Original Article

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Acute blood pressure response in hypertensive individuals with amputations after aquatic aerobic exercise: randomized crossover trial

Resposta aguda da pressão arterial em indivíduos hipertensos com amputações após exercício aeróbico aquático: ensaio clínico cruzado randomizado

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ABSTRACT

Objective: To assess the effects of an aquatic aerobic exercise session on the BP of hypertensive individuals with amputations and to evaluate whether there is a correlation between BP response to exercise and clinical aspects. **Method:** Crossover study conducted at a rehabilitation center in São Paulo, Brazil. Individuals underwent an initial assessment and were randomly allocated into an experimental session (45-minute session of aquatic aerobic exercise) and a control session (immersion at rest), alternating sessions after one week. BP was measured at rest, immediately after leaving the swimming pool and after 10, 20 and 30 minutes. **Results:** Ten patients were included (mean age: 58.9 years). The BP values for immersion at rest were significantly lower than the BP values on land (p= 0.003). There was no significant difference in BP variation between sessions. **Conclusion:** Aerobic exercise in aquatic environments does not alter the BP in amputees and can be considered a safe intervention for this parameter.

Keywords: Hypertension, Amputees, Arterial Pressure, Hydrotherapy, Exercise

RESUMO

Objetivo: Avaliar os efeitos de uma sessão de exercício aeróbio aquático na PA de indivíduos hipertensos com amputações e avaliar se existe correlação entre a resposta da PA ao exercício e aspectos clínicos. **Método:** Estudo cruzado realizado em um centro de reabilitação em São Paulo, Brasil. Os indivíduos passaram por uma avaliação inicial e foram alocados aleatoriamente em uma sessão experimental (sessão de 45 minutos de exercício aeróbico aquático) e uma sessão controle (imersão em repouso), alternando sessões após uma semana. A PA foi medida em repouso, imediatamente após sair da piscina e após 10, 20 e 30 minutos. **Resultados:** Foram incluídos dez pacientes (idade média: 58,9 anos). Os valores da PA para imersão em repouso foram significativamente inferiores aos valores da PA em terra (p= 0,003). Não houve diferença significativa na variação da PA entre as sessões. **Conclusão:** O exercício aeróbio em ambiente aquático não altera a PA em amputados e pode ser considerado uma intervenção segura para este parâmetro.

Palavras-chaves: Hipertensão, Amputados, Pressão Arterial, Hidroterapia, Exercício Físico

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Conflict of Interests
Nothing to declare

Submitted: May 20, 2024
Accepted: September 10, 2024

How to cite
Lourenço MA, Gouvêa JXM, Carvalho MELM, Baccaro VM, Magalhães DRC, Castro CRAP, et al. Acute blood pressure response in hypertensive individuals with amputations after aquatic aerobic exercise: randomized crossover trial. Acta Fisiatr. 2024;31(4):207-213.

DOI: 10.11606/issn.23170190.v31i4a226387

INTRODUCTION

Lower limb amputations lead to various clinical complications, especially in more proximal amputations.[1,2,3] Studies have shown that the risk of death from cardiovascular disease is higher in transfemoral amputees than in healthy individuals[2,4,5] due to the high prevalence of cardiovascular disease concomitant with a high amputation[6] even young adults with traumatic amputations and without previous comorbidities have a greater tendency to develop cardiovascular disease when compared to the general population of the same age.[2,7] The presence of coronary artery disease, myocardial infarction, congestive heart failure, arrhythmias and stroke have been associated with peri- and postoperative mortality in individuals with amputations,[8] and these conditions are associated with blood pressure (BP) variability and hypertension.[9,10]

Due to the clinical conditions associated with decreased levels of physical activity, individuals with amputations tend to have a deficit in physical capacity, which aggravates their clinical and functional condition.[11,12] Considering that cardiorespiratory endurance is key for performing activities, it is expected that rehabilitation programs for individuals with amputations will include an attempt to recover or increase the physical capacity of each individual.[13] In the case of lower limb amputees, in which the energy expenditure required to walk with a walking aid or prosthesis is much higher than that for a person without a disability,[13,14] this physical approach is essential for greater rehabilitation success.[13] Effective rehabilitation strategies should include appropriate cardiac precautions, such as monitoring the target heart rate (HR) and BP[2] to avoid complications and facilitate the follow-up of the proposed physical treatment.

