

Cardiovascular Topics

The effects of aquatic and land exercise on resting blood pressure and post-exercise hypotension response in elderly hypertensives

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Abstract

Objective: This study compared resting blood pressure (BP) using ambulatory BP monitoring (ABPM) responses in two groups of subjects trained in land exercise (LE) and aquatic exercise (AE), and assessed post-exercise hypotension (PEH) using ABPM, after land- and aquatic-based exercises.

Methods: ABPM (24 hours) was used to measure the baseline BP in elderly hypertensive women trained in LE and AE and the PEH induced by exercise. For this, 40 subjects were evaluated at rest and after a land- or aquatic-based exercise session (aerobic: 75% of reserve heart rate combined with resistance exercise).

Results: The daytime BP was lower for AE [systolic BP (SBP) 124 ± 1.0 mmHg, diastolic BP (DBP) 70 ± 1.5 mmHg] than for LE (SBP 134 ± 0.9 mmHg, DBP 76 ± 0.9 mmHg), but there were no differences at night-time. The aquatic exercise-induced PEH in the second hour was maintained at the 24th hour post-exercise. For land exercise-induced PEH, it was maintained at the 12th hour post-exercise. The SBP and DBP were lower at the 24th hour for AE than for LE.

Conclusion: Elderly hypertensive people trained in AE had lower baseline BP during the daytime. SBP and DBP values were lower for individuals trained in AE, and their PEH was more rapid and longer lasting after AE.

Keywords: aquatic exercise, land exercise, hypertension, elderly

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Hypertension (HTN) has been the subject of worldwide study for its clinical aspects or as a health problem. HTN is considered one of the main determinants of cardiovascular morbidity and mortality.^{1,2} Among non-pharmacological therapies recommended for HTN treatment, exercise training is essential, with reductions of around -3.5 mmHg for systolic and -3 mmHg for diastolic blood pressure (BP) being reported.³

Aerobic exercise for periods of 30 minutes of vigorous or 60 minutes of moderate intensity three to five times a week⁴ is universally the most recommended measure to lower BP among those with HTN.⁵⁻⁷ Resistance training with nine exercises three times a week for 12 weeks, at 75% intensity on one maximal repetition (1RM), with a volume of six to 10 repetitions, promotes a greater nocturnal reduction ($> 10\%$) in diastolic BP (DBP) among older hypertensive subjects than other forms of training.⁸

Individuals can benefit from one session of exercise with immediate or short-term effects that persist for up to 24 hours after an acute exercise bout, a response that is termed post-exercise hypotension (PEH); this effect is considered an important positive factor in HTN treatment.⁹⁻¹¹ Although the modalities of physical exercise (aerobic or resistance exercise) promote different responses in PEH, the magnitudes of PEH that they induce may be distinct. Aerobic exercise seems to promote a higher and longer PEH,¹² and the intensity of the exercise appears to have an influence on PEH.¹³ For resistance training there are conflicting data about its effect on PEH due to variance in factors such as the muscle mass involved, the intensity of exercise, and the interval and volume of sets and rest.^{13,14}

Aquatic physical exercise (AE) offers advantages over land exercise (LE) for the elderly as it involves lower risk of injury than LE owing to water buoyancy, and guards against joint degradation by decreasing weight-bearing loads¹⁵⁻¹⁷ and reduced joint load.¹⁸ In addition, aquatic-based exercise promotes physiological adjustments resulting from immersion that can affect BP as well as cardiac work, particularly reduction in sympathetic activity and redistribution of blood volume from the lower limbs and abdomen to the upper body.^{19,20} Therefore,

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excretion of liquids and electrolytes is increased, together with suppression of levels of the fluid-regulating hormones renin, angiotensin II, aldosterone and arginine vasopressin to control plasma volume,^{21,22} and peripheral vascular resistance is decreased.²³⁻²⁵

Several studies have established the effectiveness of planned interventions using physical exercise in the treatment of HTN with land and aquatic-based exercises,²⁶⁻³³ but comparisons between the two types of exercise regarding elderly hypertensives trained in different modalities are scarce. In addition, the effects on PEH of land- and aquatic-based exercise during the following 24 hours need further investigation.

