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TÁSSIA MAGNABOSCO SISCONETO

**EFEITO DO EXERCÍCIO AQUÁTICO NA RESPOSTA AGUDA DA PRESSÃO
ARTERIAL**

UBERLÂNDIA

2024

TÁSSIA MAGNABOSCO SISCONETO

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ARTERIAL**

Dissertação apresentada ao Programa de Pós-graduação em Ciências da Saúde da Faculdade de Medicina da Universidade Federal de Uberlândia, como requisito parcial para obtenção do título de Mestra em Ciências da Saúde.

Área de concentração: Ciências da Saúde.

Orientador: Prof. Dr. Guilherme Morais Puga
Coorientadora: Prof^ª. Dr^ª. Ana Carolina Kanitz.

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Presidente da banca: Prof. Dr. Guilherme Morais Puga.

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RESUMO

Introdução: O processo de envelhecimento é marcado por diversas alterações responsáveis pelo aumento do risco de incidência de doenças crônicas, como a hipertensão arterial (HA). Além disso, mulheres na pós-menopausa apresentam essas alterações de forma precoce através da redução dos hormônios sexuais femininos. Sabe-se que o exercício físico é capaz de promover a redução da pressão arterial (PA) após uma sessão, dentre eles, o exercício aquático é amplamente procurado por essa população e os seus efeitos são estudados para prevenção e tratamento da HA. **Objetivo:** Investigar os efeitos de uma sessão de exercício aquático, em posição vertical, na pressão arterial. **Métodos:** Foi realizada uma revisão sistemática e metanálise com busca de ensaios clínicos realizados com idosos (≥ 60 anos) e publicados até agosto de 2023 em bases digitais (EMBASE, PUBMED, Lilacs, SPORTDiscus e Web of Science). Posteriormente, foi realizado um ensaio clínico, cruzado e randomizado com 22 mulheres pós-menopausadas hipertensas ($58 \pm 4,5$ anos). Aconteceram duas sessões: exercício intervalado de alta intensidade aquático (HIIIE) e controle (CON) com duração total de 24 minutos. As avaliações foram divididas em período pré, pós-intervenção laboratorial e pós-intervenção ambulatorial, as variáveis avaliadas foram: PA de repouso e ambulatorial, variabilidade da PA e da frequência cardíaca, reatividade da PA e nitrito salivar. **Resultados:** Foram incluídos 7 estudos na metanálise e os resultados mostraram que o exercício aquático promoveu redução na pressão arterial sistólica (PAS) de -6,86 mmHg até 1 hora e em -4,14 mmHg durante 24 horas após a sessão. Porém, apresentou efeito nulo relação às respostas da pressão arterial diastólica (PAD). Além disso, a análise de subgrupos mostrou que o HIIIE reduziu a PAS em -15,50 mmHg e a PAD em -5,97 mmHg após as sessões. Já o exercício contínuo de intensidade moderada foi capaz de reduzir a PAS em -4,91 mmHg, sem efeito para a PAD até 1 hora após as sessões. Não foi possível fazer a análise de subgrupos durante 24 horas. O ensaio clínico encontrou que a sessão HIIIE promoveu redução da PAS e PAD até 1 hora e, na PAS durante 24 horas após o exercício, em comparação com a sessão CON ($p=0,04$). Não houve diferença na variabilidade da PA e frequência cardíaca, reatividade da PA e concentração de nitrito ($p>0,05$). **Conclusão:** O exercício aquático agudo é capaz de reduzir a PA de idosos e de mulheres pós-menopausadas hipertensas até 24 horas após as sessões. Assim, o exercício aquático realizado em posição vertical, pode ser considerado benéfico para a redução da PA, contribuindo para a prevenção e tratamento da HA.

Palavras-chave: Exercício Físico; Hipertensão; Hipotensão Pós-Exercício; Idoso; Pós-menopausa.

ABSTRACT

Introduction: The aging process is marked by several changes responsible for increasing the risk of chronic diseases, such as arterial hypertension (AH). Additionally, postmenopausal women experience these changes early due to the reduction of female sex hormones. It is known that physical exercise can promote a reduction in blood pressure (BP) after a session, among them, aquatic exercise is widely sought after by this population, and its effects are studied for the prevention and treatment of AH. **Objective:** To investigate the effects of a session of aquatic exercise, in a vertical position, on blood pressure. **Methods:** A systematic review and meta-analysis were conducted with a search for clinical trials conducted with the elderly (≥ 60 years) and published until August 2023 in digital databases (EMBASE, PUBMED, Lilacs, SPORTDiscus, and Web of Science). Subsequently, a randomized crossover clinical trial was conducted with 22 hypertensive postmenopausal women (58 ± 4.5 years). Two sessions took place: aquatic high-intensity interval exercise (HIIE) and control (CON) with a total duration of 24 minutes. Assessments were divided into pre-intervention, post-laboratory intervention, and post-ambulatory intervention periods; the variables evaluated were: resting and ambulatory BP, BP and heart rate variability, BP reactivity, and salivary nitrite. **Results:** Seven studies were included in the meta-analysis, and the results showed that aquatic exercise promoted a reduction in systolic blood pressure (SBP) of -6.86 mmHg up to 1 hour and - 4.14 mmHg during 24 hours after the session. However, it showed a null effect on diastolic blood pressure (DBP) responses. Additionally, subgroup analysis showed that HIIE reduced SBP by -15.50 mmHg and DBP by - 5.97 mmHg after sessions. On the other hand, continuous moderate-intensity exercise reduced SBP by -4.91 mmHg, with no effect on DBP up to 1 hour after sessions. Subgroup analysis for 24 hours was not possible. The clinical trial found that the HIIE session promoted a reduction in SBP and DBP up to 1 hour and SBP during 24 hours after exercise, compared to the CON session ($p=0.04$). There was no difference in BP and heart rate variability, BP reactivity, and nitrite concentration ($p>0.05$). **Conclusion:** Acute aquatic exercise is capable of reducing BP in the elderly and hypertensive postmenopausal women up to 24 hours after sessions. Thus, aquatic exercise performed in a vertical position may be considered beneficial for reducing BP, contributing to the prevention and treatment of AH.

Keywords: Exercise; Hypertension; Post-Exercise Hypotension; Aged; Postmenopause.

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LISTA DE ABREVIACÕES E SIGLAS

AE - Átrio esquerdo

FC – Frequência cardíaca

HA – Hipertensão arterial

HIIE – exercício intervalado de alta intensidade

HPE – Hipotensão pós-exercício

NO – Óxido nítrico

PA – Pressão arterial

PAS - Pressão arterial sistólica

RVP - Resistência vascular periférica

VE - Ventrículo esquerdo

VFC – Variabilidade da frequência cardíaca

VPA – Variabilidade da pressão arterial

LISTA DE ABREVIACÕES E SIGLAS

ABPM - Ambulatory blood pressure
AH - Arterial hypertension
ARV - Average real variability of BP over 24 hours.
AUC - Area under the curve
BMI - Body mass index
BP - Blood pressure
BPV - Blood pressure variability
CON – Control session
DBP - Diastolic blood pressure
GEE - Generalized estimating equation
HF - Power in the high-frequency range.
HIIE - High-intensity interval exercise
HR - Heart rate
HRV - Heart rate variability
IPAQ - International Physical Activity Questionnaire
JBI - Joanna Briggs Institute
LF - Power in the low-frequency range.
LF/HF ratio - Ratio of low frequency to high frequency.
MD - Mean differences
MICE - Moderate-intensity continuous exercises
NO₂ - Nitrite concentration
PEH - Post-Exercise Hypotension
RMSSD - Root Mean Square of Successive Differences.
RPE - Rated Perceived Exertion
SBP - Systolic blood pressure
SD 24h - Standard deviation of BP over 24 hours;
SDdn - Standard deviation of BP weighted by the duration of day and night;
SDNN - Standard Deviation of all NN intervals.
SMD - Standardized mean differences
WHR - Waist-to-hip ratio

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1. INTRODUÇÃO

O envelhecimento é um processo, marcado por modificações morfológicas, funcionais, bioquímicas e psicológicas (PAPALÉO NETTO, 2013), que podem ser fisiológicas ou patológicas, aumentando o risco de incidência de doenças crônicas, como a hipertensão arterial (HA). No Brasil, a HA atinge mais de 70% dessa população (BARROSO et al., 2021) e é mais prevalente nas mulheres na pós-menopausa em relação à pré-menopausa, devido a redução dos hormônios sexuais femininos (ZAROS; ZANESCO, 2013).

O processo de envelhecimento cardiovascular é marcado por diversas modificações estruturais e funcionais, como a redução da função autonômica cardíaca, redução da variabilidade da frequência cardíaca (VFC), aumento da atividade nervosa simpática, redução da biodisponibilidade de óxido nítrico (NO), além de alterações nas paredes arteriais que levam à maior resistência vascular periférica (AFIUNE, 2013). Ademais, mulheres na pós-menopausa apresentam maior redução da sensibilidade barorreflexa simpática quando comparado aos homens (FU; OGOH, 2019), além do aumento dos marcadores de estresse oxidativo (CASTELÃO; GAGO-DOMINGUEZ, 2008). Todas essas modificações do sistema cardiovascular são responsáveis pela alteração da pressão arterial (PA) levando à HA.

A Diretriz Brasileira de Hipertensão Arterial (BARROSO et al., 2021) traz o exercício físico como tratamento não medicamentoso e preventivo para o desenvolvimento da doença. Além disso, já é bem definido na literatura que o exercício aeróbico é capaz de reduzir a PA de forma aguda, denominado hipotensão pós-exercício (HPE), levando à uma redução crônica (BRITO et al. 2018). Porém, essa redução é influenciada por diversos fatores como nível da PA inicial, intensidade e duração do exercício (BRITO; QUEIROZ; FORJAZ, 2014). Além disso, a resposta da PA após o exercício também é diferente em relação ao meio que ele está sendo realizado como ambiente aquático vs terrestre (NGOMANE et al., 2019).

O exercício realizado no meio aquático é amplamente procurado por idosos e mulheres na pós-menopausa, principalmente, pela redução da carga articular, causada pela flutuabilidade na água (BATTERHAM; HEYWOOD; KEATING, 2011). Além disso, a imersão em água aquecida (28 a 32°C) promove diversos benefícios cardiovasculares, como a redução da resistência vascular periférica, aumento do retorno venoso e redução da PA (PENDERGAST et al., 2015; SIK PARK et al., 1999). Diante da relevância da HPE no tratamento e prevenção da hipertensão, é de suma importância compreender os efeitos do exercício aquático no sistema cardiovascular, principalmente nas respostas da PA imediatamente e durante 24 horas após as sessões, além dos mecanismos fisiológicos envolvidos.

2. FUNDAMENTAÇÃO TEÓRICA

2.1 Hipertensão arterial, envelhecimento e menopausa:

O envelhecimento é um processo dinâmico e progressivo, marcado por modificações morfológicas, funcionais, bioquímicas e psicológicas, que são responsáveis pela perda da capacidade de adaptação do indivíduo ao meio ambiente. Além disso, o envelhecimento é um fenômeno universal, porém as modificações ocorrem de maneira individual, ocasionando maior vulnerabilidade e incidência de doenças (PAPALÉO NETTO, 2013).

O aumento da expectativa de vida ocorreu de modo lento graças às melhores condições sociais, de saneamento e acesso aos medicamentos. No Brasil, foi observado uma menor taxa de fecundidade e maior queda de mortalidade, contribuindo para o aumento da expectativa de vida populacional. Foi observado que o grupo composto por pessoas acima de 65 anos cresceu de 3,5% em 1970 para 5,5% em 2000. Além disso, é projetado que em 2050 esse grupo corresponderá a 19% da população total brasileira e representará 16,7% da população mundial (NASRI, 2008). É possível observar também que a população idosa será predominantemente feminina, correspondendo a 76 idosos para cada 100 idosas. Em 2022 as mulheres representaram cerca de 51% da população brasileira. Quando observado a idade acima de 65 anos, as mulheres representaram 6,17% da população feminina enquanto os homens representaram 4,74% da população masculina (IBGE, 2022).

Durante o processo de envelhecimento ocorrem alterações fisiológicas ou patológicas, aumentando o risco de incidência de doenças crônicas, como a HA. A HA é caracterizada como uma doença geralmente assintomática influenciada por diversos fatores (genética, etnia, sedentarismo, idade, entre outros) e apresenta alterações no sistema renina-angiotensina-aldosterona, na regulação autonômica cardíaca, e em outros sistemas que controlam a função vascular (BARROSO et al., 2021). Desse modo, é um importante fator de risco para a mortalidade cardiovascular, principalmente em idosos (GIUSEPPE et al., 2023). No Brasil, a HA atinge 32,5% da população com mais de 18 anos e esse número tende a aumentar para mais de 70% quando se considera a população idosa (BARROSO et al., 2021).