However, due to the frequent clinical complications related to the cardiovascular condition, such as decompensation of BP levels, individuals with amputations undergoing a rehabilitation program tend to interrupt their treatment more frequently, hampering their rehabilitation progress and possible prosthetic fitting and contributing to clinical and functional decline.[15] Commonly, in clinical practice, physical therapy needs to be discontinued due to increases in BP in response to the increased cardiorespiratory demand imposed, hindering the performance of the proposed exercises during preprosthetic and prosthetic rehabilitation.[6,15]

Aquatic physical therapy is part of the rehabilitation program of individuals with amputations, in which, through the physical principles of water, favors a gain in physical functioning and independence and allows for preprosthetic preparation by involving physical conditioning training.[16] There are reports that immersion in thermoneutral water leads to cardiovascular changes such as increased systolic volume without substantial changes in HR and a persistent increase in cardiac output, with a consequent change in BP.[17] However, the actual BP response to immersion is not yet clear because studies diverge with respect to recording changes in BP levels,[17,18] especially during physical activity in a water environment – some studies with hypertensive individuals who performed aquatic aerobic exercise show a significant decrease in BP postrest compared to baseline BP levels.[19,20,21]

To date, no studies have evaluated the BP behavior of hypertensive individuals with amputations after physical activity under immersion. Considering that these patients tend to present complications related to increased BP during exercise and that aerobic activities play an important role in the rehabilitation process of individuals with amputations, it is necessary to elucidate the actual acute BP response during an aquatic aerobic exercise session in these individuals.

OBJECTIVE

The aim of this study was to determine the effects of an aquatic aerobic exercise session on BP in hypertensive individuals with amputations and whether this form of exercise can be considered hemodynamically safe for this population; and evaluate whether there is a correlation between exercise BP variation and clinical data.

METHOD

A randomized crossover trial was conducted in the Aquatic Physical Therapy Department of the Associação de Assistência à Criança Deficiente (AACD) in São Paulo (SP), Brazil. The study was approved by the ethics committee of the institution under opinion no. 2.618.038/2018 and registered on Clinical Trial Registry Number RBR-3F9K4R.

Participants were selected from the institution's electronic medical records, and after telephone contact and an invitation to participate in the study, they were informed about the details of the research. If they agreed and were able to participate, an informed consent form was signed.

Study design

Individuals selected for participation in the study were randomly allocated to one of two groups to start in either a control session (CS) or experimental session (ES) and then performed the other session one week after the initial session.

Eligibility criteria

Individuals with a unilateral transfemoral amputation, who were male (women were not included to avoid possible hormonal interference), aged between 40 and 65 years, with a medical diagnosis of systemic arterial hypertension (SAH) controlled with medication, with systolic blood pressure (SBP) ≤160 mmHg and diastolic blood pressure (DBP) ≤ 100 mmHg at rest at the time of assessment; and already adapted to the water environment (so that a possible anxiety or fear of being in the pool could be avoided) were included. Individuals with a body mass index (BMI)[22] corrected for amputees greater than or equal to 30 kg/m², with decompensated diabetes mellitus (DM) according to a previous medical assessment, with a history of a cardiovascular event (acute myocardial infarction, stroke) in the last three months, who were smokers, with renal failure, and had orthopedic problems or any physical or mental impairment that would hinder physical exercise were excluded.

A total of 45 transfemoral amputees were selected after a review of the medical records. After being contacted by telephone, 20 individuals were excluded because they did not meet the inclusion criteria, and 14 were excluded for other reasons, such as difficulty with transportation to the institution and no interest in participating in the study. Therefore, 11 participants were included.

During the collection period, an individual presented clinical complications (due to decompensated DM) in the week after his initial assessment and was excluded from the study, for a final sample of 10 patients.