In light of the benefits of AE, this study compared resting BP using ambulatory BP monitoring (ABPM), the clinical gold-standard methodology for assessing BP status, in two groups of trained subjects with equivalent cardiorespiratory capacity performing either LE or AE. In addition, using ABPM, we assessed PEH after AE and LE among older women with HTN.

Methods

This was a controlled clinical trial developed at the Exercise Physiology Laboratory (LABFE) of the school of Physical Education of Ouro Preto, Minas Gerais, Brazil. The study protocol was approved by the Research Ethics Committee of the Federal University of Ouro Preto under protocol: 38383314.3.0000.5150.

The study population consisted of 40 elderly hypertensive women, 20 trained in land-based exercise and 20 in aquatic-based exercise. To be included, the subjects had to meet the following criteria: aged over 60 years, hypertensive, female, in regular treatment for BP control, and enrolled in recurrent physical exercise for at least six months before evaluation for a minimum of twice a week. Subjects with symptomatic cardiorespiratory disease or cardiac alterations, the metabolic syndrome, renal or hepatic disease, cognitive impairment, and any other medical contra-indications of physical exercise were excluded.

The participants were divided randomly into four groups:

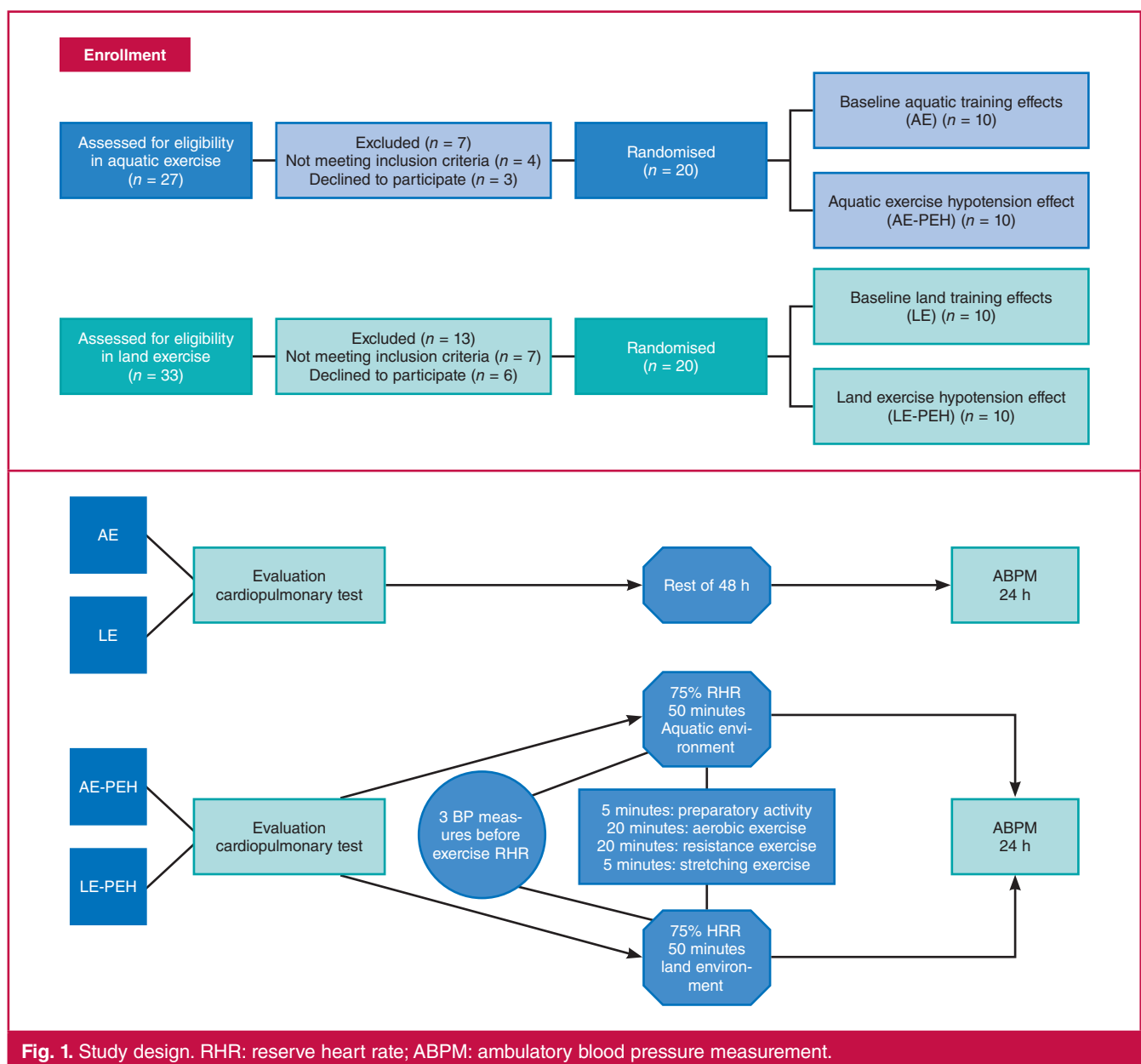


Fig. 1. Study design. RHR: reserve heart rate; ABPM: ambulatory blood pressure measurement.

Table 1. General profile of the two hypertensive groups

	LE-PEH (n = 10)	AE-PEH (n = 10)	LE (n = 10)	AE (n = 10)
Age (years)	67 ± 3	64 ± 3	65 ± 3	70 ± 2
BMI (kg/m ²)	26.4 ± 3.4	25.7 ± 2.8	27.3 ± 3.3	26.5 ± 5.2
Peak VO ₂ (ml/kg/min)	23.4 ± 3.4	22.6 ± 2.1	25.7 ± 4.7	24.8 ± 3.4
Resting SBP (mmHg)	140 ± 4.4	153 ± 5.0	130 ± 8.3	128 ± 9.8
Resting DBP (mmHg)	85 ± 4.3	90 ± 5.6	82 ± 4.2	81 ± 8.1
Antihypertensive drugs (n)	2 (1–2)	1 (1–2)	2 (2–3)	1 (1–2)
Diuretic (%)	60	50	60	50
ACE inhibitor (%)	20	0	20	0
ARB (%)	80	80	60	80

