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Elderly Hypertensive Subjects Have a Better Profile of Cardiovascular and Renal Responses during Water-Based Exercise

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ABSTRACT

Gomes SG, Silva LG, Santos TM, Totou NL, Souza PM, Pinto KMC, Coelho DB, Becker LK. Elderly Hypertensive Subjects Have a Better Profile of Cardiovascular and Renal responses during Water-Based Exercise. **JEPonline** 2016;19(4):21-31. The purpose of this study was to evaluate the cardiovascular and renal responses in elderly hypertensive subjects during land exercise (LE) and water-based exercise (AE). Eighteen women were subjected to an immersion session during resting (IR) and 2 LE and AE sessions. The subjects' blood pressure (BP), heart rate (HR), urinary samples, and baroreflex index were measured before and after each session. The IR session resulted in bradycardia and increased urinary production. Compared to the LE session (52 ± 5 beats·min^{-1}; P = 0.03), the AE session during immersion produced a lower increase in HR (46 ± 6 beats·min^{-1}). In addition, diastolic blood pressure range during the LE session was negative in relation to the AE session (AE, -4 ± 3.5 mmHg vs. LE, 5 ± 2 mmHg; P = 0.04). The results indicate that the cardiovascular and renal responses are different both at rest and during exercise in elderly hypertensive subjects.

Key Words: Hypertension, Cardiovascular, Renal, Water-Based Exercise

INTRODUCTION

Recent statistics show that hypertension is the most prevalent disease in the world, but there is a possibility to change it (21). Exercise guidelines for hypertension performed by several professional organizations and committees show that aerobic exercise training reduces blood pressure (BP) by 1 to 5 mmHg in individuals with hypertension. Moderate to vigorous aerobic physical activity for at least 12 wks, 3 to 4 sessions·wk^{-1} for 40 min per session is the most effective program (24). Although these guidelines are a cornerstone for the prevention and treatment of hypertension, there still remain certain concerns in the literature about exercise and BP reduction that need to be better understood. This includes, in particular, the analysis of more personalized exercise programs in order to maximize the effectiveness of regular exercise as an anti-hypertensive therapy (24).

While it is generally acknowledged that land exercise and water-based exercise programs are generally acceptable and effective for treating hypertension, some elderly hypertensive patients have movement limitation from knee osteoarthritis (2,10,15). Hence, the stiffness, swelling, and pain make it hard for these patients to engage in land exercise. That is why exercise during immersion is such a great alternative, especially since it has been showed that maximal oxygen uptake and heart rate (HR) are lower during water running compared to a standard treadmill protocol (31).

It is also evident that warm water immersion results in specific physiological changes in the hormonal, cardiovascular, and renal systems. As an example, the primary hemodynamic alterations are: (a) decreased total peripheral resistance, BP, and HR; and (b) increased end-systolic volume and cardiac output. Regarding the hormonal and renal systems, the changes are an increase in the excretion of urine (dieresis) and sodium in the urine (natriuresis) as well as enhanced atrial natriuretic peptide levels in the circulation. There is also an inhibition of the renin-angiotensin-aldosterone system (12).

Yoo and colleagues (35) indicated that, although underwater treadmill walking resulted in a gradual increase in systolic blood pressure, diastolic blood pressure, mean arterial blood pressure, and HR of stroke patients, the mean maximum increases were smaller during the water exercise than during the land exercise. The smaller increases may due to the decrease in peripheral resistance, which is observed during water exercise more so than during land exercise (9). Fabri and colleagues (7) indicate that exercise in water might be prescriptive for patients with hypertension, obesity, and/or mild renal disease in which retention of water and sodium occurs. Nádia et al. (32) conclude that exercise improved cardiopulmonary reflex sensitivity; and swim training led to a faster SBP reduction and a more sensitive reflex response to pressure stimuli.

Given that there are important physiological differences between land exercise and water-based exercise, the purpose of this study was to evaluate the cardiovascular and renal responses induced by immersion during rest and during a land exercise session and a water-based exercise session in elderly hypertensive subjects.

METHODS

Subjects

This study consisted of 18 elderly hypertensive women (aged, 66.8 ± 3.5 yrs; BMI, 29.2 $kg \cdot cm^{-2}$) who were not taking beta-blockers. The subjects were using combined captopril and furosemide. Procedures were performed according to the guidelines for the ethical use of individuals in scientific research, as stated by the Ethics committee on July 10, 2009, protocol 04/2009.