O sistema cardiovascular é afetado pelo processo de envelhecimento através de alterações estruturais e funcionais, refletindo nas variáveis hemodinâmicas, gerando diminuição da reserva fisiológica e reduzindo a capacidade de tolerância em várias situações nesses indivíduos (AFIUNE, 2013).

O controle autônômico do sistema cardiovascular tem ação direta sobre a PA e frequência cardíaca (FC), a regulação desses índices ocorre através da ação dos barorreceptores que modulam a resposta vagal cardíaca e a ativação simpática. As alterações arteriais são afetadas pela redução da elasticidade das paredes levando à maior resistência vascular periférica e redução do débito cardíaco, com consequente aumento da pressão arterial sistólica, pressão de pulso e velocidade da onda de pulso levando à um aumento da pós-carga (AFIUNE, 2013). Em idosos, as alterações dos vasos levam à redução da sensibilidade dos barorreceptores à variabilidade da pressão arterial (VPA), contribuindo para o declínio da função barorreflexa (AZEVEDO et al., 2019). A VPA inadequada é associada à danos aos órgãos-alvo da HA, além disso, o aumento dos picos da PA em situações de estresse pode gerar riscos cardiovasculares à essa população (NARDIN et al., 2019).

Dessa forma, o processo de envelhecimento é marcado pela redução linear da regulação autônômica cardíaca através da redução da VFC que é um mecanismo caracterizado pelas oscilações nos intervalos entre os batimentos cardíacos (intervalo RR). Além disso, pessoas hipertensas apresentam a VFC mais diminuída do que as normotensas (ANDRADE et al., 2017) o que pode estar associado com a PA elevada (HUIKURI et al., 1996). A redução da VFC é um fator de risco para o desenvolvimento de doenças cardiovasculares, por outro lado, a maior variabilidade é relacionada à maior adaptabilidade (SINGH et al., 1998).

A associação à predisposição de doenças com o processo de envelhecimento pode ser explicada pela “Teoria dos radicais livres” (HARMAN, 1956). Foi observado alterações na produção de espécies reativas de oxigênio que levam à inativação do NO, um importante vasodilatador, aumentando o estresse oxidativo e causando hipertrofia das células musculares lisas, espessamento da parede arterial, disfunção endotelial e predisposição do organismo a doenças cardiovasculares, como a HA (LIMA, 2013) (Figura 1).

Além do mais, o processo de envelhecimento é diferente na população feminina e masculina, devido principalmente aos hormônios sexuais. O envelhecimento feminino é marcado pela menopausa, que é definida como a falência total da função ovariana em produzir hormônios esteroides e ovulação, marcada pela elevação do peso corporal, alterações no perfil lipídico, alterações emocionais e alterações nas concentrações de estrogênio e progesterona (ZAROS; ZANESCO, 2013). Mulheres na pós-menopausa apresentam risco aumentado para desenvolvimento de doenças cardiovasculares relacionado ao declínio nas concentrações dos hormônios sexuais femininos, principalmente em relação ao estrogênio, que possui efeitos anti-inflamatórios e vasoprotetores (ZAROS; ZANESCO, 2013). Além disso, segundo Fu e Ogoh

(2019) a sensibilidade barorreflexa simpática é reduzida, o que pode estar associado a uma maior rigidez arterial em comparação com os homens, aumentando a prevalência de hipertensão e doenças cardiovasculares nessa população.

Foi encontrado que o estrogênio apresenta uma função importante no controle cardiovascular através da modulação da função endotelial, elevando a produção de NO, porém, após a menopausa os marcadores de estresse oxidativo estão aumentados, contribuindo para o aumento da PA (CASTELÃO; GAGO-DOMINGUEZ, 2008) através da redução da biodisponibilidade de NO, afetando na função vascular (MAJMUDAR et al., 2000).

Por fim, há uma estreita relação entre o processo de envelhecimento e as causas das doenças, como foi discutido anteriormente, pois o processo de envelhecimento modifica os sistemas e é modificado pelas doenças que acometem o indivíduo. Sendo assim, o estudo dessas alterações em cada população torna-se importante para melhor escolha de intervenções para a prevenção e o tratamento de doenças, como a HA, durante o processo de envelhecimento.

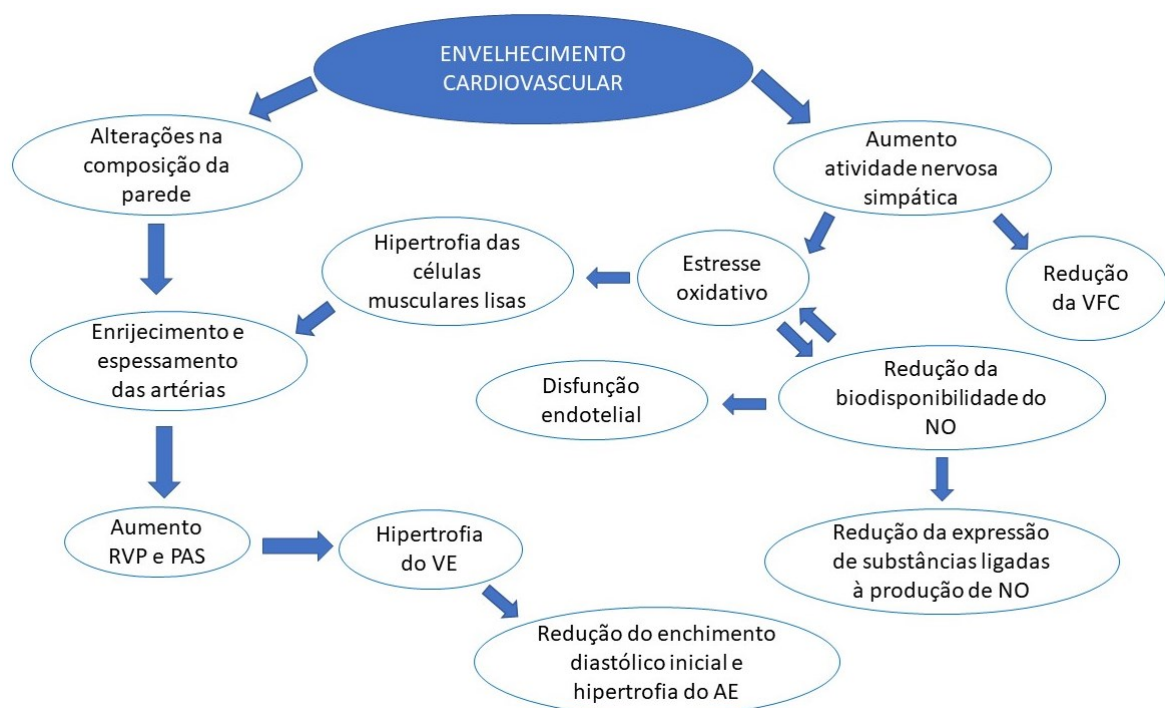


Figura 1. Impacto do envelhecimento na estrutura e função cardiovascular. VFC: Variabilidade da frequência cardíaca; RVP: Resistência vascular periférica; PAS: Pressão arterial sistólica; VE: Ventrículo esquerdo; AE: Átrio esquerdo; NO: Óxido nítrico. Fonte adaptada: Azevedo et al., 2019.

2.2 Efeito do exercício aquático na pressão arterial:

Segundo o *American Heart Association* e o *American College of Cardiology*, mudanças no estilo de vida, como por exemplo aumento do nível de atividade física e a prática regular de exercício físico, são consideradas abordagens primárias para prevenção e tratamento da HA (BARONE GIBBS et al., 2021). De fato, a literatura demonstra que a prática regular de exercício físico causa uma redução crônica importante nos valores da PA (LIU et al., 2012; IELLAMO et al., 2021).

Diferentes sessões de exercícios são estudadas devido á HPE, que se caracteriza pela redução dos valores de PA abaixo dos níveis de repouso pré-exercício e/ou de uma sessão sem exercício físico (KENNEY; SEALS, 1993). O somatório desse efeito agudo hipotensor pode levar a um efeito crônico, o qual será extremamente benéfico para a saúde do indivíduo (BRITO et al. 2018).

A magnitude da HPE aeróbico é influenciada por alguns fatores, como idade, sexo, nível da PA inicial, ritmo circadiano, intensidade e duração do exercício (BRITO; QUEIROZ; FORJAZ, 2014). Em terra, foi encontrado que após o exercício aeróbico ocorre redução do débito cardíaco associada à redução do volume sistólico (BRANDÃO RONDON et al. 2002), redução da atividade nervosa simpática, reduzindo a resistência vascular periférica (CLÉROUX et al., 1992) e, outros estudos sugerem que ao final do exercício as substâncias produzidas no endotélio, como o NO, aumentam a redistribuição sanguínea contribuindo para a hipotensão pós-exercício (GOTO et al., 2003).

Nesse sentido o exercício aquático vem sendo estudado como alternativa para prevenção e tratamento da HA, pois em imersão, o corpo apresenta uma série de ajustes fisiológicos, dentre eles a redução da resistência vascular periférica (PENDERGAST et al., 2015), supressão do sistema renina-angiotensina e ativação cardiopulmonar e barorreflexa (GABRIELSEN et al., 1996; REILLY et al., 2003) que levam a uma alteração nas funções renais (LAROCHELLE et al., 1994). Essas alterações ocorrem devido à pressão hidrostática que redireciona ~700 mL do fluxo sanguíneo das extremidades para o tórax, aumentando o retorno venoso e promovendo a redução da PA (SIK PARK et al., 1999; CHU et al., 2002). Dessa forma, acredita-se que o exercício realizado em meio aquático promove a potencialização desses efeitos, porém, uma série de fatores como, temperatura da água, posição corporal, profundidade de imersão, frequência cardíaca inicial e a redução do peso hidrostático influenciam nessas respostas fisiológicas em imersão (ALBERTON; KRUEL, 2009).

Além disso, a intensidade do exercício é um fator importante para as respostas da PA aguda (FORJAZ et al., 2004). O exercício intervalado de alta intensidade (HIIE) é um protocolo recomendado pelas diretrizes de reabilitação cardiovascular, pois exibe melhorias superiores na função vascular arterial e endotelial em comparação com o treinamento contínuo de intensidade moderada analisados em terra (WISLOFF et al., 2009), podendo alcançar benefícios cardiovasculares com uma menor quantidade de tempo de exercício por sessão. Embora os efeitos do HIIE terrestre tenham sido estudados para diversas populações, os resultados dizem a respeito da capacidade aeróbica, da força muscular e da composição corporal (DEPIAZZI et al., 2018) e faltam evidências dos seus efeitos na pressão arterial, principalmente no meio aquático.

A partir disso, é de extrema importância analisar os efeitos do exercício aquático nas respostas cardiovasculares, principalmente na PA de idosos e mulheres na pós-menopausa, já que o exercício é uma forma de tratamento e prevenção da doença.

3. OBJETIVOS

O objetivo deste estudo foi investigar os efeitos de uma sessão de exercício aquático, realizado em posição vertical, na pressão arterial.

Objetivos específicos:

- Revisar a literatura quanto aos efeitos dos exercícios aquáticos, realizados em posição vertical, nas respostas agudas da pressão arterial após o exercício em idosos.
- Verificar os efeitos metanalísticos de uma sessão de exercício aquático, em posição vertical, nas respostas da pressão arterial de idosos até 1 hora e durante 24 horas pós-exercício.
- Avaliar os efeitos agudos do exercício aquático intervalado nas respostas da pressão arterial e respostas cardiovasculares de mulheres pós-menopausadas e hipertensas.
- Verificar e comparar as respostas da variabilidade e reatividade da pressão arterial, variabilidade da frequência cardíaca e concentração de nitrito salivar de mulheres pós-menopausadas e hipertensas após uma sessão de exercício aquático com uma sessão controle.