AE-PEH: aquatic exercise PEH; LE-PEH: land exercise PEH; AE: aquatic exercise; LE: land exercise; PEH: post-exercise hypotension; VO₂: volume of oxygen; BMI: body mass index; SBP: systolic blood pressure; DBP: diastolic blood pressure; ACE inhibitor: angiotensin converting enzyme inhibitor; ARB: angiotensin II receptor blocker. Data expressed as mean ± SD.

individuals enrolled in regular AE (*n* = 20), of whom the arterial baseline pressures of 10 were evaluated for 24 hours after 48 hours of rest after their last exercise training; and in the other 10 subjects the PEH induced by an AE session was assessed. The other 20 individuals enrolled in regular LE were randomised and evaluated in the same way (Fig. 1).

Body mass was measured with a digital scale having a capacity of 150 kg and an accuracy of 100 g (EKS® SUPER 9805). Height measurement was performed with a compact stadiometer fixed to the wall, and with a range of 0 to 2.0 m and an accuracy of 1 mm (Coats Corrente® BA1010).

The heart rate (HR) was measured in both groups at rest and after a cardiopulmonary test. For this a cardiac monitor (Polar® model FT1) was used to collect resting HR. The HR recording was made in the seated position for two minutes after a rest of 10 minutes; the lowest HR reached in this period was used. The maximal HR was measured immediately after completion of the cardiopulmonary test.

For evaluation of the maximum aerobic capacity (VO_{2max}), the progressive treadmill test was applied following the Balke–Ware protocol.³⁴ The maximal VO₂ was evaluated using an open-circuit spirometry VO2000® ventilometer and an Inbramed® treadmill.^{35,36}

BP was measured at rest and after cardiopulmonary tests in both groups. For the former, the BP was assessed three times after 10 minutes of rest in a seated position at intervals of one minute, and the result was taken as the mean value, while for the latter, the BP was assessed immediately after completion of the treadmill test with a stethoscope (Missouri®) and a manual aneroid sphygmomanometer (Missouri®) with a precision of 2 mmHg.

