Postexercise Hypotension After Aquatic Exercise in Older Women With Hypertension: A Randomized Crossover Clinical Trial

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BACKGROUND
Hypertension can be prevented and modified with lifestyle interventions that include regular exercise. Aquatic exercise is widely recommended for older adults for a variety of health benefits, but few studies have assessed the immediate ambulatory blood pressure (BP) response to aquatic exercise, a response termed postexercise hypotension (PEH). Thus, we assessed PEH after a session of aquatic exercise in physically active, older women with hypertension.

METHODS
Twenty-four women 70.0 ± 3.9 years with a resting systolic (SBP)/diastolic (DBP) BP of 124.0/72.3 mm Hg and body mass index of 29.8 ± 4.1 kg/m^2 were randomly assigned to participate in a 45-minute session of moderate intensity, water-based exercise (WATER) and a 45-minute land control session (CONTROL). All experimental sessions started at 9 sharply with 7 days between them. Subjects left the experiments wearing an ambulatory BP monitor for the next 21 hours.

RESULTS
SBP was lower by 5.1 ± 1.0 mm Hg after WATER than CONTROL over 21 hours ($P < 0.001$), over awake hours by 5.7 ± 1.1 mm Hg ($P < 0.001$), and sleep hours by 4.5 ± 0.4 mm Hg ($P = 0.004$). DBP was lower following WATER compared to CONTROL: 1.2 ± 0.3 mm Hg over 21 hours ($P = 0.043$); 0.9 ± 0.6 mm Hg over awake hours ($P = 0.101$); and 1.4 ± 0.9 mm Hg over sleep hours ($P = 0.039$).

CONCLUSIONS
Aquatic exercise elicited PEH (~5 mm Hg) over 21 hours, BP reductions that are comparable in magnitude to land aerobic exercise. The immediate antihypertensive benefits of acute aquatic exercise should continue to be explored in future studies.

Keywords: aerobic exercise; ambulatory blood pressure; blood pressure; elderly; hypertension; postexercise hypotension.

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Hypertension is the most prevalent cardiovascular disease risk factor among older adults.[1,2] In Brazil, the prevalence of hypertension 68% among the older adult population,[3] which is similar to that reported in other countries. Yet, global estimates show that high blood pressure (BP) rates are greater among men age 50 years and younger and women older than 50 years,[4] especially in those post-menopausal.[5,6] Regular exercise is a well-established lifestyle intervention for the prevention, treatment, and control of systemic arterial hypertension.[7–9] Individuals can benefit from both its immediate or short-term effects that persist up to 24 hours after an acute exercise bout, a response that is termed "postexercise hypotension" (PEH),[10,11] and its more long-term, chronic effects of exercise training.[8,12] Indeed, acute and chronic aerobic exercise reduces BP 5–7 mm Hg among adults with hypertension. However, acute and chronic effects of exercise on BP are typically examined after exercise on land.

Aquatic exercise is recommended for older adults, including those with overweight and obesity, due to a lower risk of injuries than land aerobic exercise as the buoyancy of water reduces body weight by ~90%.[13] However, the body of evidence on the effects of exercise in the aquatic environment on BP is scant and inconsistent. Santos and colleagues completed a systematic review on the BP effects of acute (4 studies) and chronic (6 studies) of moderate-intensity aquatic exercise among 189 adults with hypertension.[14] A wide range of BP response was reported for the acute studies, with systolic BP (SBP) reductions ranging from 8 to 20 mm Hg for up to 60 minutes in the laboratory; and most of the acute studies did not have a control group. Only one study reported a reduction in diastolic BP (DBP) of 5 mm Hg. Regarding chronic effects, SBP reductions ranging from 4 to 36 mm Hg were reported in a meta-analysis, and DBP reductions ranging from 10 to 16 mm

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Hg were also observed. However, the effect on DBP was reported in only 3 studies. The inconsistency in results may be due to different exercise intervention characteristics including water temperature[15] and pool depth[16] and small sample sizes, among others.