**Artigo 1. EFFECTS OF POST-AQUATIC EXERCISE HYPOTENSION IN ELDERLY
INDIVIDUALS: A SYSTEMATIC REVIEW WITH META-ANALYSIS**

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1. ABSTRACT

Introduction/Objective: Aquatic exercise provides various functional and cardiovascular benefits for the elderly. However, the effects on the acute response of blood pressure still remain inconsistent. Therefore, the objective was to review the literature regarding the effects of aquatic exercises, performed in a vertical position, on the acute blood pressure responses after exercise in the elderly. **Methods:** A systematic review and meta-analysis were conducted, searching for clinical trials involving elderly individuals published until August 2023 in digital databases (EMBASE, PUBMED, Lilacs, SPORTDiscus, and Web of Science). **Results:** Eight studies with 197 individuals (mean age: 67 years; resting blood pressure: 128/75 mmHg) were included for qualitative analysis and seven studies were included in the meta-analysis. The results showed that aquatic exercise promoted a reduction in systolic blood pressure (SBP) of -6.86 mmHg within 1 hour and -4.14 mmHg for 24 hours after the session. However, it showed no effect on diastolic blood pressure (DBP) responses. Furthermore, subgroup analysis showed that HIIE reduced SBP by -15.50 mmHg and DBP by -5.97 mmHg after the sessions. On the other hand, continuous exercise of moderate intensity reduced SBP by -4.91 mmHg, with no effect on DBP up to 1 hour after the sessions. Subgroup analysis over 24 hours was not possible. **Conclusion:** Acute aquatic exercise is capable of reducing blood pressure in the elderly. **Significance:** The post-exercise blood pressure reduction is of utmost importance for the elderly in preventing cardiovascular diseases, such as arterial hypertension.

Key words: Exercise; Arterial Pressure; Post-Exercise Hypotension; Aged.

2. INTRODUCTION

Aging is a natural, dynamic, and progressive process marked by various morphological, functional, biochemical, and psychological changes that lead to increased vulnerability and a higher incidence of chronic diseases such as arterial hypertension (AH) (Papaléo Netto, 2013). According to the World Health Organization, the prevalence of AH affects 1.28 million adults aged 30-79 worldwide (WHO, 2023). Characterized as a typically asymptomatic condition, AH can be influenced by various factors (genetics, ethnicity, sedentary lifestyle, age, among others) and involves alterations in the renin-angiotensin-aldosterone system, cardiac autonomic regulation, and other systems that control vascular function (Barroso et al., 2021). Thus, it is a significant risk factor for cardiovascular mortality, especially in the elderly (Giuseppe et al. 2023).

According to the American Heart Association and the American College of Cardiology, lifestyle modifications, such as an increase in physical activity levels and regular exercise, are considered primary approaches for the prevention and treatment of AH (Barone Gibbs et al., 2021). In fact, the literature shows that regular physical exercise leads to a significant chronic reduction in blood pressure (BP) values (Liu et al. 2012; Iellamo et al. 2021).

Different exercise sessions are studied due to post-exercise hypotension (PEH), characterized by a reduction in BP values below pre-exercise resting levels and/or levels observed after a session without physical exercise (Kenney & Seals, 1993). The cumulative effect of this acute hypotensive response may lead to a chronic effect, which can be extremely beneficial for the individual's health (Brito et al., 2018).

In this context, a meta-analysis demonstrated that exercise sessions on land, whether aerobic or strength training, reduce systolic blood pressure (SBP) values by 6 and 3 mmHg, respectively, and diastolic blood pressure (DBP) values by 4 and 3 mmHg, respectively (Brito

et al., 2018). The effects of aquatic training also show benefits in SBP responses in adults and the elderly (Reichert et al., 2018).

Interest in the study of aquatic exercise has gained prominence, especially due to the specific characteristics of this environment, such as buoyancy, which provides a reduction in joint impact a crucial feature, particularly for the elderly (Alberton et al., 2013). Additionally, immersion in water induces a range of physiological adjustments, including increased diuresis, lower peripheral resistance, suppression of sympathetic activity, and consequently, a reduction in BP and heart rate values (Pendergast et al., 2015).

In this regard, the literature also focuses on BP responses following aquatic exercise sessions (Cunha et al., 2012; Cunha et al., 2017; Júnior et al., 2020; Machado et al., 2020). However, the results found still appear divergent, as some studies show significant reductions after moderate-intensity water aerobics sessions (Cunha et al., 2012; Machado et al., 2020), while there are studies demonstrating the maintenance of BP values (Cunha et al., 2017).

A meta-analysis evaluated BP responses after aquatic exercise compared to control, where the control could be land-based exercise or rest, in hypertensive individuals (>18 years) and found no differences in 24-hour responses between the sessions. However, SBP and DBP decreased during the night period (8,6 mmHg and 3,7 mmHg, respectively) compared to land-based exercise, and DBP showed a significant reduction (1.7 mmHg) after aquatic exercise versus rest (Trindade et al., 2022). It is known that methodological differences can influence these results, such as the studied population, the exercise session protocol, as well as the comparison between land and water exercise sessions. Therefore, there is currently no meta-analysis in the literature on the effects of a single session of aquatic exercise versus a control session (no exercise) on the blood pressure of elderly individuals.

Given this scenario, it is crucial to emphasize the importance of analyzing the data present in the literature regarding the effects of a session of aquatic exercise on BP, especially

in the elderly, who are the population at the highest risk for developing hypertension. Moreover, they constitute the primary audience for water aerobics classes in gyms and clubs. Thus, the aim of this study was to conduct a systematic review with meta-analysis to assess the effects of aquatic exercises, performed in a vertical position, on the acute blood pressure responses after exercise in elderly individuals.

3. METHODS

This systematic review with meta-analysis adhered to the PRISMA guidelines (Page et al., 2022). Protocol details can be accessed on the platforms Protocol.io (available at: [dx.doi.org/10.17504/protocols.io.bp2l69k3rlqe/v1](https://doi.org/10.17504/protocols.io.bp2l69k3rlqe/v1)) and PROSPERO (CRD42022375929).

3.1 Search Strategy

The searches were conducted in the following digital databases: EMBASE, PUBMED, Lilacs, SPORTDiscus, and Web of Science, up to August 18, 2023. Due to the loss of access to SPORTDiscus, searches for this database were included only up to November 24, 2022. The search was divided into three categories of terms: Exercise, Post-exercise hypotension, and Elderly. Within each category, terms were separated by union operators (i.e., "OR"), and the categories were separated by parentheses and intersection operators (i.e., "AND"). The complete search was performed only in the title and abstract using the following combination of terms in the chosen databases:

("Water exercise" OR "Water exercises" OR "Exercises in water" OR "Aquatic Exercise" OR "Aquatic Exercises" OR "Water-based exercise" OR "Water-based exercises" OR "Water-based activities" OR "Water aerobics" OR "Water aerobic exercise" OR "Water aerobic exercises" OR "Deep water" OR "Water running" OR "Running in water" OR

“Water walking” OR Aquajogging OR “Shallow water walking” OR “Aquatic environment” OR “Water resistance” OR “Exercises in a pool” OR “Pool exercise” OR “Water plyometric” OR Swimming) AND (“Post-exercise hypotension” OR “Post exercise hypotension” OR Hypotension OR “Blood pressure” OR Systolic OR Diastolic OR “Lowering blood pressure” OR “Acute blood pressure” OR “Mean blood pressure”) AND (Aged OR “Older adults” OR Elderly OR Older OR “Middle age”).

3.2 Eligibility criteria:

The following categories of studies were eligible: 1) Population: Human, both sexes, elderly (≥ 60 years); 2) Intervention: Acute session of any form of aquatic exercise in a vertical position; 3) Control: Immersion in water without exercise or rest on land; 4) Outcome: BP values after aquatic exercise (SBP, DBP, and/or mean arterial pressure - MAP); 5) Languages: English, Portuguese, and Spanish; 6) Study designs: Randomized clinical trials, non randomized trials, and cross-sectional studies; 7) Publication dates: No time limit.

3.3 Screening and data extraction process

During the screening, eligibility, inclusion, and data extraction phases, studies were independently assessed in duplicate by two reviewers (C. P. G. and T. M. S.). After reviewing the reviewers' responses, discrepancies were resolved through consensus or by a third reviewer when necessary. The studies were organized in the reference manager Rayyan (<https://www.rayyan.ai/>) and subsequently recorded in a spreadsheet for data extraction and organization. For studies that presented data only in graphs or figures without numerical representation, the WebPlotDigitizer software (<https://automeris.io/WebPlotDigitizer/>) was used to obtain numerical values and those that presented blood pressure values in standard error were transformed into standard deviation. Additionally, there was communication with the

1 authors of the studies, when necessary, information could not be obtained from the full text of
2 the included articles.

3 Data extraction for each study included: 1) General description (identification code,
4 author, publication year, language, and study design); 2) Participant details (gender, sample
5 size, and age); 3) Exercise description (modality, intensity, and volume); 4) Control description
6 (body position on land or in water); 5) Pool characteristics (water temperature); 6) Values
7 related to the primary outcome of the study (SBP and DBP values).

9 **3.4 Risk of bias and quality of evidence (GRADE)**

10 The risk of bias analysis was conducted using the tools from the Joanna Briggs Institute
11 (JBI) (Barker et al., 2023; Tufanaru et al., 2020). The Critical Appraisal tools for Randomized
12 Controlled Trials and Quasi-Experimental Studies were employed, and the assessments were
13 performed in duplicate by two independent reviewers (C. P. G. and T. M. S.). The quality of
14 evidence for each outcome was classified using the GRADEpro GDT software®, developed by
15 the Classification of Recommendations, Assessment, Development and Evaluation Working
16 Group (GRADE). The GRADE approach assesses the quality of a body of evidence (QoE)
17 defined as confidence in estimates of effects of alternative management strategies and outcome
18 is categorized as: ⊕⊕⊕⊕ (high), ⊕⊕⊕○ (moderate), ⊕⊕○○ (low), or ⊕○○○ (very low).
19 The results of these assessments are presented in the results section in both textual and graphical
20 formats.

22 **3.5 Data synthesis and quantitative approaches**

23 Data analysis was conducted using the programming language "R" (R CORE TEAM,
24 2019) through the "meta" and "metafor" packages (Viechtbauer, 2010). The data were analyzed
25 based on mean differences (MD) and standardized mean differences (SMD). The effect size

given by SMD is considered small = 0.2 to 0.49; medium = 0.5 to 0.79; and large = >0.8 (Cohen, 1988). Kendall's tau and I^2 were used as measures of heterogeneity. Pooled effects were presented through forest plots of BP responses up to 1 hour and during 24 hours after sessions. It was foreseen in the protocol the subgroup analysis, in which the studies were divided into those that conducted the analysis of BP after high-intensity interval exercises (HIIE) and those that conducted the analysis after moderate-intensity continuous exercises (MICE) *versus* a control session. Sensitivity analysis was performed by searching for outliers using the "externally standardized residuals" method (standardized residuals values greater than 1.96 on the standardized residuals plot) and searching for influential points using the methods of "difference in fits" (DFFITs, identifying values above 1 or below -1), "Covariance Ratio" (identifying values below 1), and "Cook's Distance" (identifying values much distant from the others). Publication bias analyses were conducted through a funnel plot with the Trim and Fill method and asymmetry hypothesis tests (Egger's test).

4. RESULTS

4.1 Study identification

Initially, 1156 studies were identified in the databases, and 253 were excluded as duplicates. After exclusions, the screening phase occurred, where the titles and abstracts of 903 studies were read, and those meeting the inclusion criteria were selected. Subsequently, 31 studies were identified for possible inclusion in the present work, but 4 studies could not be found in the databases. Researchers attempted to contact the authors of these studies via email and other social media platforms but were unsuccessful. In the end, 27 studies were read in full text, and only 8 were included for qualitative analysis, with 7 included for quantitative analysis (Figure 1).