The ABPM was started 48 hours after the last training session to evaluate the baseline BP in the AE and LE groups. To evaluate PEH, the ABPM was started immediately after the exercise session. Three devices of the Meditech KFT® brand, model ABPM-04, were used. The BP cuff was worn on the non-dominant arm. Subjects were instructed to maintain their customary daily activities, not to exercise, and to relax and unbend the arm during the recording interval for daytime ABPM. ABPM data were accepted with more than 75% of the measurements effectively taken. Individual BP measurements were revised for missing and erroneous values.

For comparison purposes, data were distributed across the waking period, which consisted of the mean BP of the

Table 2. Cardiovascular response to maximal effort in the cardiopulmonary test in hypertensive subjects trained in aquatic and land exercise

	AE (n = 10)	LE (n = 10)
HR (bpm)	134 (124.9–143.9)	147 (136.5–157.3)*
SBP (mmHg)	160 (150.9–191.7)	162.5 (151.3–177.9)
DBP (mmHg)	80.0 (72.4–89.6)	90.0 (84.1–90.5)*

AE: aquatic exercise; LE: land exercise; HR: heart rate; SBP: systolic blood pressure; DBP: diastolic blood pressure. **p* < 0.05 when compared to AE. Mann–Whitney test, data expressed in median and 95% confidence interval.

measurement made every 15 minutes during the periods of the day when the individual was awake (07:00 to 23:00), and the sleep period, during which the BP was measured every 30 minutes and the mean value taken when the individual was asleep (23:00 to 07:00). The result for each hour was then the average of the values recorded during that hour.

For the AE-PEH, each individual remained at rest in a seated position for 15 minutes, then BP was measured three times with a sphygmomanometer and stethoscope. Subsequently the test exercise session was started, which consisted of collective water aerobics with a duration of 50 minutes, comprising five minutes of preparatory activity, 20 minutes of aerobic exercises at 75% of reserve HR (RHR), 20 minutes of strength exercises, and five minutes of stretching. The HR was monitored by a heart rate monitor (POLAR® RS800) during the entire session. After the experimental session, ABPM was used to record BP during the following 24-hour period.

For the LE-PEH, each individual remained at rest in a seated position for 15 minutes, then the BP was measured three times with a sphygmomanometer and stethoscope. Subsequently the test exercise session was started, which consisted of aerobic collective gymnastics with a duration of 50 minutes, including five minutes of preparatory activity, 20 minutes of aerobic exercises at 75% of RHR, 20 minutes of resistance exercises, and five minutes of stretching. HR was monitored by a heart rate monitor (POLAR® RS800). After the experimental session, ABPM was used to record the BP during the following 24-hour period.

Statistical analysis

The Shapiro–Wilk test was used to evaluate the normality of the numerical data. Data are presented as mean ± standard deviation. An unpaired *t*-test with Welch's correction was used to compare the cardiopulmonary response between AE and LE, as well as the magnitude of PEH at the second, 12th and 24th hours after the session.

Two-way ANOVA was used to compare PEH for the sessions by time (second, 12th and 24th hour), as well as determine interaction effects (session and time), followed by Bonferroni's *post hoc* test. A 5% significance level was set. All statistical analyses utilised Graph Pad Prism 7.0

Results

Table 1 shows the characteristics of the experimental groups. There were no differences between the groups by age, body mass index, peak VO₂, or resting systolic BP (SBP) and DBP.

Table 2 shows the HR and BP responses to maximal effort recorded after the cardiopulmonary test. The values of HR and

