crest; L_{XP} = immersion depth at the time of xiphoid process; rMSSD = square root of the mean squared differences between adjacent normal RR intervals; pNN50 = percentage of adjacent RR intervals with greater difference in length than 50ms, BF = low frequency; HF = high frequency; LF / HF = ratio of low frequency for high frequency; $\Delta 1$ = percentage change in the soil for immersion; $\Delta 2$ = percentage change of immersion to the 15th min of recovery. Paired t test or Wilcoxon: # statistically significant difference ($p < 0.05$) than the L_{ASIS}

heart chambers and CO are dependent on the depth of immersion, since higher leakage of body fluid into the vascular system, can be reached as the hydrostatic pressure rises imposed upon the body segments.

The effect of hydrostatic pressure in the expansion vascular was described by Baecker et al. (2000). The authors reported that the pressure exerted on the body surface amounts to around 22.4 mm Hg per 30 cm of water in which the individual is immersed. Thus, the immersion fluid overload resulting from the level of the diaphragm can move about 400 to 500ml of blood to the heart, which may lead to increases in cardiac volume above 100 ml.

The results of this study confirm this hypothesis, which show an increase in levels of parasympathetic influence when the body is exposed to the stimulus of immersion and the magnitude of the vagal response is dependent of the hydrostatic pressure. Significant increase in vagal modulation in the aquatic environment was observed only when the volunteers were immersed in height of xiphoid process. And the magnitude of this variation was significantly higher when the immersion occurred at this depth (Figure 1). This result corroborates with findings from the study of Wilcock et al. (2006) in which it was shown that the magnitude of reduction in HR rest soil for immersion in the hip was 4 to 6%. This reduction was more pronounced (11-18%) when occurred in the immersion level of xiphoid process.

The effects of thermoneutral immersion for short

periods in the standing position in increased vagal tone has been described in other studies by recording HRV. Overall, these studies demonstrated increased vagal response and sympathetic suppression, as demonstrated in this study where volunteers were seated. Miwa et al. (1997) showed that immersion in the height of the shoulders triggered significant increase of AF, as well as reduction of LF / HF in 8 healthy young adult subjects, concomitant with increased SV and CO without changes BP. A year earlier (1996), the same group of researchers has shown similar results (Miwa C et al, 1996a).

Similarly, Schipke et al. (2001) observed an increase of vagal modulation during 10 min immersion in 25 young adult volunteers. A significant increase in pNN50, rMSSD, LF, HF and SDNN (standard deviation of all normal RR intervals) were detected in soil passage to the aquatic environment.

Buss (2005) evaluated 36 men (age 36 ± 6 years) not physically active, undergoing immersion level of the middle third of the sternum for 15 min in the pool with thermoneutral water (32 °C). It was observed significant increase of AF, pNN50 and SDNN components during immersion.

When evaluating the effect of immersion in water for 20 min at the neck height in thermoneutral temperature (35-36 °C) and cool temperature (26-27 °C) in 12 healthy males (age 24.5 ± 1.1 years), Mourot et al. (2008) also showed a rise in parasympathetic indices (AF and High Frequency Force on Harmonic total) during the period in

water compared to soil. Studies using microneurography also confirmed the increase in vagal modulation and suppression of muscle sympathetic nerve activity during immersion, which would be directly related to hemodynamic effects caused by temperature and depth of the water immersion (Miwa C et al, 1996b).

Another finding of this study is the standard recovery vagal stimulation triggered by immersion in L_{XP} , which gradually returned to resting values after 15 min recovery in soil (Table 2 and Figure 1). The indices of HRV in the time domain, as well as LF and HF remained elevated over the initial condition (resting on ground) in the 5th min of recovery, with values returning to pre immersion in the 15th min.

Similarly, Keller et al. (2011) evaluated the hemodynamic responses of 20 young adults physically inactive (10 hypertensive and 10 normotensive), after immersion in resting in thermoneutral water at the level of xiphoid process. In this study, the systolic blood pressure (SBP) and diastolic blood pressure (DBP) decreased significantly at 10 min of immersion, when compared to the soil, returning to baseline values at 10 min immersion recovery out of the water, without a significant change in HR.

Such behavior of HRV recovery period can be explained by the short period of immersion adopted in this work, as well as in the study by Keller et al. (2011). Studies with larger immersion times shown that the physiological effects achieved in the water can be sustained for much longer (Kwee et al., 2000; Elvan-Taşpinar A, et al, 2006). However, no studies were found that have evaluated the relationship between immersion time and the maintenance time of the physiological effects achieved in the aquatic environment.

The practice of physical and aquatic rehabilitation becomes increasingly popular for individuals in different health conditions (Ferreira et al., 2010). Knowing that individuals with cardiovascular disease have a lower HRV due, in part, to increase of sympathetic stimulation, immersion in water increases the activity of the parasympathetic ANS, may prove to be a procedure for rehabilitation and prevention of morbidity and mortality of these patients (Ferreira et al., 2010). However, there was a wide variation in immersion protocols between studies, making it difficult for standardization that establishing immersion for therapeutic purposes in certain population groups. Furthermore, this study was conducted in healthy young subjects at rest condition, which cannot be extrapolated to other populations and health conditions in different levels and different immersion times.

Thus, further studies are needed to determine the clinical and physiological effects of immersion in thermoneutral water to certain groups of patients, at short and long term as for development of protocols for immersion specific to these groups.

CONCLUSION

The results of this study suggest that 10 min of immersion in water on height of xiphoid process promotes changes in sympathetic-vagal balance of physically active young adults, characterized by increased vagal tone.

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