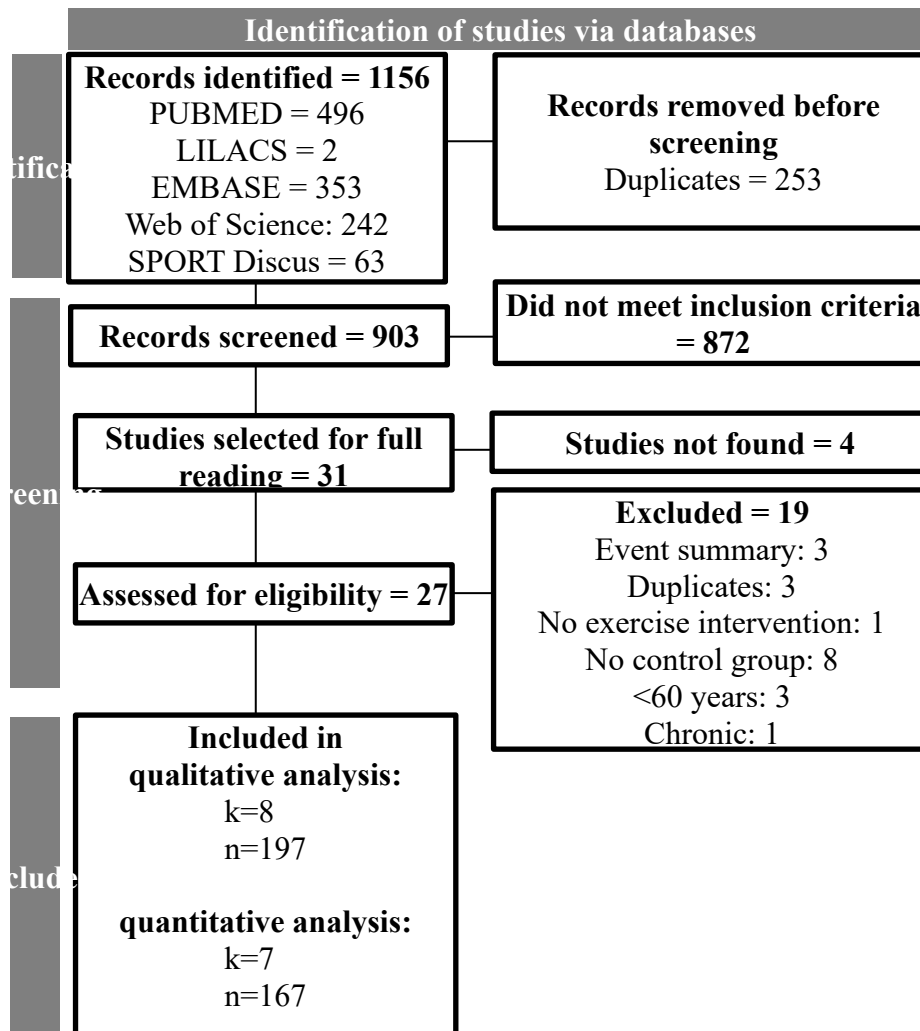


Figure 1. Flowchart of the search. PRISMA, 2020. k: number of studies; n: number of participants.

4.2 Qualitative analysis

Eight studies were included, all of them conducted in Brazil (Table 1). A total of 197 individuals participated, including 152 women, 15 men, and 30 of undefined sex, with an average age of 67.6 ± 1.7 years. Seven studies involved medicated hypertensive elderly people, while another study did not specify whether the sample had this condition, with an average resting blood pressure of 128/75 mmHg. Regarding the modalities of aquatic exercises, five studies implemented water aerobics interventions (comprehensive exercises for upper and lower limbs), one study performed HIIIE (1 minute of running and 2 minutes of walking), one

study conducted immersed walking, and another study included both a HIIE session (jumping exercises) and a walking session.

All studies included a control session; however, in only two studies, the session was immersed, and in two others, the control method was not described. The intervention and control sessions took place in the same pool, with a temperature between 28 to 32°C. The intensity in four studies was estimated using the perceived exertion index (RPE) according to the Borg Scale (RPE 4 and 5 from Borg's 0 to 10; RPE 9 to 17 from Borg's 6 to 20). Two studies estimated intensity through exercise maximum heart rate (70 to 75%), and another used reserve heart rate (60 to 89%).

Regarding BP measurements, five studies used an automatic monitor from 10 minutes to 1-hour post-session, and three studies performed ambulatory 24-hour post-exercise blood pressure monitoring (ABPM):

Up to 1 hour after sessions: Cunha et al. (2012) found a significant reduction 30 minutes after exercise compared to intragroup resting values, both in SBP and DBP. In 2017, the same authors observed a reduction in BP after 30 minutes compared to immediately after exercise; however, SBP and DBP levels returned to normal resting values after exercise. In 2021, the same authors found a significant reduction in SBP by up to 4.6 mmHg 30 minutes after exercise compared to the control session.

Júnior et al. (2018) found reductions in SBP and DBP at 15, 30, 45, and 60 minutes after exercise compared to rest and the control session. At 45 minutes, SBP decreased by 18 mmHg, and DBP decreased by 4 mmHg compared to pre-aquatic exercise values. Machado et al. (2020) also found significant reductions in BP 30 minutes after exercise compared to the control session.

Over 24 hours after the sessions: Cunha et al. (2018) conducted the same intervention as in 2017, evaluating BP over 24 hours, and found a significant reduction in SBP and DBP up to 12 hours post-exercise compared to the control session.

Marçal et al. (2022) found that the HIIE session led to a greater reduction in SBP after 45 minutes compared to the first post-session measurement than the walking session. Additionally, both sessions did not induce changes in BP over 24 hours. However, Ngomane et al. (2019) found that walking resulted in a reduction in daytime and nighttime SBP and daytime DBP compared to the control session (-4.5 to -9.5 mmHg) and daytime DBP (-4.1 to -6.5 mmHg) compared to exercise.

Table 1. Qualitative analysis of included studies.

Study	Population	Exercise	Control	Water temperature	Post-exercise BP analysis interval	Peak post-exercise SBP hypotension	Outcome
Cunha, R.M et al (2012)	16W hypertensive (66 ± 2 years); BP:136/75 mmHg	40 min of water aerobics (moderate intensity RPE 13 Borg 6 - 20)	40 min sitting or standing on land	28,5 °C	First measure: 10min Last measure: 30min	Automatic monitor: 30 min	↓ SBP DBP
Cunha, R.M et al (2017)	50W hypertensive (67 ± 4 years); BP:113/66 mmHg	45 min of water aerobics (moderate intensity 70 to 75% HRmax)	45 min sitting or standing on land	NI	First measure: 10min Last measure: 30min	Automatic monitor: 30 min	↔ SBP DBP
Cunha, R.M et al (2018)	24W hypertensive (70 ± 3 years); BP:124/72 mmHg	45 min of water aerobics (moderate intensity 70 to 75% HRmáx)	45 min sitting or standing on land	NI	First measure: 15min Last measure: 24h	ABPM 24h: 12h	↓ SBP DBP
Cunha, R.M et al (2021)	30W hypertensive (68 ± 3 years); BP:128/72 mmHg	45 min of water aerobics (moderate intensity 70 to 75% HRmáx)	45 min sitting or standing on land	28 °C	First measure: 10min Last measure: 30min	Automatic monitor: 30 min	↓ SBP ↔ DBP
Júnior, E.A.S et al (2018)	12W hypertensive (66 ± 4 years); BP:132/75 mmHg	45 min HIIE (intensity 60 to 89% HRR)	45 min standing immersed	29 °C	First measure: 15min Last measure: 60min	Automatic monitor: 45 min	↓ SBP DBP

Machado, O.A.S et al (2020)	30 M and W (67 ± 5 years); BP:136/88 mmHg	40 to 60 min of water aerobics (moderate intensity RPE 4 to 5, Borg 0-10)	NI	NI	Single measure: 30 min	Automatic monitor: 30 min	↓ SBP DBP
Marçal, I.R et al (2022)	20 M and W hypertensive (M=9 e W=11, 67 ± 7 years), BP:125/74 mmHg	25 min HIIE (intensity RPE moderate 15 to 17 hard; recovery 9 to 11, Borg de 6-20)	30 min sitting immersed	30 - 32 °C	First measure: 45min Last measure: 24h	Automatic monitor: 45 min ABPM 24h: 13h	45 min: ↓ SBP ↔ DBP
		30 min immersed walk (intensity RPE moderate 11 to 13, Borg 6-20)				Automatic monitor: 45 min ABPM 24h: 3h30min	24h: ↔ SBP DBP
Ngomane, A.Y. et al (2019)	15 M and W hypertensive (M=6, W=9, 66 ± 4 years); BP:131/81 mmHg	40 min immersed walk (intensity RPE moderate 11 to 13, Borg 6-20)	40 min sitting, NI whether on land or immersed	29 - 32 °C	First measure: 45min Last measure: 24h	Automatic monitor: 45 min ABPM 24h: 1h30min	45 min: ↓ SBP ↔ DBP 24h: ↓ SBP DBP

1

2

W: women; M: men, BP: resting blood pressure; RPE: perceived exertion index; RPE: Rated perceived exertion; HR: heart rate; HRR: heart rate reserve; NI: Not informed; ABPM: ambulatory blood pressure; SBP: systolic blood pressure; DBP: diastolic blood pressure; HIIE: high-intensity exercise.

4.3 Quantitative Analysis

As a means of controlling heterogeneity, the study by Machado et al. (2020) was not included in the meta-analysis, as it was the only study that presented BP results in delta and did not provide raw values. Therefore, the study exhibits high heterogeneity compared to the other included studies.

Up to 1 hour after the sessions: The meta-analytic results for SBP and DBP are presented in Figures 2 and 3, respectively. Aquatic exercise showed a favorable effect on SBP response (SMD = -0.58 [-0.89; -0.27], $i^2 = 33\%$), representing an average reduction of -6.86 mmHg [-10.72; -3.00], $i^2 = 50\%$. It showed a null effect for DBP (SMD = -0.20 [-0.52; 0.11], $i^2 = 36\%$), with an average reduction of -1.91 mmHg [-4.70; 0.87], $i^2 = 49\%$. Sensitivity analyses did not identify potential outliers.

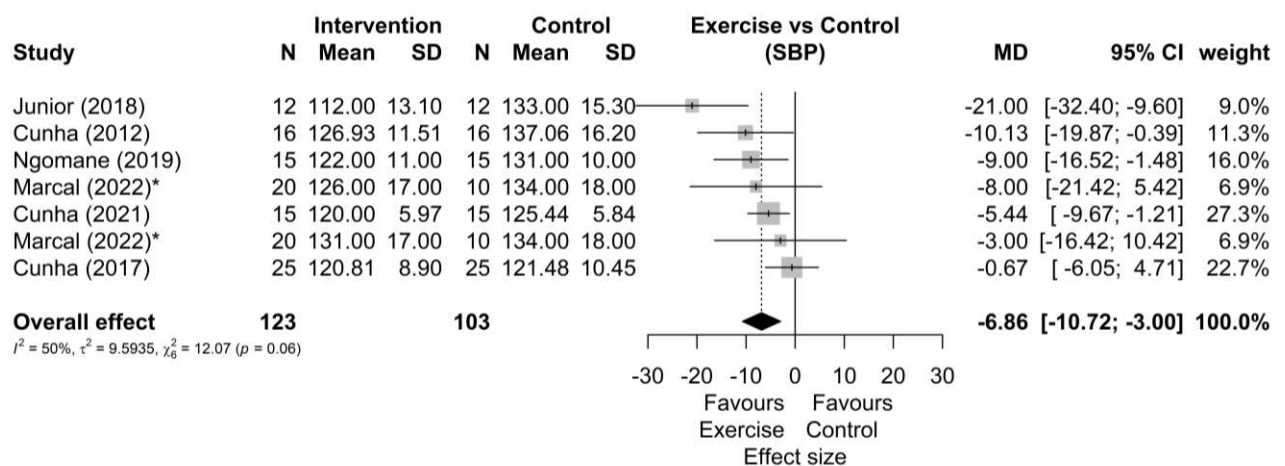


Figure 2. Forest plot: SBP up to 1 hour after sessions. SBP: Systolic blood pressure; MD: Mean differences; *Same study.

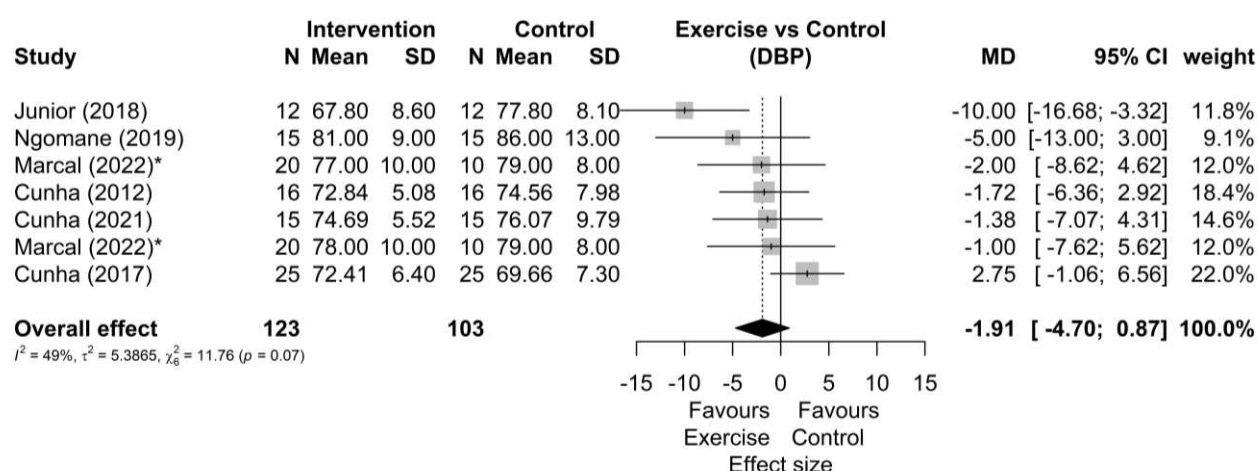


Figure 3. Forest plot: DBP up to 1 hour after sessions. DBP: Diastolic blood pressure; MD: Mean differences; *Same study.