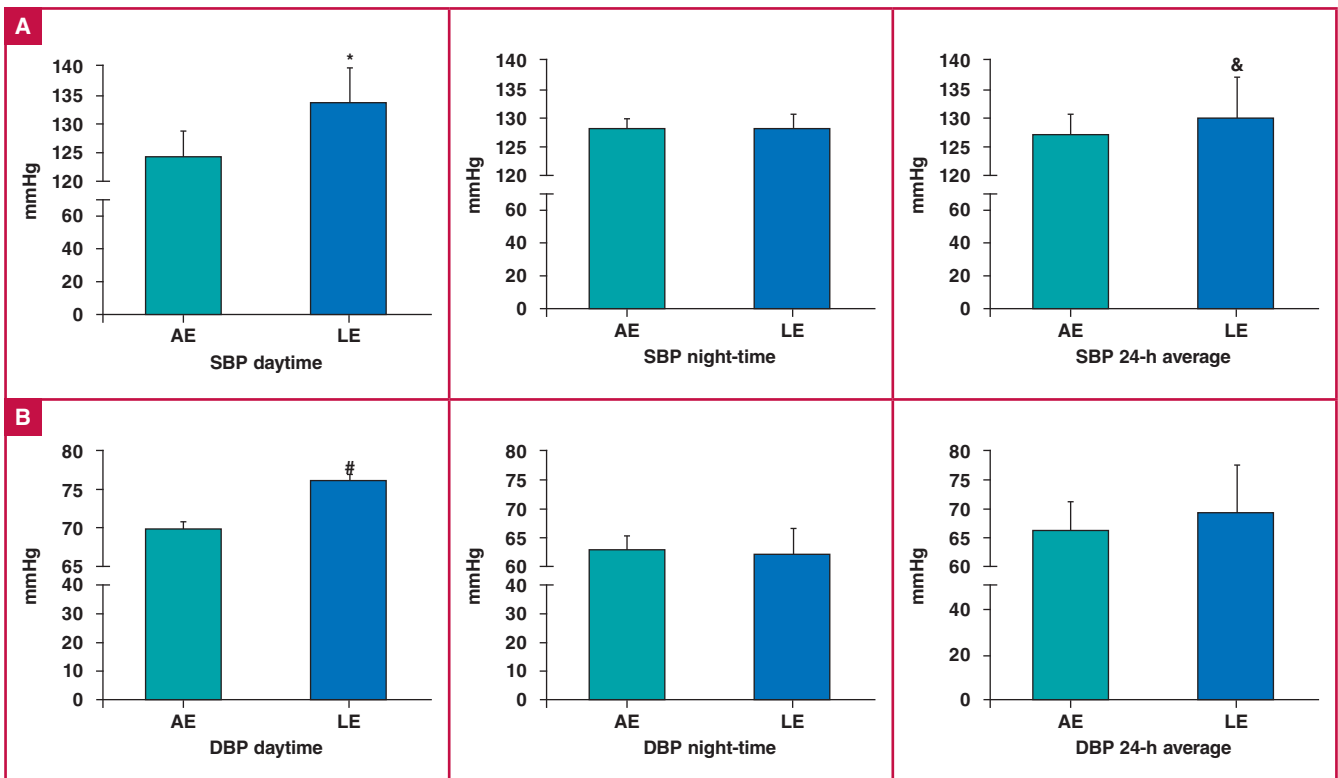


Fig. 2. Average SBP (A) and DBP (B) during the daytime, night-time, and over 24 hours. AE: aquatic exercise; LE: land exercise **p* < 0.0001 when compared with AE, SBP daytime (AE 124 ± 4 mmHg, LE 134 ± 6 mmHg); #*p* < 0.0001 when compared with AE, DPB daytime (AE 70 ± 3 mmHg vs LE 76 ± 4 mmHg); **p* < 0.02 when compared with AE, SBP 24 hours (AE 121 ± 5 mmHg vs LE 125 ± 10 mmHg)

DBP were significantly higher in the LE than the AE group, but there were no differences observed in SBP.

Fig. 2 shows the values of SBP (A) and DBP (B) during the daytime, night-time and total 24 hours (daytime plus night-time). The AE group showed lower values for daytime SBP (124 ± 4

mmHg) and DBP (70 ± 3 mmHg) than the LE group (SBP: 134 ± 6 mmHg, DBP: 76 ± 4 mmHg), as well as for the 24-hour average for SBP (AE: 121 ± 5 mmHg vs LE: 125 ± 10 mmHg). There was no difference between the groups during the night-time or for the 24-hour average of DBP.