Our group has demonstrated the safety of prescribing aquatic exercise for 45 minutes at 70–75% of maximum heart rate (HR) adjusted for the aquatic environment among older women with hypertension.[17] In another study using the same exercise protocol, we found a reduction in SBP of 7.4 mm Hg for up to 20 minutes during recovery in the laboratory, but not DBP, compared to control session among middle-aged, overweight to obese women with hypertension on BP medication.[18]

We are one of the few that have completed randomized controlled trials investigating the efficacy of aquatic exercise to elicit PEH among adults with hypertension. The American College of Sports Medicine and other professional organizations do not routinely recommend aquatic exercise for the prevention, treatment, and control of hypertension, cautioning that more data are needed to establish the efficacy and safety of this exercise modality as antihypertensive lifestyle therapy. To the best of our knowledge, there are no studies assessing PEH using ambulatory BP monitoring (ABPM), the clinical gold standard methodology for assessing BP status,[7] after aquatic exercise among older women with hypertension. Thus, this randomized control trial aimed to assess the effects of an water-based exercise session on BP using ABPM among well-controlled older adults with hypertension taking medication for their high BP.

METHODS

We conducted a randomized clinical trial with a crossover design. This research project was reviewed and approved by Instituto de Cardiologia do Rio Grande do Sul/Fundação Universitária de Cardiologia institutional review board (protocol number 552.001 by Leonardo Martins Pires). The study follows the principles of the "Declaration of Helsinki". All subjects read and signed an informed consent form before participating in the study. Additionally, this study follows the recommendations as proposed by the CONSORT "Statement".[19]

Study sample

The inclusion criteria were: resting SBP ≤160 mm Hg and DBP ≤100 mm Hg documented by a physician (Table 1); 65 to 80 years of age; and physically active on land but not water (exercising 3 or more days per week as determined by the International Physical Activity Questionnaire long-form, IPAQ).[20] The exclusion criteria were: any febrile condition and/or infectious diseases; no other chronic diseases or conditions other than hypertension; body mass index >35 kg/m^2; active smoker; or physical or mental limitations that prevent exercising. Interestingly, only women responded to our invitation to participate in our study and, therefore, our participants were all females.

Table 1. Mean characteristics of the women (*n* = 24)

	Mean ± SD (95% CI)
Age (years)	70.0 ± 3.9 (68.4–71.6)
Body mass (kg)	68.9 ± 10.0 (64.7–73.1)
Height (cm)	152.3 ± 7.3 (149.2–155.3)
BMI (kg/m^2)	29.8 ± 4.1 (28.1–31.5)
Resting SBP (mm Hg)	124.0 ± 13.0 (118.4–129.4)
Resting DBP (mm Hg)	72.3 ± 8.3 (68.8–75.8)
Resting HR (bpm)	66.7 ± 13.8 (60.9–72.5)
β-Blockers	2
CCB	1
Diuretics	1
ACE inhibitor or ARBs	6
Diuretics + CCB	6
CCB + β-Blockers	1
β-Blockers + ACE inhibitors	1
CCB + ARBs	4
Diuretics + β-Blockers + ACE inhibitors	1
Diuretics + CCB + ARBs	1

Abbreviations: ACE, angiotensin-converting enzyme; ARBs, angiotensin II receptor blockers; BMI, body mass index; CCB, calcium channel blockers; CI, confidence interval; DBP, diastolic blood pressure; HR, heart rate; SBP, systolic blood pressure.

Study procedures

On visit 1, we explained to the participants the study procedures and answered their questions. Those who agreed to participate were asked to sign an informed consent form. During this visit, their medical history and BP were taken.

On visit 2, measurements of body weight and height were made to calculate body mass index. All subsequent experiments were randomly assigned with a randomized code generated by a blinded investigator using an automated digital system (www.randomization.org). All sessions occurred at the same time (9–9:45 AM) with 7 days between sessions.

Experimental sessions

The aquatic exercise session (WATER) was a continuous session of dynamic water-based exercise which consisted of a dynamic warm-up period (5 minutes), an active exercise period (35 minutes), and a cooldown period (5 minutes) to total 45 minutes. HR was continuously measured with heart monitors (Polar, RS 800 CX) to confirm the intensity of the WATER session. The WATER intensity was calculated according to the formula proposed by Kruel for exercise in an aquatic environment[21] as follows: HR for exercise = % × (HRmax − ΔHR); % is the intensity of exercise; HRmax is the maximum HR (estimated by 220 − age); ΔHR represents the difference between resting HR on land and resting HR in the water environment. Exercise intensities were 55–60% HRmax during warm-up; 70–75% HRmax during active exercise; and 55–60% HRmax during cooldown (Table 2). Besides, we used the Borg Rating of Perceived Exertion Scale to measure exercise intensity level in those participants on β-blockers, exercising between 13 and 14 on the Borg scale.