1 The analysis of funnel plots indicates a potential publication bias, as the trim and fill
2 analyses suggested 2 missing studies for SBP and 3 studies for DBP (Figure 4 A and B,
3 respectively). However, the asymmetry test does not indicate a potential publication bias for
4 SBP (Egger's Test: p-value = 0.10) but does for DBP (Egger's Test: p-value = 0.01).

5

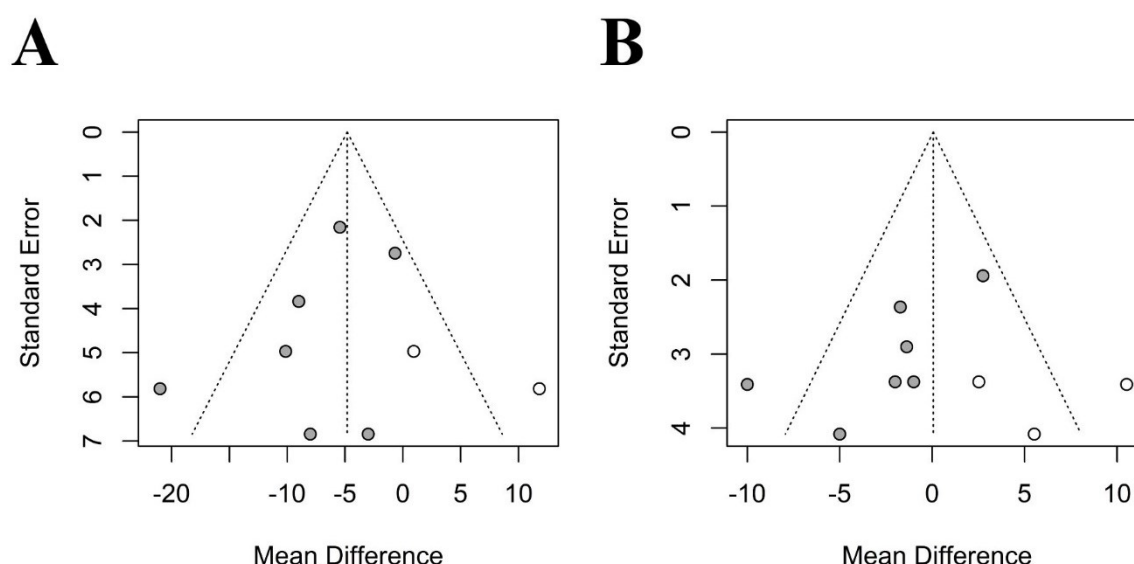


Figure 4. Funnel plot up to 1 hour after sessions. A: Systolic blood pressure; B: Diastolic blood pressure.

6

7

1 **Over 24 hours after the sessions:** The meta-analytic results for SBP and DBP are
2 presented in Figures 5 and 6, respectively. Aquatic exercise showed a favorable effect on SBP
3 response (SMD = -0.41 [-0.79; -0.02], $i^2= 0\%$), reducing by -4.14 mmHg [-7.75; -0.53], $i^2 =$
4 0%. It also showed a null effect for DBP (SMD = -0.21 [-0.59; 0.17], $i^2= 0\%$), with an average
5 reduction of -1.29 mmHg [-3.57; 0.98], $i^2 = 0\%$. Sensitivity analyses did not identify potential
6 outliers.

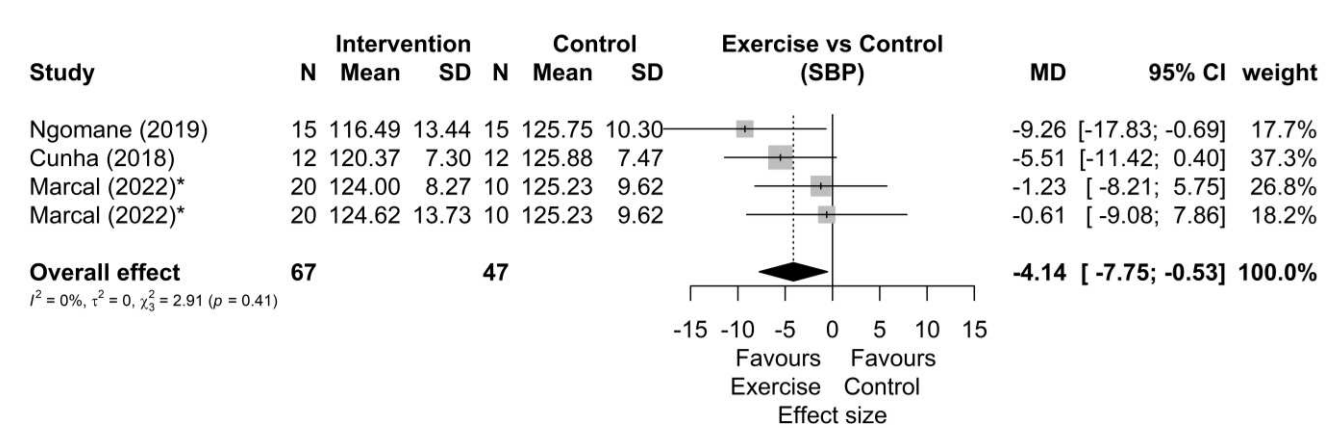


Figure 5. Forest plot: SBP over 24 hours after sessions. SBP: Systolic blood pressure; MD: Mean differences; *Same study.

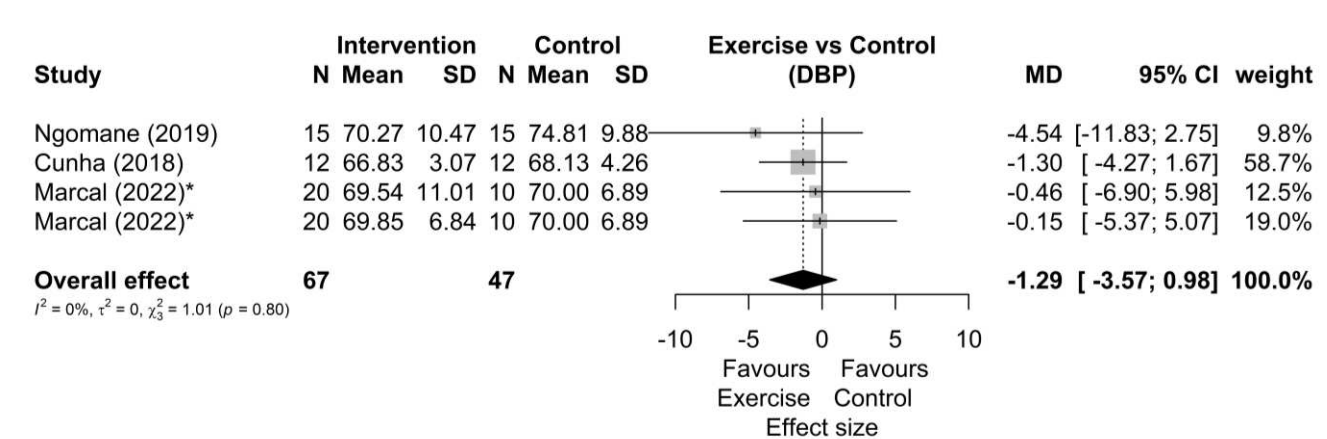


Figure 6. Forest plot: DBP over 24 hours after sessions. DBP: Diastolic blood pressure; MD: Mean differences; *Same study.

7 Funnel plot analysis indicated no missing studies for either SBP or DBP (Figure 7 A
8 and B, respectively). Additionally, the asymmetry tests do not indicate a potential publication
9 bias for SBP (Egger's Test: p-value = 0.97) and for DBP (Egger's Test: p-value = 0.78).

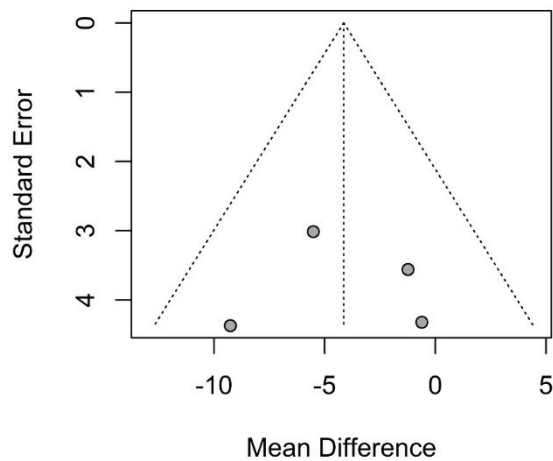
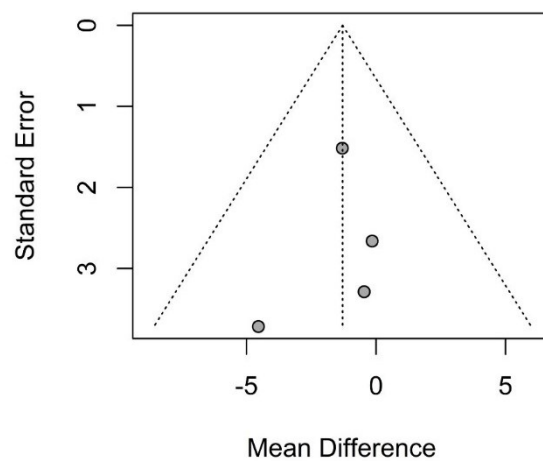
A**B**

Figure 7. Funnel plot over 24 hours after sessions. A: Systolic blood pressure; B: Diastolic blood pressure.

4.4 Subgroup analysis

Up to 1 hour after the sessions: Only two studies (Júnior et al., 2018; Marçal et al., 2022) conducted HIIE, and 5 studies conducted MICE (Cunha et al., 2012, 2017, 2021; Ngomane et al., 2019; Marçal et al. 2022).

HIIE: Showed a favorable effect on SBP response up to 1 hour after exercise, representing a mean reduction of -15.50 mmHg [-24.40; -6.61], $i^2 = 52\%$, (SMD = -0.87 [-1.54; -0.20], $i^2 = 61\%$). Regarding DBP, HIIE led to a reduction of -5.97 mmHg [-11.51; -0.43], $i^2 = 64\%$, (SMD = -0.63 [-1.28; -0.02], $i^2 = 61\%$).

MICE: Showed a favorable effect on SBP response up to 1 hour after exercise, representing a mean reduction of -4.91 mmHg [-7.75; -2.07], $i^2 = 16\%$, (SMD = -0.47 [-0.79; -0.16], $i^2 = 22\%$). It also showed a null effect for DBP, representing a mean reduction of -0.18 mmHg [-2.51; 2.14], $i^2 = 8\%$ (SMD = -0.06 [-0.36; 0.25], $i^2 = 0\%$).