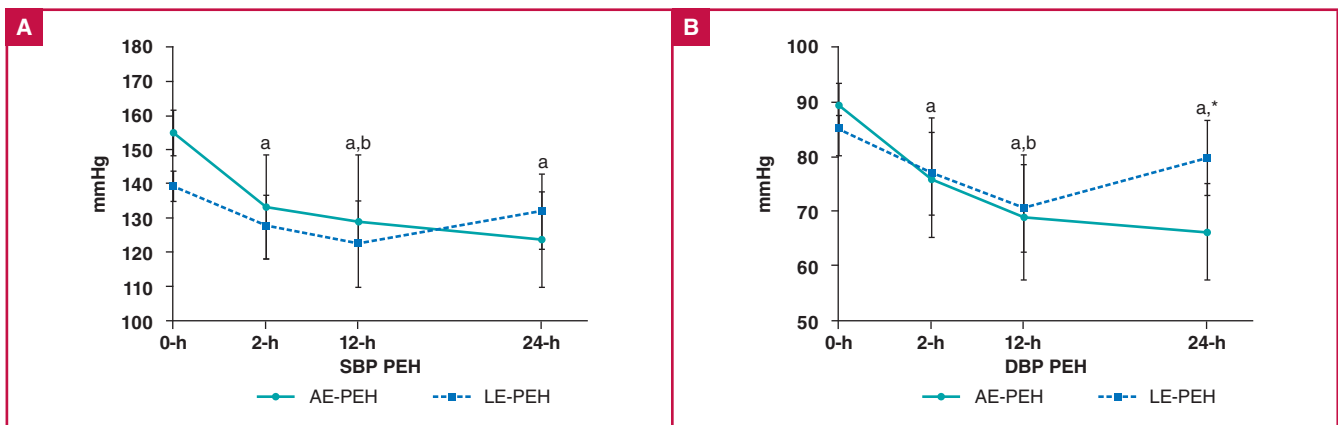


Fig. 3. SBP (A) and DBP (B) PEH in the AE and LE groups at the second-, 12th- and 24th-hour time points. a: represents the difference between AE-PEH baseline and the time points, b: represents the difference between LE-PEH baseline and the time points, *represents the difference between the groups at the same time point. a: *p* < 0.001 when compared to AE-PEH at 0 hours (SBP/DBP AE-PEH: baseline (0 h) 155 ± 7/90 ± 4 mmHg, second hour 133 ± 15/76 ± 11 mmHg, 12th hour 129 ± 19/69 ± 11 mmHg, 24th hour 123 ± 14/66 ± 9 mmHg); b: *p* < 0.03 when compared to LE-PEH at 0 hours (SBP/DBP LE-PEH: baseline (0 h) 139 ± 5/85 ± 2 mmHg, 12th hour 122 ± 9/71 ± 8 mmHg); **p* < 0.01 when compared with LE-PEH (DBP AE-PEH 66 ± 9 mmHg, LE-PEH 80 ± 7 mmHg). AE: aquatic exercise; LE: land exercise; PEH: post-exercise hypotension. Two-way ANOVA with Bonferroni correction, data expressed as mean ± SD. Interaction for SBP: *p* = 0.0544, DBP: *p* = 0.0099.