The study training session consisted of 18 groups of exercise performed continuously, each lasting on average 2 minutes and 30 seconds. Of these groups, 4 were lower-limb training exercise; 4 upper-limb; and 10 both upper- and lower-limb (combined). Each session had 3 components: warm-up including 2 combined exercise groups; cooldown at the end of the session; and the main part including 4 upper-limb, 4 lower-limb, and 6 combined exercise groups, alternating body segments.

The control session (CONTROL) was a 45-minute session with no exercise. During this session, participants remained seated or standing as desired. They read, talked, and drank water, but did nothing else.

BP measurements

BP measurements were taken and monitored using a ABPM protocol according to standard procedures.[22] BP monitoring devices (Spacelab, Redmond, WA) were used to obtain BP over 21 hours that consisted of 4 measurements per hour over awake period (10 AM to 10 PM) and 2 measurements per hour over sleep period (10 PM to 6 AM). All sessions started at 9 AM sharp and lasted 45 minutes. After the session, the participants remained in the sitting position for 15 minutes. At 10 AM sharp, the ABPM device was placed. BP measurements started at 10 AM (1st measure) and continued up to 6 AM the next day (totaling 21 hours). For data analysis, we calculated hourly averages for awake and sleep (during the same periods as mentioned above), and over 21 hours. SBP and DBP data are presented in 2 different manners: readings per hour during the day and the night periods, and the BP response determined as the difference (delta) between each hourly BP measurement from baseline after WATER compared to CONTROL.

Table 2. The protocol of the acute water exercise session

Session period	Exercise intensity	Heart rate
Warm-up (5 minutes)	55–60%	69.5 ± 2.1–77 ± 2.3 bpm
Active exercise (35 minutes)	70–75%	92 ± 2.7–99.5 ± 2.9 bpm
Cooldown (5 minutes)	55–60%	69.5 ± 2.1–77 ± 2.3 bpm

"Heart rate" (HR) was calculated as follows: % "Exercise intensity" × (HRmax − ΔHR); HRmax is the maximum HR (estimated by 220 − age); ΔHR represents the difference between resting HR on land and resting HR in the water environment; bpm: beats per minute.

Statistical analysis

The minimum sample size was determined based on a previous study conducted by our research group.[18] We estimated a sample size of 20 individuals for a 5% significance level, power of 80%, and a 5 mm Hg difference in SBP. We performed the Shapiro–Wilk test to assess the normality of distribution of numerical data. Data were described as mean ± SDs. A generalized estimating equation tested the differences between sessions by time (hourly; awake and sleep periods, and over 21 hours), as well as their interactions (session and time), followed by Bonferroni's *post-hoc* test. A 5% significance level was set.

RESULTS

We conducted a randomized crossover clinical trial; 33 women were recruited to the study, but 6 refused to participate for personal reasons. Thus, 27 women were randomized. After the first exercise session, 3 of them were excluded because they did not return for a subsequent

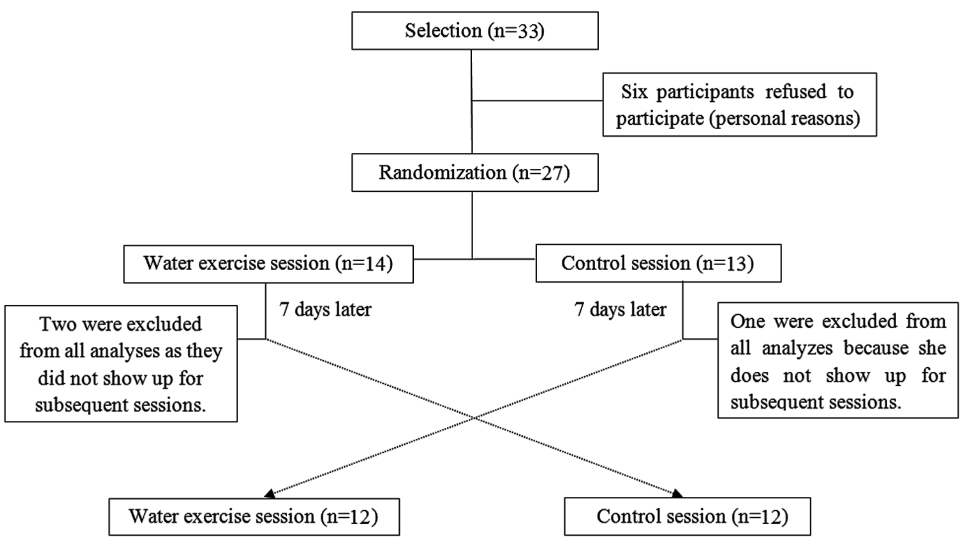

Figure 1. Design of the study.

session (Figure 1). Therefore, the final sample consisted of 24 participants.