Procedures

Cardiopulmonary Exercise Test in Land and Water

The maximal aerobic capacity was determined through two submaximal progressive tests: (a) the Astrand (1980) Test using an electromagnetic bike (ERGOFIT®); and (b) the Conconi test (19) using an aquatic bicycle (Hidrocycle®). Both tests were randomized and performed at an interval of 48 hrs.

Protocol 1

Responses during Immersion While Resting (IR)

Each subject began the IR session by sitting 30 min out of the water. Then, the subject remained in the water for 60 min at the level of the xiphoid process at a pool temperature of 30 ± 2 °C, which was followed by another 60 min in a seated recovery from the water. A blood sample, HR, BP, and urinary volume were collected before and after immersion and 1 hr after the immersion. Samples were collected in the morning between 8:00 and 9:00 a.m. All subjects emptied the bladder upon waking up. They eat a breakfast with a total of 200 mL net intake. Each subject's HR and BP were measure by a heart rate monitor (Pollar RS800 HR) and a sphygmomanometer (Heine Gamma G7 Aneroid), respectively. Urine volume was measured using a graduated pipette. Plasma and urine osmolality were measured by a Osmette® osmometer. Plasma and urinary levels of sodium and potassium were measured by a spectrophotometer flame Micronal B 462®.

Protocol 2

Responses during Exercise

Seven days after the IR session, the subjects performed 20 min of land (LE) and water-based exercise (AE) at 85% of maximum load found in progressive tests. The AE was carried out with the water at the xiphoid process level. The water temperature was 30 ± 2 °C. A blood sample, HR, BP, and urinary volume were collected before and after the exercise session.

Heart Rate Variability and Baroreflex Sensitivity Analysis

The heart rate variability and barorreflex index were evaluated during immersion at rest and after the exercises sessions (AE and LE). Heart rate recordings were obtained using a HR monitor (RS800, Polar Electro Oy, Finland). The validity of the RS800 HR monitor has recently been reported to be similar to electrocardiographic recordings (33). The HR recordings were manually filtered for excluding artifacts and exported for heart rate variability (HRV) analysis using custom designed software (Kubios HRV v2.0, University of Kuopio, Finland). The examined HRV parameters were: (a) low-frequency power (LF) (0.04–0.15 Hz); (b) high-frequency power (HF) (0.15–0.4 Hz); and (c) the ratio between the low and high-frequency bands of the power spectral analysis.

Baroreceptor reflex stimulation was evaluated by RR interval using the Valsalva maneuver. The subjects were given specific instructions and time to practice the maneuver. For example, while in the resting supine position, each subject expired with a closed glottis into a mouthpiece-tubing connected to an aneroid manometer to maintain a constant expiratory intra-oral pressure of 40 mmHg for 20 sec according to standardized protocol (4,14,17,18). The parasympathetic drive during phase IV was quantified by calculating the Valsalva ratio, as previously recommended (11). The barorreflex index was determined before immersion during resting, during immersion while resting, and after AE and LE.

Statistical Analyses

The data were analyzed using the Graph Pad Prism 6 program and expressed as means ± standard error. The Shapiro-Wilk normality test was applied. The IR data analyses were performed using analysis of variance followed by Newman Keuls post-test. For the exercise (AE and LE) data and cardiopulmonary tests it was used the paired *t* test. The significance level was set at P<0.05.

RESULTS

Cardiopulmonary Exercise Test on Land and in the Water

Using progressive tests in this study show that there are no differences on aerobic capacity in LE (15.09 ± 1.13 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$) compared to AE (10.86 ± 0.9 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$).

Cardiovascular Changes during Immersion at Rest (IR)

The IR session resulted in a significant decrease in HR (P = 0.048) compared to pre-immersion, after immersion, and 1 hr after immersion. Figure 1A depicts the subjects' bradycardia during IR compared to the land situations. There was no significant difference in SBP or DBP during immersion (Figure 1B and C).