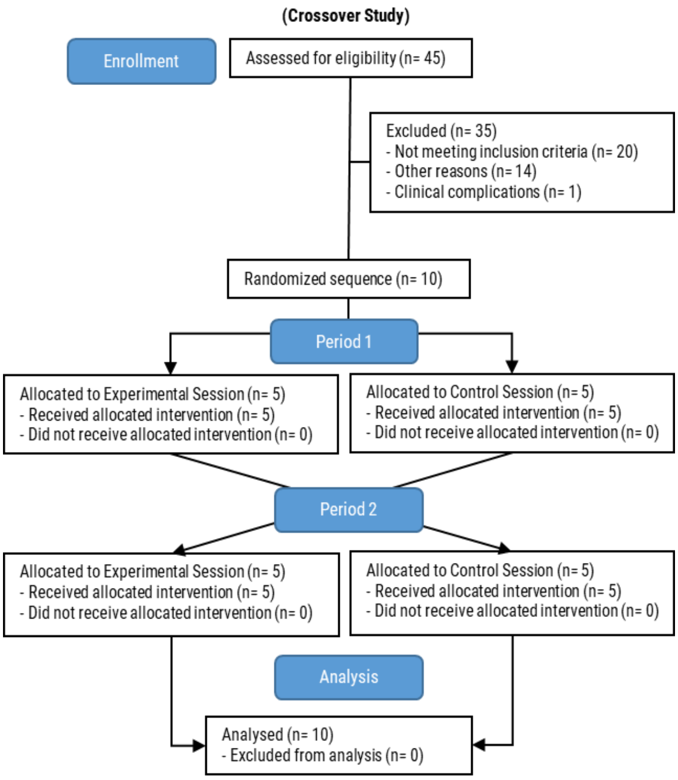

Figure 1. Cross-over Study - CONSORT Diagram

Collection procedures

First, the participants were assessed on land, where sociodemographic data such as age, ethnicity and current occupation; clinical data such as amputation cause and laterality, time since amputation, time of diagnosis of SAH, other comorbidities, medications use, history of previous physical activity (sedentary or participant in regular physical activity), previous smoking or alcohol use; physical functioning data such as main form of locomotion, use or not of a prosthesis, Amputee Mobility Predictor (AMP) score[23] and 2-minute walk test;[24] anthropometric data such as height, weight, corrected BMI,[22] waist-hip ratio; and vital signs at rest such as SBP, DBP and HR were collected. The following materials were used: scale, tape measure, digital arm sphygmomanometer (Omron model HEM 7320), and cardiac monitor (Polar FT1).

After the assessment, random allocation was performed by simple lottery, and the participants were initially divided into the ES and CS, and after exactly one week, the other session was performed (at the same time as the previous session). The individual who performed the initial CS performed the ES after one week and the individual who performed the initial ES performed the CS after one week. The CS served as a basis for comparing the acute BP response presented after aquatic aerobic exercise in the ES.

The ES of aquatic aerobic exercise lasted 45 minutes and consisted of 5 minutes of warm-up, 35 minutes of continuous aerobic activity ("pedaling" with the stump and preserved lower limb, with the trunk stabilized) and 5 minutes of cool down, performed in a pool with thermoneutral water (average of 33.5 ºC) and a depth of 140 cm, with the whole body immersed, keeping only the head out of the water.

The participants performed the session using a pulsimeter to control and maintain HR during exercise in the aquatic environment. The exercise training range was predicted according to the formula published by Kruel et al.[25] exercise HR = % x (HRmax - ΔHR), where % is the exercise intensity, HRmax is the maximum HR estimated by the calculation 220 – age, and ΔHR is the difference between HR at rest outside the pool and HR at rest inside the pool. The intensity ranged from 55-60% HRmax during warm-up, 70-75% HRmax during the proposed aerobic exercise, and 55-60% HRmax during cool down.

In the CS, which also lasted 45 minutes, the participants remained seated, in the same aquatic environment, with the body immersed and the head out of the water but without performing any physical activity. If they wished, they were allowed to talk during the session but had to remain at rest.