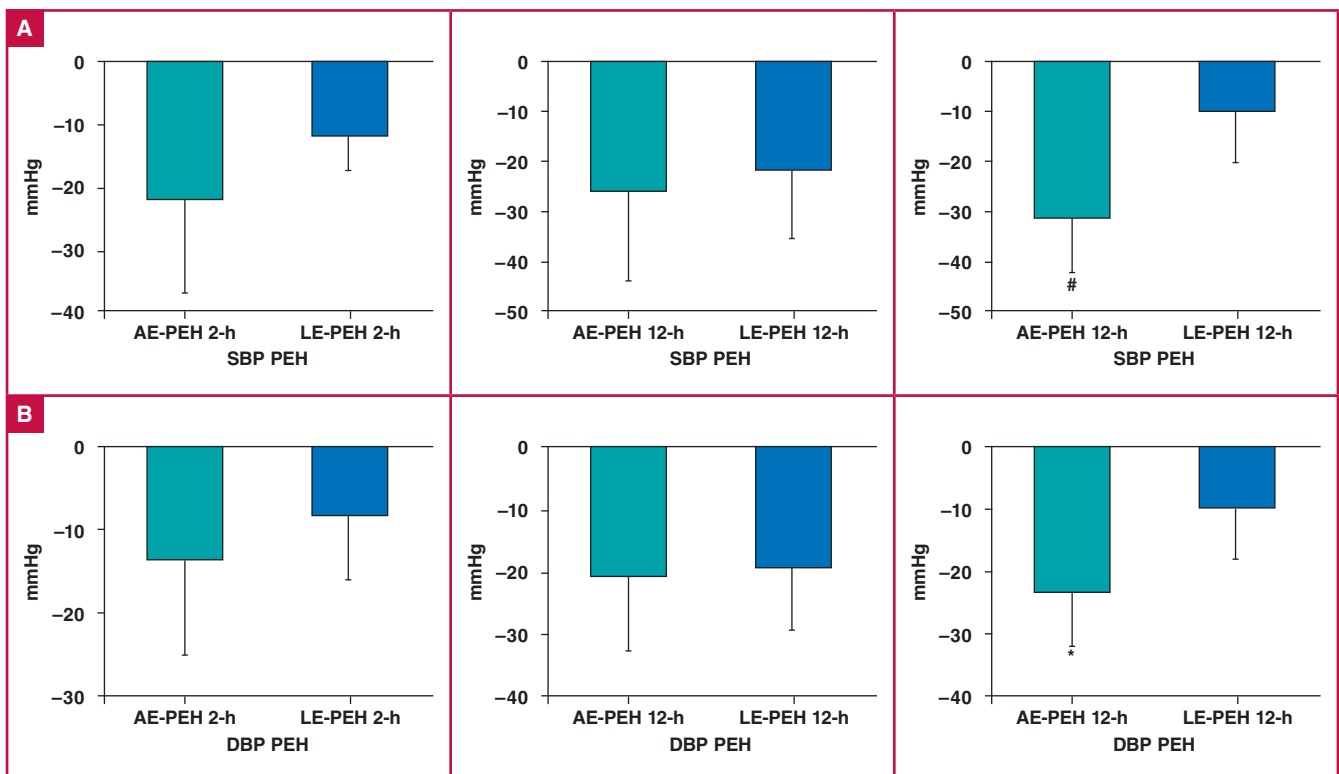


Fig. 4. Magnitude of PEH in the exercise groups AE-PEH and LE-PEH for SBP (A) and DBP (B) at the second, 12th and 24th hour. PEH: post-exercise hypotension. # $p < 0.001$ when compared with LE-PEH 24th hour (SBP AE-PEH -31 ± 10 mmHg vs LE-PEH -10 ± 10 mmHg); * $p < 0.01$ when compared with LE-PEH 24th hour (DBP AE-PEH -23 ± 9 mmHg vs LE-PEH -10 ± 8 mmHg). Unpaired t -test with Welch's correction, data expressed as mean \pm SD.

Fig. 3 shows the PEH for SBP (A) and DBP (B) in the AE-PEH and LE-PEH groups at the second, 12th and 24th hours after the exercise session, those times being chosen because the individuals were then awake. The AE-PEH data show that PEH was maintained from the second to the 24th hour, while for the LE group, maintenance of PEH was observed only until the 12th hour. There was no difference in PEH at the second and 12th hour between the groups, but for DBP, at the 24th hour, AE-PEH values were lower (66 ± 9 mmHg) than those of LE-PEH (80 ± 7 mmHg).

Fig. 4 shows SBP (A) and DBP (B) for the groups AE-PEH and LE-PEH. There was no difference in PEH at the second and 12th hours between the groups, but the 24th hour PEH was higher for the AE group (SBP: -31 ± 11 mmHg, DBP: -23 ± 8 mmHg) than for the LE group (SBP: -10 ± 10 mmHg, DBP: -10 ± 8 mmHg).