Table 1 shows characteristics of the study participants. On average, the older women were obese and were well-controlled on the antihypertensive medications they were taking for their high BP. Twelve subjects reported high levels of physical activity as measured by the IPAQ, totaling 1,504 minutes.week^{-1} (~5,665 kcal) for work, home, and leisure physical activity and 224 minutes.week^{-1} (~1,133 kcal) of moderate-intensity physical activity. In turn, 9 participants reported moderate levels of physical activity, totaling 916 minutes.week^{-1} (~3,634 kcal) for work, home, and leisure activities and 112 minutes.week^{-1} of moderate-intensity physical activity (~634 kcal).

Figure 2 shows the hourly changes in SBP and DBP from baseline after WATER versus CONTROL. PEH was demonstrated for SBP and DBP after WATER, with major reductions seen 11 to 13 hours following exercise.

Compared to CONTROL, SBP was reduced after WATER by 5.1 ± 1.0 mm Hg over 21 hours ($P < 0.001$), by 5.7 ± 1.1 mm Hg during awake hours ($P < 0.001$), and by 4.5 ± 0.4 mm Hg during sleep hours ($P = 0.004$) (Figure 3). In turn, DBP was lower following WATER compared to CONTROL: 1.2 ± 0.3 mm Hg over 21 hours ($P = 0.043$); 0.9 ± 0.6 mm Hg over awake hours ($P = 0.101$); and 1.4 ± 0.9 mm Hg over sleep hours ($P = 0.039$) (Figure 3).

DISCUSSION

This is the first randomized controlled crossover clinical trial that assessed the effects of an aquatic exercise session on BP using ABPM among physically active older women with hypertension. The main finding of our study was that