In both sessions, the BP was measured in a sitting position, using the digital monitor on the left upper limb, always outside the pool and at different times, to evaluate the acute BP response and its behavior after immersion at rest/during the exercise recovery period. BP was checked before the session (after 20 minutes at rest), immediately after the session in the pool, and at 10, 20 and 30 minutes after the end of the session – T0, T1, T2, T3, T4, respectively, also at rest.

Statistical analysis

All statistical and graphical tests were performed using IBM SPSS statistics[26] or Microsoft Excel®. The results with a descriptive level lower than 5% ($p<0.05$) were considered significant and the confidence intervals (CIs) reported are 95% (alpha 0.05). Variables are described by their frequency and CI or by measures of central tendency and dispersion. The normal distribution of the quantitative variables was assessed using the Kolmogorov-Smirnov test.

To test the hypothesis that there is no mean difference in SBP, DBP or HR over time between the ES and CS, a fixed effects model was constructed using repeated measures analysis of covariance. The association between quantitative and qualitative variables was estimated using the paired Student's t test, and the correlation between the quantitative variables was tested using the Spearman's correlation coefficient.

RESULTS

The participants had a mean age of 58.9 years, and all amputations had a vascular etiology. Most participants were retired (80%) and previously smoked (90%) and consumed alcohol (90%) and were considered sedentary before amputation (70%) and after amputation (90%). Regarding activity, short-distance walks in the community (50%), mainly using axillary crutches (40%), was the most reported form (Table 1).

The most prevalent comorbidities were DM and heart disease; all participants were using more than one antihypertensive drug, and 20% had undergone previous cardiovascular interventions (Table 2).

There was a significant difference in BP when comparing rest on land ($p= 0.003$) with rest under water immersion ($p= 0.004$). The SBP and DBP values were lower under immersion than on land. The SBP, DBP and HR were normally distributed and expressed as means. The descriptive values are shown in Table 3.

The mean SBP, DBP and HR were calculated in each session separately and at each time that the parameter was measured (at rest before immersion, immediately after the session in the pool and 10, 20 and 30 minutes after leaving the pool), from T0 to T4.

Table 1. Sociodemographic, clinical and functionalcharacteristics; N= 10; CI= 95%

	n	%	95% CI
Ethnicity			
Black	1	10	0 – 30
Mixed	4	40	10 – 70
White	5	50	20 – 80
Laterality of the amputation			
Right	6	60	30 – 90
Left	4	40	10 – 70
Type of walking			
At home	1	10	0 – 30
Short-distance in the community	5	50	20 – 80
Long-distance in the community	4	40	10 – 70
Primary locomotion			
Prosthesis	2	20	0 – 50
Forearm crutches	2	20	0 – 50
Axillary crutches	4	40	10 – 70
Walker	1	10	0 – 30
Manual wheelchair	1	10	0 - 30

Legend: n: number of participants; CI: Confidence Interval

Table 2. Clinical/cardiovascular characteristics

	No (n)	Yes (n)	95% CI
Comorbidity			
DM	3	7	40 – 90
POAD	6	4	10 – 70
Cardiopathy	4	6	30 – 90
Other	8	2	0 – 50
Anti-hypertensive Medication			
Beta-blockers	7	3	10 – 60
Adrenergic inhibitors	8	2	0 -50
Calcium channel blockers	7	3	10 – 60
Diuretics	4	6	30 – 90
ACE inhibitors	5	5	20 – 80
Vasodilators	8	2	0 – 50
AT receptor blockers	7	3	10 – 60
Previous Cardiac Intervention	8 (80%)	2 (20%)	

Legend: n: number of participants; CI: Confidence Interval; DM: diabetes mellitus; POAD: peripheral obstructive arterial disease; ACE: angiotensin-converting enzyme; AT: angiotensin

There was no significant difference in the SBP and DBP measurements between the ES and CS for times T0, T1, T2, T3 and T4, indicating that when aquatic aerobic exercise was performed, participant BP was the same as that in the session of rest in the water environment.