- 1 **Over 24 hours after the sessions:** Only one study (Marçal et al., 2022) evaluated BP
- 2 during 24 hours after HIIE, for this reason it was not possible to perform subgroup analysis.
- 3

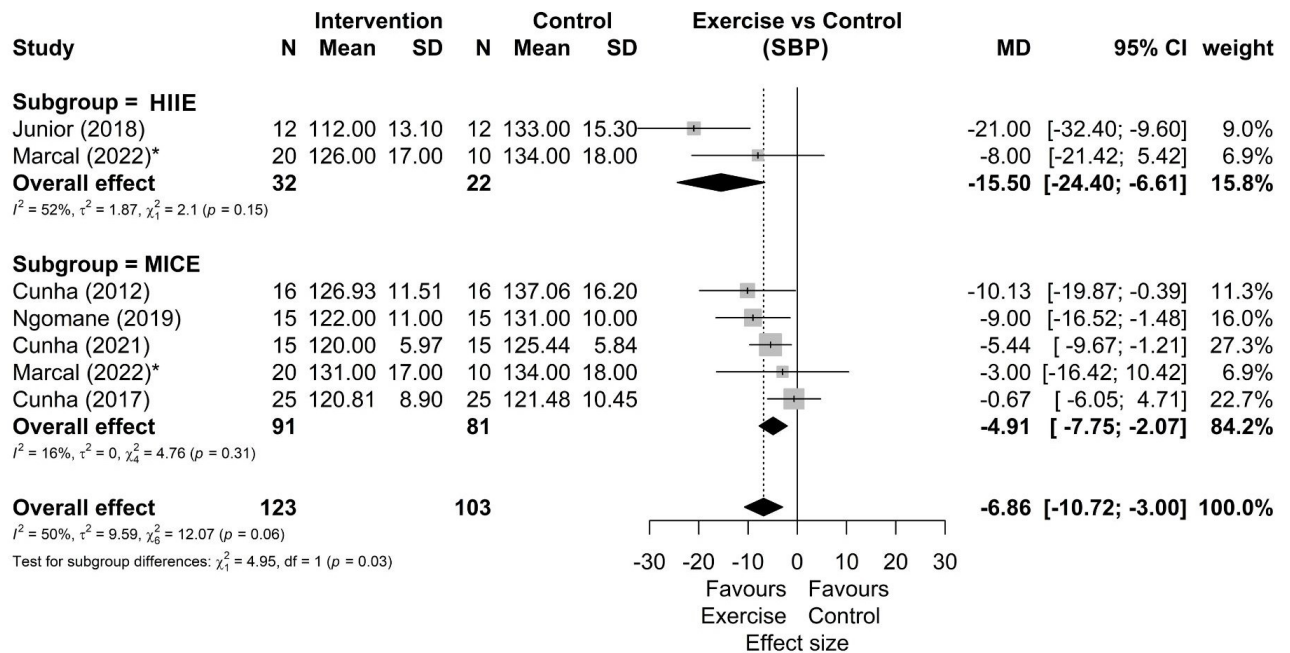


Figure 8. Forest plot subgroup analysis: SBP up to 1 hour after sessions. SBP: Systolic blood pressure; MD: Mean differences; HIIE: High-intensity interval exercise; MICE: Moderate-intensity continuous exercises; *Same study.

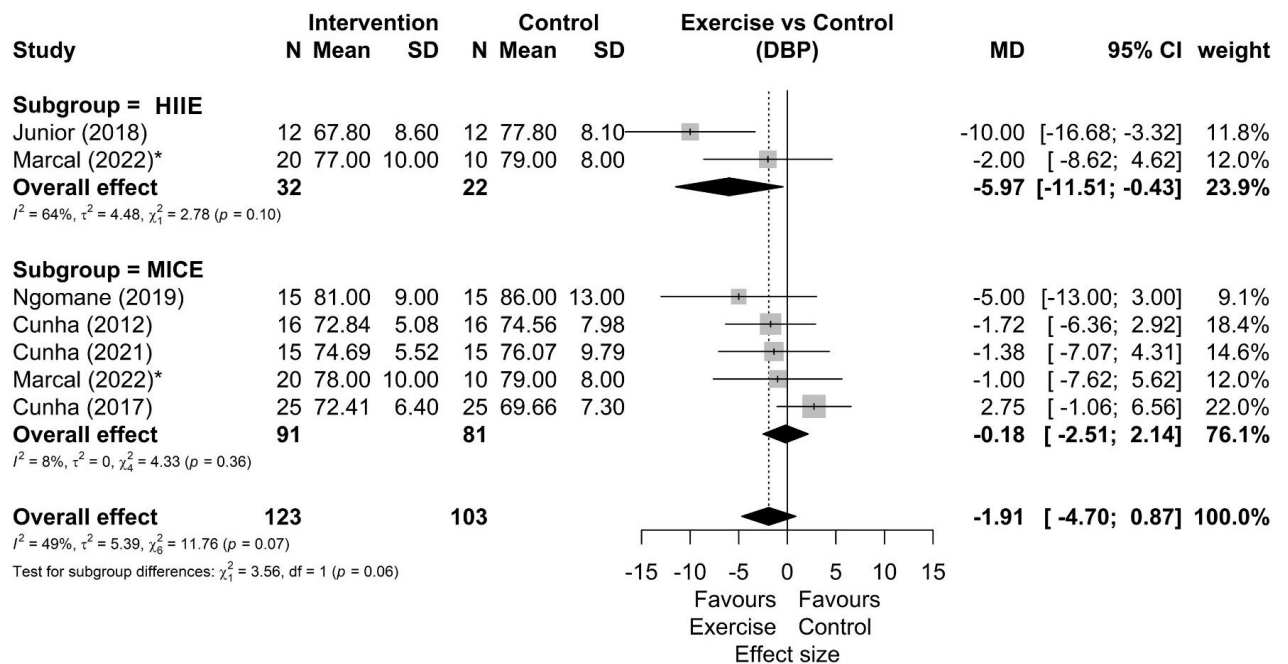


Figure 9. Forest plot subgroup analysis: DBP up to 1 hour after sessions. DBP: Diastolic blood pressure; MD: Mean differences; HIIE: High-intensity interval exercise; MICE: Moderate-intensity continuous exercises; *Same study.

4.5 Bias Analysis and quality of evidence (GRADE)

Overall, the clinical trials showed a low risk of bias in the assessed domains (Table 2).

Regarding randomized clinical trials, all of them used online randomization or an envelope method (question 1). However, Marçal et al. (2022) was the only study that did not describe the procedure for allocation concealment (question 2) of the draw (e.g., whether the envelope was numbered and sealed), presenting a potential bias related to selection and allocation. All interventions did not apply to treatment and assessor blinding (questions 4 and 5). Additionally, the sessions occurred identically to the intervention of interest (question 6), indicating no bias related to intervention administration.

No study provided information about outcome assessors (question 7). However, the results in all studies were measured in the same way between intervention and control sessions (question 8), and the measures used for BP assessment were through validated protocols and devices (question 9). Therefore, the studies show low bias related to outcome assessment, detection, and measurement.

Regarding bias related to participant retention (question 10), only the study by Júnior et al. (2018) did not describe sample loss throughout the study. Participants were analyzed in the groups they were randomized into (question 11), and only Cunha et al. (2021) did not explain all the tests performed in the statistical analysis, in addition to lacking a sample size calculation (question 12). Finally, all studies presented a well-conducted standard randomized clinical trial design (question 13), in which only the study by Cunha et al. (2021) was not a crossover trial; however, all individuals had the same baseline characteristics.

Regarding non-randomized clinical trials, both were clear about "cause" and "effect" (question 1). Machado et al. (2020) did not present the baseline characteristics of participants in each comparison session, indicating a possible selection bias (question 2) since it is not a crossover trial. In both studies, participants were not exposed to another intervention

1 simultaneously with the intervention of interest (question 3), with only the exercise and control
2 sessions (question 4). Furthermore, outcome measures were taken multiple times both before
3 and after the session (question 5). Cunha et al. (2012) was confusing regarding follow-up, as it
4 did not indicate if there was sample loss during the sessions, and Machado et al. (2020) did not
5 provide sample size and loss information for each session (question 6).

6 All BP results were measured in the same way in both sessions and studies (question 7)
7 and were measured using equipment validated in the literature (question 8). Finally, the study
8 by Cunha et al. (2012) performed an incorrect statistical test for the analysis of BP at different
9 time points, and Machado et al. (2020) did not provide an adequate description of the statistical
10 analysis, weakening the validity of the results (question 9).

11 The quality analysis performed by the GRADE software indicated high certainty of
12 evidence ($\oplus\oplus\oplus\oplus$) for all outcomes assessed, including SBP and DBP during 1 hour and
13 during 24 hours after the aquatic exercise session (Annex 2).

1 Table 2. Bias Risk Analysis.

	Bias related to selection and allocation			Bias related to administration of intervention			Bias related to assessment, detection and measurement of the outcome			Bias related to participant retention	Statistical Conclusion Validity		
RCTs	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13
Cunha, R.M et al (2017)	+	+	+	NA	NA	+	-	+	+	+	+	+	+
Cunha, R.M et al (2018)	+	+	+	NA	NA	+	-	+	+	+	+	+	+
Cunha, R.M et al (2021)	+	+	+	NA	NA	+	-	+	+	+	+	-	+
Júnior, E.A.S et al (2018)	+	+	+	NA	NA	+	-	+	+	?	+	+	+
Marçal, I.R et al (2022)	+	?	+	NA	NA	+	-	+	+	+	+	+	+
Ngomane, A.Y. et al (2019)	+	+	+	NA	NA	+	-	+	+	+	+	+	+

Non-RCT	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Cunha, R.M et al (2012)	+	+	-	+	+	?	+	+	-
Machado, O.A.S et al (2020)	+	-	-	+	+	-	+	+	-

Legend			
Yes +	No -	Confused ?	Not applicable NA

RCTs: randomized controlled trials; Non- RCT: non-randomized controlled trials; Q: questions.

5. DISCUSSION

The aim of this systematic review and meta-analysis was to assess the effects of aquatic exercises, performed in a vertical position, on acute BP responses in the elderly. The results showed that aquatic exercise promoted a reduction in SBP of -6.86 mmHg up to 1 hour and -4.14 mmHg during 24 hours after the session. However, it showed a null effect on DBP responses. Additionally, subgroup analysis showed that HIE reduced SBP by -15.50 mmHg and DBP by -5.97 mmHg after sessions. On the other hand, continuous moderate-intensity exercise reduced SBP by -4.91 mmHg, with no effect on DBP up to 1 hour after sessions.

A recent meta-analysis conducted with hypertensive individuals compared the hypotensive effects of an aquatic exercise session with a control session and found similar results. The study indicated that exercise in the aquatic environment reduced -6,0 mmHg in SBP and -1,9 mmHg in DBP, but without significant effects over 24 hours (Trindade et al., 2022). Acute BP responses are of great clinical relevance as they provide important data on chronic BP adaptations in addition to reducing acute cardiovascular risk (Kenney & Seals, 1993).

The combination of these acute effects can lead to a series of physiological adaptations in BP (Wegmann et al., 2017). Indeed, the literature includes two meta-analyses demonstrating the long-term benefits of aquatic interventions on BP in adults and the elderly (Igarashi & Nogami, 2018; Reichert et al., 2018). SBP significantly decreased by -8,4 mmHg (Igarashi & Nogami, 2018) and -10,58 mmHg (Reichert et al., 2018), while DBP also showed reductions of -3,3 mmHg (Igarashi & Nogami, 2018) and -4,40 mmHg (Reichert et al., 2018).

The magnitude of post-exercise hypotension is influenced by several factors that should be considered when interpreting the results. The literature indicates that predictors modulating the BP response after exercise include baseline BP, age, and physical fitness (Pescatello et al.,

2004). Moreover, in the comparison between normotensive and hypertensive individuals, those with elevated BP exhibit a more pronounced response in PEH (Cardoso et al., 2010). Among the studies included in this meta-analysis, three involved physically active older adults (Cunha et al., 2012, 2017, 2018), three included sedentary older adults (Cunha et al., 2021; Ngomane 2019; Marçal 2022), and one did not specify the level of physical activity (Junior et al., 2018). Indeed, Iellamo et al. (2021) suggested that, in hypertensive elderly individuals, the training status associated with the type of exercise may induce different responses in PEH.

Another factor that should be observed is the environment in which the exercise is being performed, as physiological responses in aquatic and terrestrial environments are distinct in response to the same intensity and volume stimuli (Kruel et al., 2013). In this regard, when comparing the effects of exercise on PEH in different environments (aquatic versus terrestrial), Ngomane et al. (2019) found that SBP was reduced below resting levels 45 minutes after an aerobic training protocol performed in the water, but not after a similar protocol in the terrestrial environment. Additionally, it is crucial to note that only two studies (Júnior et al., 2018; Marçal et al., 2022) implemented the control session immersed under the same conditions as the exercise session. Consequently, the BP results related to aquatic exercise are more reliable due to the physiological changes occurring during immersion.

According to the review by Alberton and Kruel (2009), several factors such as water temperature, body position, immersion depth, initial heart rate, and reduction of hydrostatic weight influence physiological responses in immersion. Most studies (Cunha et al., 2012; 2021; Júnior et al., 2018; Marçal et al., 2022; Ngomane et al., 2019) conducted the sessions with water temperature between 28 and 32°C, while the remaining studies (Cunha et al., 2017; 2018; Machado et al., 2020) did not provide this information. Furthermore, only the studies by Júnior et al. (2018) and Marçal et al. (2022) indicated the immersion depth (xiphoid process).