Discussion

The main finding of this study was that elderly hypertensive subjects trained in AE had different baseline BP responses from land-trained subjects. During the daytime, SBP and DBP values were lower for aquatic-trained hypertensive subjects. In addition, the PEH induced by AE was more rapid and lasted longer than that induced by LE, based on data recorded 24 hours after the exercise session. Another interesting result was the cardiovascular response after a cardiopulmonary test: maximal HR and DBP were higher for land-trained than aquatic-trained subjects.

Both training environments have been shown to be efficacious in reducing BP, but aquatic training caused a more impressive reduction (-10.58 mmHg) than that due to land aerobic training (-3.5 mmHg) or resistance training (-1.8 mmHg).³ The baseline data show that AE induced lower BP values, an effect appearing during the awake period, which could be due to higher sympathetic tonus activity during the awake period than at night, as data show that in the daytime there is a prevalence of sympathetic tonus.³⁷

AE modulates the sympathetic drive differently from that observed for LE. In AE, one should consider the effect of hydrostatic pressure, which induces an increase in blood concentration in the thorax³⁸ and reflexively decreases the heart rate. Increased venous return during immersion stimulates cardiopulmonary receptors, which decrease sympathetic activity and total peripheral resistance.³⁹ Bradycardia also occurs during immersion.⁴⁰ In addition, data reported in the literature show that aquatic-based exercise induces a different response associated with renal sympathetic nerve activity,²³ as well as higher suppression of the vasopressin and renin-angiotensin systems, from that of physical activities on land.^{41,42}

The maximal response to the cardiopulmonary test shows that both groups had the same $VO_{2\text{ max}}$, but, interestingly, hypertensives trained in AE had lower HR and DBP during maximal effort. The chronic effect of AE ameliorates arterial peripheral resistance, and the decrease in levels of epinephrine, norepinephrine and endothelin-1 associated with an increase in nitric oxide levels can improve the BP response during exercise, including DBP.⁴³ We found that elderly hypertensive subjects had

a better profile of cardiovascular responses during AE. The DBP decreases during aquatic cycle ergometer exercise were greater than in the case of the same exercise intensity on land.⁴⁴

Our data show that PEH for SBP and DBP lasted for 24 hours after AE, which was longer than for LE. Similarly, Ngomane⁵⁰ showed that heated AE was more effective in producing PEH for 11–18 hours after a bout of exercise than LE. The higher PEH after AE was observed in reduced SBP and DBP during the daytime, but there was no difference found in any other haemodynamic variable assessed: arterial stiffness, endothelial reactivity or heart rate variability. Our findings likewise corroborate the results of Bocalini,⁴⁵ who verified that water ergometric exercise was effective in promoting a higher magnitude of PEH in older hypertensive women with more apparent outcomes in untreated women, than LE.

Concerning the mechanisms associated with PEH, several have been presented in the literature as playing a major role in these effects on BP: reduction in sympathetic activity,⁴⁶ attenuation of cardiac adrenergic receptor sensitivity, decreased catecholamine synthesis with changes in renin and angiotensin release as a result,⁴⁷ lesser peripheral vascular resistance⁴⁸ and stroke volume,⁴⁹ and synthesis of vasopressin²¹ and endothelins.⁵⁰ The mechanism whereby AE creates lasting PEH however needs better elucidation.

Our study used a session of combined aerobic and resistance exercises for AE, and PEH was longer and started earlier (two hours after the exercise session) than for LE. This result is in agreement with Ferrari,⁵¹ who used concurrent training, aerobic plus resistance training, to show a reduction in BP in the first hour after training in hypertensive subjects participating in LE, but such an effect may not last as long as that of aerobic exercise alone. Similarly, Cunha³² found that moderate-intensity AE elicited PEH for SBP and DBP for over 21 hours. Pinto⁵² assessed the effect of concurrent training in water on normotensive subjects to show a similar effect on PEH from resistance and aerobic exercise.

Conclusion

Our study shows that elderly hypertensive individuals who exercised in water had lower SBP and DBP during the day than those trained in land exercise. In addition, hypotension was induced more quickly (two hours) by the exercise session after water-based exercise and lasted longer (24 hours) than that induced by land-based exercise. These data show that water-based exercise has a different pressure control than land-based exercise, such that water-based exercise constitutes a potential clinical approach for the treatment of hypertension.

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