In the evaluation of HR between the two sessions, there was a mean difference of 10.9 bpm, with HR being slightly higher in the ES group than in the CS group. When HR was evaluated between the two groups with regard to evaluation times, a sig-nificant increase in HR in the ES was observed immediately after leaving the pool (time T1), returning to baseline levels over time. When correlating the variation (final - initial) in SBP, DBP and HR after exercise (from T0 to T4) with data such as time since amputation, time since smoking cessation, number of comorbid-ities and number of antihypertensive medications, the only mod-erate (negative) correlation was observed between time since amputation and variation in DBP, indicating that there was less variation in DBP between the time points measured as the time since amputation increased (Table 4).

Table 3. Descriptive statistics of SBP, DBP and HR for the different sessions and time points

Session	Time	Mean	95% CI	
			Lower limit	Upper limit
SBP Control	T0	131.6	120.1	143.1
	T1	147.0	135.5	158.5
	T2	138.5	127.0	150.0
	T3	136.1	124.6	147.6
	T4	135.7	124.2	147.2
	Total	137.8	132.6	142.9
SBP Experimental	T0	138.5	127.0	150.0
	T1	140.0	128.5	151.5
	T2	129.8	118.3	141.3
	T3	129.6	118.1	141.1
	T4	127.5	116.0	139.0
	Total	133.1	127.9	138.2
DBP Control	T0	79.6	74.3	84.9
	T1	82.8	77.5	88.1
	T2	81.6	76.3	86.9
	T3	80.0	74.7	85.3
	T4	78.4	73.1	83.7
	Total	80.4	78.1	82.8
DBP Experimental	T0	77.9	72.6	83.2
	T1	77.3	72.0	82.6
	T2	76.1	70.8	81.4
	T3	77.3	72.0	82.6
	T4	77.1	71.8	82.4
	Total	77.1	74.7	79.5
HR Control	T0	75.2	68.1	82.3
	T1	70.2	63.1	77.3
	T2	70.1	63.0	77.2
	T3	70.7	63.6	77.8
	T4	71.6	64.5	78.7
	Total	71.5	68.3	74.7
HR Experimental	T0	77.8	70.7	84.9
	T1	90.3	83.2	97.4
	T2	81.9	74.8	89.0
	T3	81.4	74.3	88.5
	T4	80.8	73.7	87.9
	Total	82.4	79.2	85.6

Legend: T0: at rest before entering the pool; T1: immediately after the pool session; T2: 10 minutes after the pool session; T3: 20 minutes after the pool session; T4: 30 minutes after the pool session; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; HR: Heart rate; CI: Confidence Interval

Table 4. Spearman correlation test

		Time since amputation (months)	Number of comorbidities	Number of antihypertensive medications	Time since smoking cessation
Systolic blood pressure (difference T0 and T4)	Correlation coefficient (*r*)	-0.282	-0.501	0.108	0.033
	P value	0.43	0.140	0.767	0.932
	N	10	10	10	9
Diastolic blood pressure (difference T0 and T4)	Correlation coefficient (*r*)	**-0.674	-0.391	0.145	-0.444
	P value	*0.033	0.264	0.69	0.232
	N	10	10	10	9
Heart rate (difference T0 and T4)	Correlation coefficient (*r*)	-0.414	-0.386	-0.558	-0.333
	P value	0.234	0.270	0.094	0.381
	N	10	10	10	9

*Legend: * p <0.05; ** r between 0.5 and 0.7: moderate correlation, r values lower than this range indicate a weaker correlation, while higher r values indicate a stronger correlation*

DISCUSSION

In the present study, the BP (SBP and DBP) values decreased when the individuals were at rest immersed in water compared to the values on land, and there was no significant difference in BP variation between the sessions.

The physiological effects provided by water are broad and involve cardiac, respiratory, renal and musculoskeletal responses.[27] During immersion, water exerts pressure on the body, i.e., hydrostatic pressure.[27,28] As an effect on the venous return system, which is sensitive to external pressure differences, there is variation in the hydrostatic pressure gradient, displacing blood to the largest vessels of the abdominal cavity and to the heart.