Therefore, such methodological differences may interfere with BP responses and compromise the quality of the studies.

The exercise intensity is also an important variable for BP reduction. In this regard, only two studies (Júnior et al., 2018; Marçal et al., 2022) conducted HIIE, and 6 studies conducted MICE (Cunha et al., 2012, 2017, 2018, 2021; Ngomane et al., 2019; Marçal et al., 2022). When analyzing BP responses in HIIE and MICE subgroups, both showed a favorable effect on SBP response up to 1 hour after exercise, representing a mean reduction of -15.50 mmHg and -4.91 mmHg, respectively. Regarding DBP, HIIE led to a reduction of -5.97 mmHg after exercise, and MICE had no effect. Furthermore, only one study (Marçal et al., 2022) evaluated the BP responses of elderly people during 24 hours after the HIIE session. This result shows the gap in the literature on the effects of aquatic HIIE on BP.

Although HIIE promotes an important reduction in both SBP and DBP after exercise, MICE present more robust and reliable results, due to the greater number of studies present in the literature. Two meta-analyses (Marçal et al., 2021; Perrier-Melo et al., 2020) assessed BP responses in hypertensive and normotensive individuals after a session of terrestrial HIIE vs. MICE. Marçal et al., (2021) found that the effects on BP up to 1 hour after the session were similar between the sessions, while Perrier-Melo et al., (2020) reported that HIIE induced greater post-exercise hypotension (SBP -3 mmHg; DBP -1.3 mmHg). Furthermore, HIIE led to a greater reduction in BP (-5.3 mmHg) than MICE (-1.63 mmHg) during daytime ambulatory monitoring (Marçal et al., 2021). Despite the significant findings, few studies were included in both meta-analyses.

Evidence suggests that the mechanisms by which aquatic exercises reduce BP and exert their hypotensive effects are due to the reduction of peripheral vascular resistance (Pendergast et al., 2015), suppression of the renin-angiotensin system, and activation of cardiopulmonary and baroreflex mechanisms (Gabrielsen et al., 1996; Reilly et al., 2003), leading to alterations

1 in renal functions (Larochelle et al., 1994). These changes occur due to hydrostatic pressure,
2 redirecting approximately 700 mL of blood flow from the extremities (increasing venous return)
3 to the chest (Sik Park et al., 1999; Chu et al., 2002).

4 Considering that the elderly population has a higher prevalence of cardiovascular risks,
5 the effects of immersion associated with physical exercise reduce adverse effects. Additionally,
6 most studies were conducted with elderly hypertensive women (Cunha et al., 2012, 2017, 2018,
7 2021; Júnior et al., 2018). It is known that post-menopause is marked by various hormonal and
8 functional changes, leading to a higher risk of cardiovascular diseases such as arterial
9 hypertension (Abbas et al., 2018). Therefore, PEH is of great relevance for the elderly
10 population in the treatment and prevention of hypertension, and it is crucial to understand the
11 effects of aquatic exercise on the cardiovascular system and the magnitude of acute adaptations
12 in this context.

13 However, some limitations of the present meta-analysis should be emphasized. The
14 level of training appears to have a significant influence on the HPE response, which should be
15 monitored or observed since it may present divergent values for future research, comparing
16 sedentary and trained older adults in the aquatic environment. The prescription of exercise
17 intensity in some studies was based on the heart rate achieved in maximum tests conducted on
18 land, which could overestimate the values of training in the aquatic environment. Additionally,
19 most studies conducted the control session on land, where the BP response is different when
20 compared to the aquatic environment.

21 Future studies should explore the effects of aquatic exercise on BP in other hypertensive
22 populations, such as postmenopausal women and men. Additionally, we emphasize the
23 importance of conducting studies with different exercise protocols (e.g., high-intensity interval
24 training), as they may elicit different blood pressure responses. It is suggested to standardize
25 the control session under the same conditions as the aquatic intervention, such as immersion in

the same pool and the same body position. Furthermore, few studies presented the effects of blood pressure during the 24 hours after aquatic exercise, which may have influenced the meta-analysis results.

Finally, we highlight the importance of this study as the first meta-analysis on post-aquatic exercise hypotension in the elderly, given the clinical significance of reducing blood pressure for this population.

6. CONCLUSION

This systematic review and meta-analysis provide evidences that aquatic exercise performed in the upright position promotes a reduction in SBP for up to 1 hour and for 24 hours, without a significant effect on DBP of elderly people. Furthermore, subgroup analysis showed that HIIE and MICE reduced SBP and only HIIE reduced DBP up to 1 hour after the sessions. This study brings relevant results to clarify the literature on the importance of aquatic exercise in acutely reducing blood pressure in the elderly. In addition to presenting gaps in the literature regarding the lack of acute interventions with high-intensity aquatic exercises and blood pressure assessment over 24 hours.

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8. ANNEXES

8.1 ANEXX 1. JBI BIAS RISK ANALYSIS

JBICritical Appraisal tool for assessment of risk of bias for randomized controlled trials: Critical Appraisal tools for use in JBI Systematic Reviews

Bias related to selection and allocation

1. Was true randomization used for assignment of participants to treatment groups?
2. Was allocation to treatment groups concealed?
3. Were treatment groups similar at the baseline?

Bias related to administration of intervention/exposure

4. Were participants blind to treatment assignment?
5. Were those delivering the treatment blind to treatment assignment?
6. Were treatment groups treated identically other than the intervention of interest?

Bias related to assessment, detection and measurement of the outcome

7. Were outcome assessors blind to treatment assignment?
8. Were outcomes measured in the same way for treatment groups?
9. Were outcomes measured in a reliable way

Bias related to participant retention

10. Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analysed?

Statistical Conclusion Validity

11. Were participants analysed in the groups to which they were randomized?
12. Was appropriate statistical analysis used?

13. Was the trial design appropriate and any deviations from the standard RCT design (individual randomization, parallel groups) accounted for in the conduct and analysis of the trial?

Checklist for quasi-experimental studies (non-randomized Experimental Studies):

Critical Appraisal tools for use in JBI Systematic Reviews

1. Is it clear in the study what is the ‘cause’ and what is the ‘effect’ (i.e. there is no confusion about which variable comes first)?
2. Were the participants included in any comparisons similar?
3. Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?
4. Was there a control group?
5. Were there multiple measurements of the outcome both pre and post the intervention/exposure?
6. Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analyzed?
7. Were the outcomes of participants included in any comparisons measured in the same way?
8. Were outcomes measured in a reliable way?
9. Was appropriate statistical analysis used?

1 8.2 ANNEX 2. QUALITY OF EVIDENCE (GRADE)

Water exercise compared to control for reduce the pressure of the elderly

Patient or population: reduce the pressure of the elderly

Intervention: water exercise

Comparison: control

Outcomes	Nº of participants (studies) Follow-up	Certainty of the evidence (GRADE)	Relative effect (95% CI)	Anticipated absolute effects	
				Risk with control	Risk difference with water exercise
Systolic blood pressure for 1 hour after exercise (SBP 1h) assessed with: SBP value during 1 hour after exercise	226 (7 RCTs)	⊕⊕⊕⊕ High ^a	-	The mean systolic blood pressure for 1 hour after exercise was 130.85 mmHg	MD 6.86 mmHg lower (10.72 lower to 3 lower)
Diastolic blood pressure for 1 hour after exercise (DBP 1h) assessed with: DBP value during 1 hour after exercise	226 (7 RCTs)	⊕⊕⊕⊕ High ^b	-	The mean diastolic blood pressure for 1 hour after exercise was 77.44 mmHg	MD 1.91 mmHg lower (4.7 lower to 0.87 higher)
Systolic blood pressure for 24 hours after exercise (SBP 24h) assessed with: SBP value for 24 hours after exercise follow-up: mean 1 days	114 (4 RCTs)	⊕⊕⊕⊕ High	-	The mean systolic blood pressure for 24 hours after exercise was 125.52 mmHg	MD 4.14 mmHg lower (7.75 lower to 0.53 lower)
Diastolic blood pressure for 24 hours after exercise (DBP 24h) assessed with: DBP value for 24 hours after exercise follow-up: mean 1 days	114 (4 RCTs)	⊕⊕⊕⊕ High	-	The mean diastolic blood pressure for 24 hours after exercise was 70.73 mmHg	MD 1.29 mmHg lower (3.57 lower to 0.98 higher)

*The risk in the intervention group (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI).

CI: confidence interval; MD: mean difference

GRADE Working Group grades of evidence

High certainty: we are very confident that the true effect lies close to that of the estimate of the effect.

Moderate certainty: we are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.

Low certainty: our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect.

Very low certainty: we have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect.

2 Explanations:

3 a. Two possible missing studies were identified using the Trim and Fill test.

4 b. A possible risk of publication bias was identified using the Egger's Regression test.

**Artigo 2. EFFECT OF INTERVAL AQUATIC EXERCISE ON CARDIOVASCULAR
AND SALIVARY NITRITE ACUTE RESPONSES IN HYPERTENSIVE
POSTMENOPAUSAL WOMEN**

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1. ABSTRACT

Introduction/Objective: A physical exercise session promotes post-exercise hypotension, an important effect for the control of blood pressure (BP) in hypertensive individuals. However, there is a lack of studies on BP responses after a session of aquatic high-intensity interval exercise (HIIE). Therefore, the present study aimed to evaluate the acute effects of HIIE on cardiovascular and salivary nitrite responses in hypertensive postmenopausal women.

Methods: A clinical, crossover, and randomized trial was conducted with 22 postmenopausal hypertensive women (58 ± 4.5 years). Two sessions took place: HIIE and control (CON), each lasting a total of 24 minutes. Evaluations were divided into pre-intervention, post-laboratory intervention, and post-ambulatory intervention periods. The evaluated variables included resting and ambulatory BP, BP reactivity, heart rate (HR), and salivary nitrite. Statistical analysis included generalized estimating equation, paired t-test, area under the curve (AUC), and Wilcoxon test, with $\alpha = 0.05$.

Results: There was a reduction in the AUC for both systolic and diastolic BP during the 60 minutes and systolic BP during the 24 hours after the HIIE session compared to CON ($p=0.04$). There was no difference in 24-hour BP, BP variability and reactivity, HR variability, and nitrite ($p > 0.05$).

Conclusion: The HIIE session led to a reduction in systolic and diastolic BP during 60 minutes and in systolic BP during 24 hours in postmenopausal hypertensive women.

Significance: The study reinforces that interval aquatic exercise is effective for acute BP reduction, providing an important clinical response for hypertensive individuals.

Key words: Hypertension; Cardiovascular Diseases; Postmenopause; Exercise.

2. INTRODUCTION

In Brazil, arterial hypertension (AH) affects more than 70% of the elderly population (Malachias et al., 2017), prevalent in women after menopause, due to the decline in the hormones estrogen and progesterone. The decline in estrogen is associated with a reduction in the bioavailability of nitric oxide, which increases markers of oxidative stress and contributes to an increase in blood pressure (BP) (Castelão & Gago-Dominguez 2008), affecting vascular function (Majmudar et al., 2000).

Ambulatory blood pressure (ABPM) is characterized by peaks and reductions throughout the day and night, defining blood pressure variability (BPV). Inappropriate BPV is associated with damage to target organs in hypertension. Moreover, increased BP peaks during stressful situations can pose cardiovascular risks to this population (Nardin et al., 2019). It is well-documented in the literature following the exercise session, BP values are reduced below resting BP, pre-session levels, or below levels measured on a control day without exercise (Cunha et al., 2013), resulting in a post-exercise hypotension (PEH) effect that can lead to a chronic reduction over time (Brito et al., 2018).

Vascular function can be assessed through heart rate variability (HRV), which is a mechanism characterized by oscillations in the intervals between heartbeats (RR interval). Reduced HRV is a risk factor for the development of cardiovascular diseases, while greater variability is associated with increased adaptability (Singh et al., 1998). The aging process is marked by a linear reduction in autonomic cardiac regulation, and hypertensive individuals exhibit lower HRV compared to normotensive individuals (Andrade et al., 2017), which may be linked to elevated blood pressure (BP) (Huikuri et al., 1996). It is known that physical exercise can influence HRV by increasing vagal modulation and decreasing sympathetic tone, making it an important prognostic indicator for various diseases (Routledge et al., 2010).