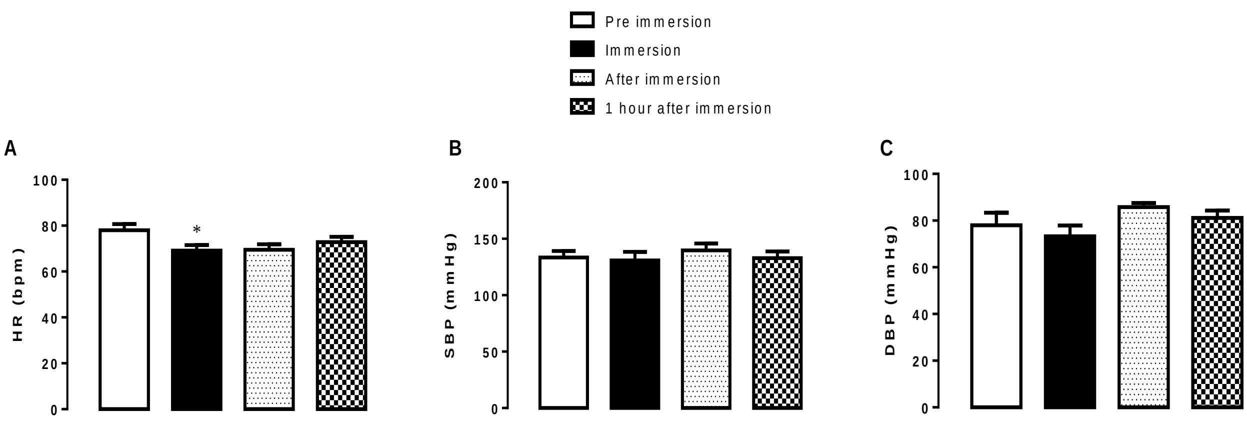

Figure 1. Heart Rate, Systolic Blood Pressure, and Diastolic Blood Pressure during Pre-Immersion, Immersion, After Immersion, and 1 hr after Immersion. *P<0.048 significantly different from Pre-Immersion, After Immersion, and 1 hr after Immersion.

Renal Changes during Immersion at Rest (IR)

Compared to pre-immersion the urinary response to immersion show a significant increase in urinary production, but there was no significant difference 1 hr after the immersion period (Table 1). Urinary concentration of sodium, potassium, and osmolarity were lower after immersion and 1 hr after immersion compared to pre-immersion (Table 1). The consequent decrease in urine osmolarity and the higher urine volume resulted in positive free water clearance after immersion and 1 hr after immersion (Table 1), which indicates that immersion produced dilute urine with free water excretion.

Table 1. Urine Parameters Before, After Immersion, and 1 Hr Immersion during Rest.

	Pre-Immersion	Immersion	1 Hr After Immersion
Urinary volume (mL)	141 ± 35	292 ± 34†	250 ± 21
Sodium (mEq)	126 ± 18*	54 ± 6	47 ± 9
Potassium (mEq)	25 ± 6*	17 ± 7	20 ± 7.4
Osmolarity ($Osm \cdot L^{-1}$)	341 ± 52 #	167 ± 35	130 ± 26
Water Free Clearance (mL)	-190 ± 48**	65 ± 60	56 ± 23

† P<0.009 compared to Pre-Immersion, *P<0.004 compared to Immersion and 1 hr after Immersion, #P<0.001 compared to Immersion and 1 hr after Immersion, **P<0.0005 compared to Immersion and 1 hr after Immersion

Renal Responses on Land and during Water-Based Exercises

The subjects had a higher urine production after exercise in water. When compared to the land exercise, urinary rate was AE (4.3 ± 1 ml) and LE (7 ± 1.6 ml) P = 0.02. The excretion of solutes was not different between AE and LE.

Cardiovascular Responses on Land and during Water-Based Exercises

The subjects' HR rise during exercise in the water session (AE, 46 ± 6 beats·min^{-1}) was lower compared to the HR rise during the LE exercise session (52 ± 5 beats·min^{-1}) (Figure 2A, P<0.04). The subjects' BP increased in response to exercise, but it was not significantly different from the LE exercise SBP (Figure 2B). The DBP response was negative (i.e., decreased) in the water session (AE, -4 ± 3.5 mmHg) compared to LE session (5 ± 2 mmHg, P = 0.04) (Figure 2C).