The cardiovascular effects of immersion include bradycardia, peripheral vasoconstriction and blood diversion to vital areas. Bradycardia caused by immersion is superimposed on tachycardia because exercise increases the oxygen demand, and to avoid hypoxemia, there is a compensatory increase in HR.[17,27,28]

Studies have shown that elderly men and women with hypertension without amputations exhibit reduced SBP and DBP after water exercise [20,21,30,31] and after exiting the water,[20,21] corroborating the findings of the present study. The hypothesis that likely explains these results is that exercise promotes BP reduction by reducing cardiac output (CO), which is associated with decreased HR and sympathetic tone in the heart (less sympathetic intensification and greater vagal withdrawal). In immersion, there is an increase in pulmonary capillary blood flow, and with this, there is an increase in the systolic volume and a decrease in HR, resulting in a decrease in BP values.[17-20,27-30]

A systematic review that evaluated the effect of aquatic physical therapy on hypertensive individuals concluded that aquatic exercises decreased both acute BP (immediately after exercise) and had effects on the chronic response, showing that aquatic exercises are an efficient alternative in the treatment of hypertension.[30] Although this finding is not the focus of this study, which evaluated acute responses only, there was a reduction in BP at immersion and maintenance of BP levels without significant variation after exercise in individuals with amputations.

There was no difference in BP between the ES and CS groups or in the intragroup evaluation of time points. These data were similar to previous findings with elderly and hypertensive individuals[29] and hypertensive women after aquatic exercise, i.e., BP decreased in the experimental group when compared to that in the control group.[20] It can thus be inferred that thermoneutral water is a medium that assists in the maintenance of BP during exercise, and it is suggested that this liquid medium is a safe environment for this parameter because no changes were observed in BP during aquatic exercise. The small sample size limited the inference about type II error, but the study design, paired and randomized, reduced possible biases. In addition, by observing the descriptive data, the mean BP values in the ES group were lower than those in the CS group, reinforcing this hypothesis.

Regarding the comparison between the effects of aquatic exercise and exercise on land on BP, studies with other populations[19,28] showed that although both protocols reduced SBP and DBP, aquatic exercise was more effective at decreasing BP values when compared to exercise on land. This finding demonstrates the hypotensive effect of aerobic exercise, especially exercise performed in aquatic environments with thermoneutral temperatures.[19,28]

The HR immediately after exiting the pool in the ES increased from 77.8 to 90.3 bpm; in the CS, the HR decreased from 75.2 to 70.2. Although the physical effects of water cause bradycardia in immersion, exercise tachycardia compensates to avoid a reduction in oxygen demand – which is increased during exercise - protecting the body against hypoxia and other complications.[17,25,27,28]

Thus, the increase in HR is expected due to the demand of aerobic exercise, thus showing the effectiveness of exercise for cardiorespiratory fitness and supporting the hypothesis of the safety of the exercise, given that even with aerobic activity, HR returned to baseline values 10 minutes after exercise and was not increased in relation to the CS.

The literature on the subject is scarce. Thus, further clinical trials with longer intervention protocols are suggested to confirm the efficiency of aquatic exercise in the rehabilitation of this population, strengthening the results found.

The results of this study corroborate other findings and show that aerobic training in aquatic environments is safe because there is no significant variability in BP, thus being an effective alternative for the treatment and rehabilitation of these individuals.

The somatotype meso-endomorph was the most common in SA, followed by endo-mesomorph in a non-atrophic sample with overweight, but hypertrophic and lean in ankylosing and hypotrophic spondylitis, and lean in PSA. Meso-endomorph predominate in males while endomorph mesomorph in females. Endo-mesomorph presents long-lived disease and mesomorph endomorph presents longer diagnosis time. Meso-endomorph and mesomorph endomorphs aggregate three phenotypes whereas endo-mesomorph and endomorph mesomorph aggregate two phenotypes, and balanced mesomorph one phenotypes. Future studies, including somatotype, spondyloarthritis, and their clinical and social profiles, may reveal a potential correlation with SA prognosis and offer crucial information for therapeutic decisions.

CONCLUSION

Aerobic exercise in aquatic environments does not alter the BP in individuals with amputations and can be considered a safe intervention for this parameter. There were no correlations between the studied variables and BP variation. Aquatic aerobic exercise may be an efficient and hemodynamically safe alternative to assist in the rehabilitation of hypertensive adults with amputations.

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