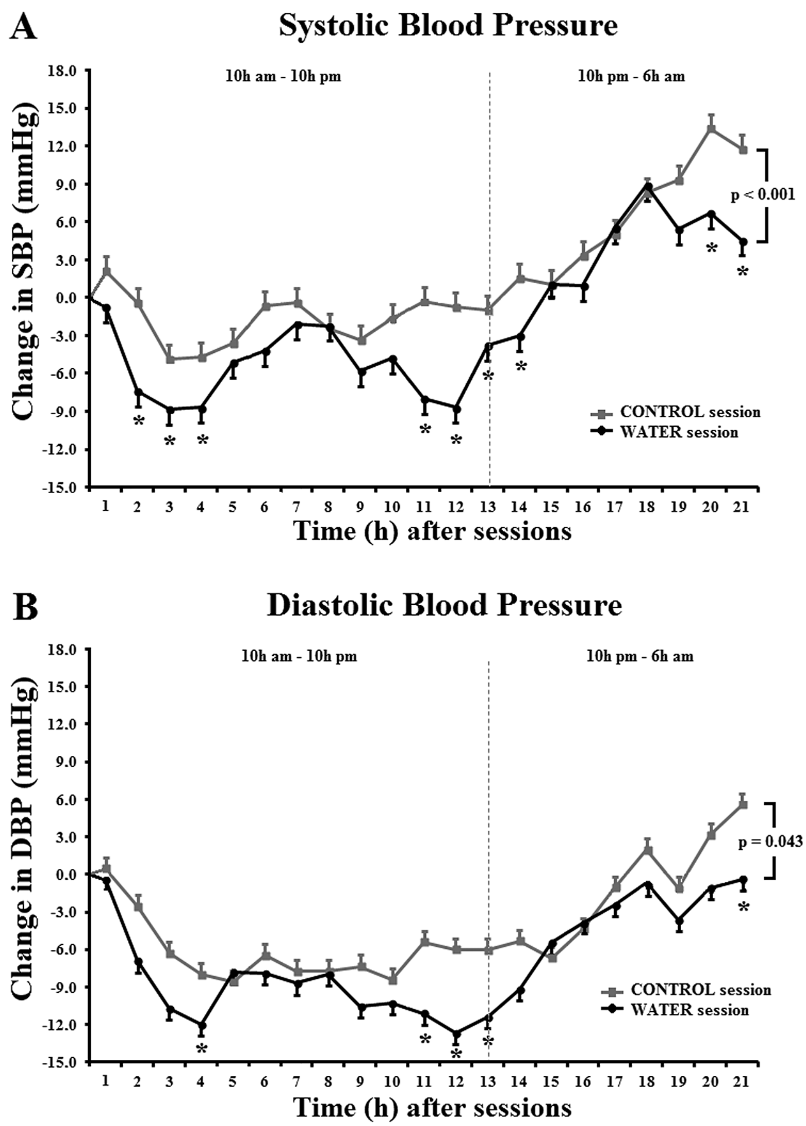

Figure 2. Kinetics of blood pressure at each exercise session compared to baseline. A generalized estimating equation (GEE) with repeated measures followed by Bonferroni's *post-hoc* test was used. (**A**) SBP, $P < 0.001$ for session and time. (**B**) DBP, P(session) = 0.043 and P(time) < 0.001. *$P < 0.05$ vs. control group during the same period. Abbreviations: DBP, diastolic blood pressure; SBP, systolic blood pressure.

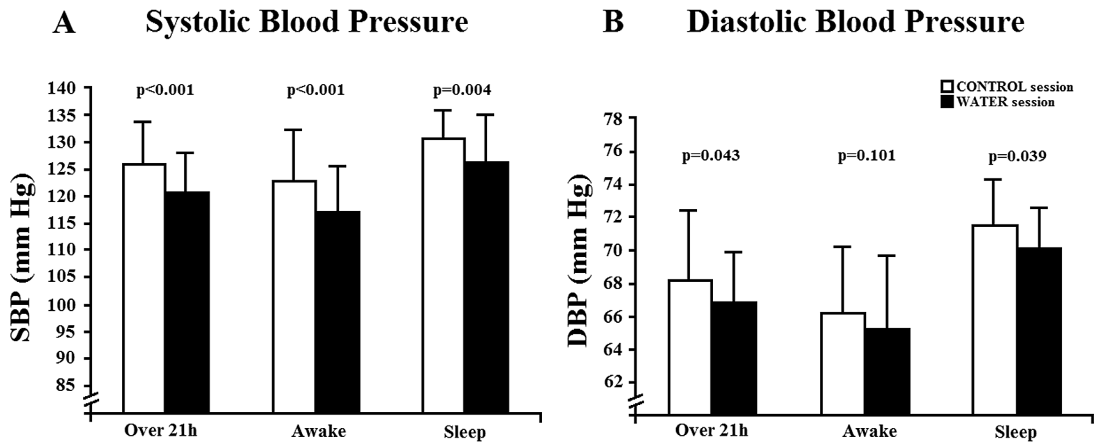

Figure 3. Changes in blood pressure during each exercise session. (**A**) SBP, systolic blood pressure and (**B**) DBP, diastolic blood pressure. Over 21 hours: all period analyzed; awake: 10 to 10 ; sleep: 10 to 6 .

moderate-intensity aquatic exercise elicited PEH for SBP and DBP over 21 hours. SBP was lower by ~5 mm Hg over 21 hours, ~6 mm Hg over awake hours, and ~4 mm Hg over sleep hours. Furthermore, DBP was lower by ~1 mm Hg over 21 hours and the night hours, but not over awake hours. These findings are consistent with and expand upon earlier findings from our laboratory. Previously, we found that a single aquatic exercise session reduced SBP by 7.4 mm Hg for up to 20 minutes in the laboratory among pharmacologically treated middle-aged women who were overweight to obese, with no change in DBP.[18]

The magnitude of PEH elicited by WATER is comparable to land aerobic exercise as reported by Brandao-Rondon, Alves[23] and Ciolac, Guimaraes[24] for cycling. Besides, our results were also comparable to Lakin, Notarius[25] using cycling (reduction in SBP by 3.1 mm Hg) and WATER (reduction in SBP by 5.2 mm Hg). Collectively, these findings suggest that the concurrent American College of Sports Medicine guidelines for the prevention, treatment, and control of hypertension be expanded to include WATER. Nonetheless, future research should continue to explore the BP merits of WATER due to the limited nature of the size of this literature.