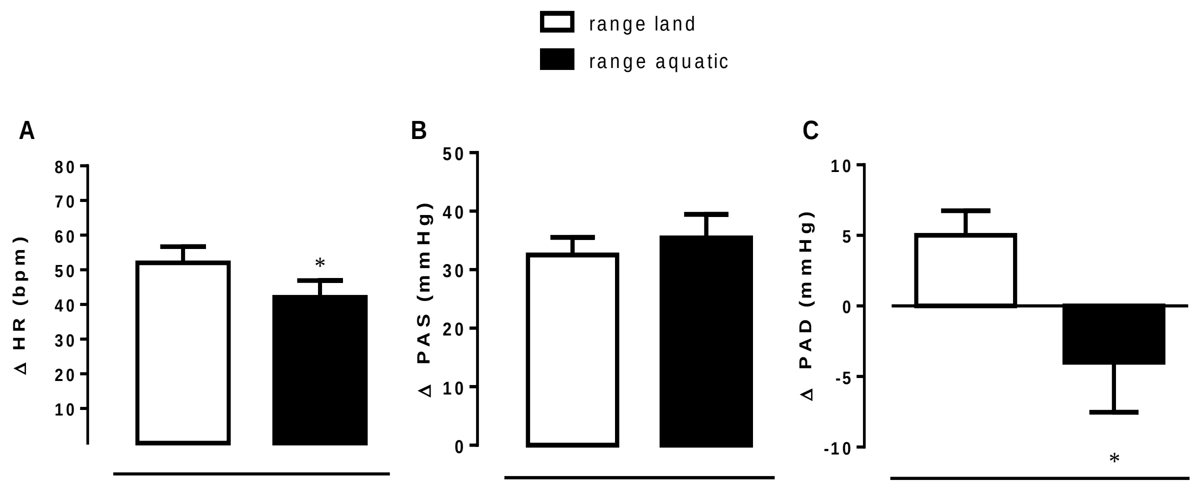

Figure 2. Heart Rate, Systolic Blood Pressure, and Diastolic Blood Pressure Range in responses during the Land Exercise and the Aquatic (water) Exercise. *P<0.04 compared to land

Sprectral and Baroreflex Results

The spectral analysis show that there was no difference in the LF/HF balance between the two exercise environments (AE = 0.36 ± 0.07 Hz vs. LE = 0.28 ± 0.03 Hz). The baroreflex index show a significantly greater decrease in IR (0.1 ± 0.04 %·sec^{-1}) compared to the land exercise (2.3 ± 0.5 %·sec^{-1}) (P = 0.05). In addition, the same behavior was observed during the water-based exercise (AE, 0.6 ± 0.1 %·sec^{-1}) compared to land exercise (LE, 2.2 ± 0.5 %·sec^{-1}) (P = 0.02) (Figure 3).

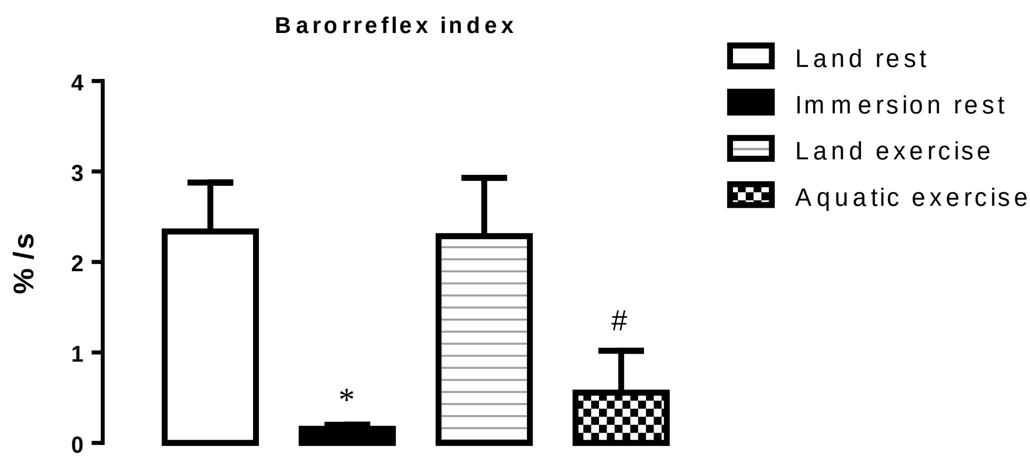

Figure 3. Barorreflex Index during Immersion Rest and after the Land Exercise and the Aquatic Exercise. *P<0.05 compared to Immersion during resting, #P = 0.02 compared to Land Exercise