The mechanisms for the immediate BP benefits of WATER *per se* are not yet clear but may be due to a reduction in peripheral vascular resistance[26] and suppression of the renin–angiotensin system.[27] The hydrostatic effects of immersion in water redirects ~700 ml of blood flow from the extremities (increased venous return) to the thorax.[16] These vascular alterations cause a stretching of the atrium and an increase in right intraventricular pressure, leading to increased cardiac output.[15] Mechanical stretching of atrial and/or arterial baroreceptors causes a marked reduction in renal sympathetic nerve activity and increases urine flow and sodium excretion.[28] Furthermore, hydrostatic compression of the chest leads to elastic loading of the chest wall and negative pressure breathing,[26] producing a cardiopulmonary reflex. Collectively, these changes produce compensatory bradycardia that, in addition to increased diuresis due to suppression of vasopressin secretion,[29] would elicit reductions in BP after a session of aquatic exercise.

This study has some limitations. We did not have a control group for the aquatic environment and the study participants exercised in an outdoor pool. However, this is a real-life scenario and we believe our findings evidence an effective PEH response in hypertensive elderly individuals. We did not measure HRmax values but rather used age-based estimates. Since there was a potential for bias, we monitored exercise sessions using the Borg Rating Scale. Another limitation was that of the 24 participants, 5 were on β-blockers. We also monitored their exercise intensity level using the Borg Rating Scale, without compromising the exercise session. To confirm, we (statistically) tested for BP differences between users and nonusers of β-blockers and all results were similar. In turn, strengths of our study include a randomized controlled crossover design and use of ABPM.

In conclusion, our study showed that physically active, well-controlled older women with hypertension experience clinically meaningful BP benefit from WATER. Overall, SBP in the WATER was lowered by ~5 mm Hg compared to CONTROL group over 21 hours after the exercise bout. Our results have a strong clinical implication since they have magnitude similar to those found in aerobic exercise, according to literature. Thus, we recommend further investigations to examine chronic effects and confirm the potential long-term hypotensive effect of water-based exercise in subjects with systemic arterial hypertension.

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DISCLOSURE

The authors declared no conflict of interest.