DISCUSSION

The purpose of this study was to evaluate the cardiovascular and renal responses in elderly hypertensive subjects during land exercise (LE) and water-based exercise (AE). The results show important differences in the subjects' cardiovascular response during immersion and exercises performed on land and in the water. The immersion during resting induced bradycardia, and a significant change in the baroreflex index. During exercise, the subjects' HR increase was lower in the water while DBP was reduced during exercise performed in the water. In addition, the baroreflex sensitivity was lower in the water exercise session compared to the land exercise session. Renal results show significant diuresis induced by immersion during resting with positive water clearance, and after exercise water diuresis was higher in comparison to the land exercise session.

Immersion at Resting

Several studies (3,13,30,31) indicate that HR is decreased during thermoneutral water immersion. In subjects with heart failure, the bradycardic response is impaired during immersion (5). This is the first work that shows the HR response to hypertensive subjects during immersion and in water-based exercise. The data show that elderly hypertensive subjects present HR decrease during immersion at rest that can be attributed to central hypervolemia, which stimulates the cardiopulmonary receptors reducing sympathetic nerve activation (26,29). The redistribution of blood flow during immersion promotes a differentiated cardiovascular control either while resting or during exercise in addition to higher values of cardiac output and a decrease in peripheral vascular volume and HR (23).

With respect to BP, Park et al. (23) indicate that immersion results in an increase in SBP in normotensive subjects while resting. Mourot et al. (20) reported a decrease in BP in younger healthy subjects, which is contrary to our findings of no change in SBP or DBP during immersion while resting.

Immersion during resting induced diereses with an increase in urine flow after immersion, which has been observed by Nakamitsu et al. (22) and Rim et al. (27) in healthy subjects. The diuresis was accompanied by a change in free water clearance, and the results showed a lower solute and osmolarity in the urine after IR. The changes induced by the immersion can be attributed to antidiuretic hormone suppression, which is also observed during immersion and, in addition, the water immersion decreases plasma renin activity (22). These changes are induced by the stimulation of cardiac volume receptor via an increase in intrathoracic blood volume (6).

Exercise Response

The subjects' increase in HR during AE was lower compared to LE. Data in literature showed that underwater exercise reduce workout of the cardiovascular system. Yoo et al. (35) observed in stroke patients that increase in blood pressure and HR while walking on an underwater treadmill were significantly lower than when walking on a land treadmill. Lim and colleagues (16) reported the same behavior in young healthy subjects. The change in HR was higher in the land walking group versus the aquatic walking group (16).

In the present study, there was no difference in the increase in SBP during AE and LE. But, there was a decrease in DBP during the water-based exercise. As pointed out by Mourot et al. (20), the increase in venous return after water immersion stimulates the cardiopulmonary baroreceptors that can lead to a decrease in sympathetic tone and systemic vascular resistance. The subjects' BP response during the water-based exercise and the land walking exercise demonstrated that walking in the water resulted in a better effect. In agreement, Rodriguez et al. (28) reported that water exercise resulted in a greater hypotensive effect in their young healthy women versus walking at a similar intensity on land (28).

The importance of the arterial baroreflex during exercise is a function of several factors. The increase in arterial pressure evoked by activation of the exercise pressor reflex, the stimulation of the baroreflex receptors, and the control of the arterial pressure are a function of the subjects' cardiovascular response to the exercise (25). Our results indicate for the first time the differences between baroreflex index during land exercise and during water-based exercises. Our results indicate a decrease in baroreflex index during immersion and during the water-based exercise.

Acute loads of cardiopulmonary receptors in humans and animal models demonstrate a decrease in baroreflex activity (1,8). Stimulation of the cardiopulmonary reflex during immersion probably contributes to the baroreflex response during immersion and during the water-based exercise. Data from the present study show indicate that underwater exercise modulates differently the cardiovascular responses, the barorreflex response, and the renal function in the elderly hypertensive subjects.

CONCLUSIONS

The results indicate that the cardiovascular and renal responses are different both at rest and during exercise in elderly hypertensive subjects. These findings should help motivate other researchers to develop a physical training program that contributes to better cardiovascular and renal responses during exercise in hypertensive subjects.

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