REFERENCES

1. Safar ME, Benetos A. Factors influencing arterial stiffness in systolic hypertension in the elderly: role of sodium and the renin-angiotensin system. *Am J Hypertens* 2003; 16:249–258.
2. Zieman SJ, Melenovsky V, Kass DA. Mechanisms, pathophysiology, and therapy of arterial stiffness. *Arterioscler Thromb Vasc Biol* 2005; 25:932–943.
3. Picon RV, Fuchs FD, Moreira LB, Fuchs SC. Prevalence of hypertension among elderly persons in urban Brazil: a systematic review with meta-analysis. *Am J Hypertens* 2013; 26:541–548.
4. Kearney PM, Whelton M, Reynolds K, Muntner P, Whelton PK, He J. Global burden of hypertension: analysis of worldwide data. *Lancet* 2005; 365:217–223.
5. Reckelhoff JF. Gender differences in the regulation of blood pressure. *Hypertension* 2001; 37:1199–1208.
6. Coylewright M, Reckelhoff JF, Ouyang P. Menopause and hypertension: an age-old debate. *Hypertension* 2008; 51:952–959.
7. Chobanian AV, Bakris GL, Black HR, Cushman WC, Green LA, Izzo JL Jr, Jones DW, Materson BJ, Oparil S, Wright JT Jr, Roccella EJ; Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure. National Heart, Lung, and Blood Institute; National High Blood Pressure Education Program Coordinating Committee. Seventh report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure. *Hypertension* 2003; 42:1206–1252.
8. Cornelissen VA, Smart NA. Exercise training for blood pressure: a systematic review and meta-analysis. *J Am Heart Assoc* 2013; 2:e004473.
9. Pescatello LS, MacDonald HV, Lamberti L, Johnson BT. Exercise for hypertension: a prescription update integrating existing recommendations with emerging research. *Curr Hypertens Rep* 2015; 17:87.
10. Cavalcante PA, Rica RL, Evangelista AL, Serra AJ, Figueira A Jr, Pontes FL Jr, Kilgore L, Baker JS, Bocalini DS. Effects of exercise intensity on postexercise hypotension after resistance training session in overweight hypertensive patients. *Clin Interv Aging* 2015; 10:1487–1495.
11. Keese F, Farinatti P, Pescatello L, Monteiro W. A comparison of the immediate effects of resistance, aerobic, and concurrent exercise on postexercise hypotension. *J Strength Cond Res* 2011; 25:1429–1436.
12. Moraes MR, Bacurau RF, Simões HG, Campbell CS, Pudo MA, Wasinski F, Pesquero JB, Würtele M, Araujo RC. Effect of 12 weeks of resistance exercise on post-exercise hypotension in stage 1 hypertensive individuals. *J Hum Hypertens* 2012; 26:533–539.
13. Barbosa TM, Garrido MF, Bragada J. Physiological adaptations to head-out aquatic exercises with different levels of body immersion. *J Strength Cond Res* 2007; 21:1255–1259.
14. Santos NS, Costa RFd, Kruel LFM. Effects of aquatic aerobic exercises on blood pressure in hypertensive adults: systematic review. *Brazil J Phys Act Health* 2014; 19:548–558.
15. Cider A, Sunnerhagen KS, Schaufelberger M, Andersson B. Cardiorespiratory effects of warm water immersion in elderly patients with chronic heart failure. *Clin Physiol Funct Imaging* 2005; 25:313–317.
16. Park KS, Choi JK, Park YS. Cardiovascular regulation during water immersion. *Appl Human Sci* 1999; 18:233–241.
17. Cunha RM, Vilaça-Alves J, Noleto MV, Silva JS, Costa AM, Silva CN, Póvoa TI, Lehnen AM. Acute blood pressure response in hypertensive elderly women immediately after water aerobics exercise: A crossover study. *Clin Exp Hypertens* 2017; 39:17–22.
18. Cunha RM, Arsa G, Neves EB, Lopes LC, Santana F, Noleto MV, Rolim TI, Lehnen AM. Water aerobics is followed by short-time and immediate systolic blood pressure reduction in overweight and obese hypertensive women. *J Am Soc Hypertens* 2016; 10:570–577.
19. Schulz KF, Altman DG, Moher D; CONSORT Group. CONSORT 2010 statement: updated guidelines for reporting parallel group randomised trials. *BMJ* 2010; 340:c332.
20. IPAQ Research Committee. *Guidelines for Data Processing and Analysis of the International Physical Activity Questionnaire (IPAQ) - Short and Long Forms*. 2005.
21. Kruel LF, Peyré-Tartaruga LA, Coertjens M, Dias AB, Da Silva RC, Rangel AC. Using heart rate to prescribe physical exercise during head-out water immersion. *J Strength Cond Res* 2014; 28:281–289.
22. SBC. Sociedade Brasileira de Cardiologia. *V Diretrizes Brasileiras de Monitorização Ambulatorial da Pressão Arterial Arq Bras Cardiol* 2011; 97:1–24.
23. Brandão Rondon MU, Alves MJ, Braga AM, Teixeira OT, Barretto AC, Krieger EM, Negrão CE. Postexercise blood pressure reduction in elderly hypertensive patients. *J Am Coll Cardiol* 2002; 39:676–682.
24. Ciolac EG, Guimarães GV, D'Avila VM, Bortolotto LA, Doria EL, Bocchi EA. Acute aerobic exercise reduces 24-h ambulatory blood pressure levels in long-term-treated hypertensive patients. *Clinics (Sao Paulo)* 2008; 63:753–758.
25. Lakin R, Notarius C, Thomas S, Goodman J. Effects of moderate-intensity aerobic cycling and swim exercise on post-exertional blood pressure in healthy young untrained and triathlon-trained men and women. *Clin Sci (Lond)* 2013; 125:543–553.
26. Pendergast DR, Moon RE, Krasney JJ, Held HE, Zamparo P. Human physiology in an aquatic environment. *Compr Physiol* 2015; 5:1705–1750.
27. Larochelle P, Cusson JR, du Souich P, Hamet P, Schiffrin EL. Renal effects of immersion in essential hypertension. Carvedilol Study Group. *Am J Hypertens* 1994; 7:120–128.
28. Epstein M, Johnson G, DeNunzio AG. Effects of water immersion on plasma catecholamines in normal humans. *J Appl Physiol Respir Environ Exerc Physiol* 1983; 54:244–248.
29. Hammerum MS, Bie P, Pump B, Johansen LB, Christensen NJ, Norsk P. Vasopressin, angiotensin II and renal responses during water immersion in hydrated humans. *J Physiol* 1998; 511 (Pt 1):323–330.