1 There is evidence that aerobic training induces improvements in blood pressure,
2 oxidative stress, nitric oxide bioavailability, autonomic tone, and baroreflex sensitivity in
3 hypertensive postmenopausal women (Lin & Lee, 2018). However, clinical trials examining
4 the effects of a single session of aerobic exercise on blood pressure response in this population,
5 especially in an aquatic environment, are lacking.

6 Exercise performed in warm water elicits immediate physiological effects due primarily
7 to hydrostatic pressure, which promotes increased venous return (Chu et al., 2002), increased
8 cardiac output (Hall, 1990), increased diuresis (Srámek et al., 2000), and consequently, a
9 reduction in blood pressure. These properties contribute to improvements in hemodynamic
10 variables important for individuals with hypertension, such as reduced peripheral vascular
11 resistance (Pendergast et al., 2015) and decreased sympathetic nervous system activity (Perini
12 et al., 1998).

13 It is known that physiological responses during aquatic exercises can vary according to
14 variables such as body position, temperature, and immersion depth (Alberton & Kruehl, 2009).
15 Additionally, exercise intensity is an important factor in BP responses. High-intensity exercise
16 (HIIIE) is a protocol recommended by cardiovascular rehabilitation guidelines as it demonstrates
17 superior improvements in arterial and endothelial vascular function compared to continuous
18 moderate-intensity training analyzed on land (Wisloff et al., 2009). HIIIE can achieve
19 cardiovascular benefits with a shorter exercise time per session. While the effects of terrestrial
20 HIIIE have been studied for various populations, the results relate to aerobic capacity, muscle
21 strength, and body composition (Depiazzi et al., 2018), and there is a lack of evidence regarding
22 its effects on BP.

23 To date, few studies have investigated the BP response following a HIIIE session for
24 older hypertensive individuals (Junior, et al., 2018; Marçal, et al., 2022). Junior, et al. (2018)
25 observed a reduction in systolic (SBP) and diastolic (DBP) BP after 45 minutes in women. This

was the only study in which the control session involved standing and immersion, sharing the same characteristics as the exercise session. Nevertheless, ABPM behavior over 24 hours was not assessed, and it was not described whether the women exhibited the same hormonal profile concerning menopause.

Considering that postmenopausal women have a higher prevalence of cardiovascular risks, the effects of immersion combined with physical exercise mitigate the adverse effects caused by this period (Kim et al., 2021). Given the relevance of PEH in the treatment and prevention of hypertension, it is of utmost importance to understand the effects of intense aquatic exercise on the cardiovascular system, especially regarding immediate and 24-hour blood pressure responses, as well as the physiological mechanisms involved.

Finally, there is a lack of studies where the control session shares the same immersion and body position characteristics as the exercise session, as BP responses vary according to the environment. Therefore, the present study aims to evaluate the acute effects of interval aquatic exercise on cardiovascular and salivary nitrite responses in postmenopausal hypertensive women.

3. METHODS

3.1 Characterization of the study

This was a randomized, crossover clinical trial involving physical exercise for postmenopausal hypertensive women, conducted at the School of Physical Education and Physiotherapy of the Federal University of Uberlândia during the years 2022 and 2023. The study consisted of two sessions, control (CON) and aquatic high-intensity interval exercise (HIIE), randomized through the Randomizer platform (<https://www.randomizer.org/>), with a minimum interval of 48 hours between them. The research was approved by the Ethics

Committee of the Federal University of Uberlândia (CAAE: 58033422.4.0000.5152) and registered in the Brazilian Clinical Trials Registry (1111-1285-7808).

3.2 Population:

Women aged between 45 and 65 years were recruited for the study. They were postmenopausal (1 year of permanent amenorrhea), medicated hypertensive individuals who had not engaged in regular physical exercise for at least three months. Exclusion criteria included individuals with osteomuscular problems or cardiovascular complications that would hinder physical exercise, those with a medical certificate attesting to their fitness for physical exercise, no history of stroke or acute myocardial infarction, non-smokers, and no diagnosis of Diabetes Mellitus. Data from those who did not attend all tests and sessions were excluded.

The sample size was calculated based on the study by Cunha et al. (2018). The calculation was performed using the G*POWER program version 3.1.9.7, adopting a significance level of 0.05 and a power of 80%. The main variables of interest were 24-hour SBP (Cohen's $d = 0.66$) and 24-hour DBP (Cohen's $d = 0.35$) results after an intervention similar to the present study. Thus, considering the smallest calculated effect size, a minimum sample size of 34 individuals was determined.

3.3 Study design

During the first visit, participants were informed about the study's objectives, methodological procedures, risks, and benefits of the sessions, and subsequently, they signed the Informed Consent Form. Next, a medical history form was filled out, covering age, disease history, and medication use. Additionally, participants completed the International Physical Activity Questionnaire (IPAQ) short version, validated for Brazilian elderly women in Benedetti et al.'s (2004) study. The questionnaire assesses the level of physical activity through

eight questions, classifying participants as very active, active, irregularly active, or sedentary based on their responses. After completing these forms, anthropometric testing, body composition assessment, and scheduling for familiarization took place. Subsequently, the HIIE and CON sessions occurred in a randomized manner.

The experimental sessions were divided into 4 stages (Figure 1):

1. Pre-intervention: Resting data for resting heart rate (HR), blood pressure (BP) and a saliva sample were collected for 7 minutes.

2. Intervention: Control or exercise session, lasting 24 minutes.

3. Laboratory post-intervention: Immediately after the session, the participant remained at rest for 60 minutes, during which:

- Minute 0: Saliva samples were collected.
- Minutes 15 to minute 60: Resting HR and BP were measured.
- After minute 60: A saliva sample was collected.

4. Ambulatory post-intervention: The Ambulatory Blood Pressure Monitoring (ABPM) device was configured and installed to monitor BP for 24 hours.

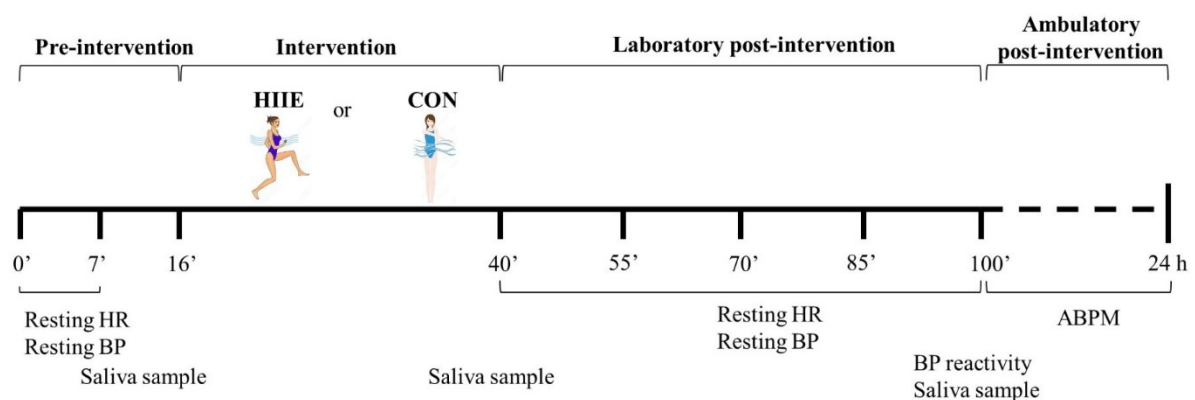


Figure 1. Study Design. HIIE: high-intensity interval exercise session; CON: control session; BP: blood pressure; HR: heart rate; ABPM: ambulatory blood pressure monitoring.

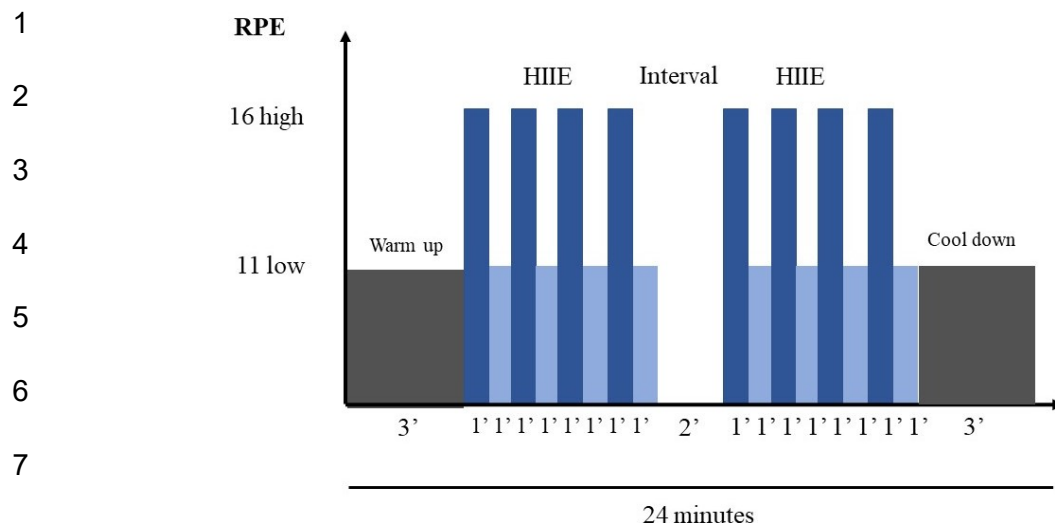
3.4 Session protocol

Session Protocol: Initially, participants were familiarized with aquatic exercise and the Borg Rating of Perceived Exertion scale (6-20), which is recommended for prescribing aquatic exercise intensity using the Rated Perceived Exertion (RPE) (Andrade et al., 2022).

The HIIE session lasted for 24 minutes, comprising 3 minutes of warm-up (frontal and lateral displacement with shoulder adduction and abduction), 2 blocks of 8 minutes of interval exercises, with 1 minute of high intensity (RPE 16, stationary running) followed by 1 minute of low intensity (RPE 11, global hydrotherapy exercises for upper and lower limbs), with a 2-minute interval between them (static rest), and 3 minutes of cool down (static stretching) (Figure 2).

The CON session consisted of 24 minutes of standing still in the water. During the first 10 minutes of the session, the researcher talked to the participants about the benefits of exercise for blood pressure control. Subsequently, 10 minutes of static stretching for the lower and upper limbs were performed, and at the end, another 4 minutes of conversation took place. The conversation and stretching activities were conducted to keep the participant standing without moving around the pool.

The sessions took place at the same time (7:00 to 9:00 AM), in the same pool, with an average temperature of $31.2 \pm 1.3^{\circ}\text{C}$. The pool used for the sessions has various depth levels. Therefore, the ideal level was chosen according to the participant's height, with the aim of everyone performing the sessions with the depth of immersion in the xiphoid process.



measurement at home was conducted using ABPM (Dyna Mapa Cardios, Brazil) to SBP and DBP values every 20 minutes for 24 hours.

The SBP and DBP values from ABPM were used in assessing blood pressure variability (BPV) according to the protocols described by Ortega et al. (2008):

- SD 24h: Standard deviation of BP over 24 hours;
- SDdn: Standard deviation of BP weighted by the duration of day and night;
- ARV: Average real variability of BP over 24 hours.

- Blood pressure reactivity:

To assess BP reactivity under mental stress, the Stroop words and colors protocol (Stroop, 1935) was used for 3 minutes. The test involves a video on a computer screen positioned in front of the participant, changing images every 2 seconds. The participant must then quickly say the color of the letters on the screen, with each image featuring a mismatch between the background color, the color of the letters, and the word formed (which is always the name of another color). At the end of the test, the volunteer indicates on a scale the difficulty of the test, according to the following classification: 0 = not stressful; 1 = slightly stressful; 3 = very stressful; and 4 = extremely stressful (Callister et al., 1992). BP was measured by auscultatory method with a stethoscope and sphygmomanometer at each minute of the test.

- Heart rate variability:

HR was monitored using the POLAR® H10 heart rate monitor. Sympathetic activity was estimated by measuring HRV using the same monitor. R-R intervals were monitored (1000Hz) for 7 minutes pre-session and 60 minutes post-session in the seated position, with spontaneous breathing, considering the final five minutes of each evaluated point. After the measurements, the data were transferred to the computer using Elite HRV® and exported to

Excel files (Microsoft®). HRV analyses were performed using the Kubios HRV 2.2 program, validated for this analysis by Tarvainen et al. (2014). Data analysis was performed in two ways: 1 - time domain (RMSSD and SDNN); 2 - frequency domain (HF LF, LF/HF ratio).

- RMSSD: Root Mean Square of Successive Differences.
- SDNN: Standard Deviation of all NN intervals.
- HF: Power in the high-frequency range.
- LF: Power in the low-frequency range.
- LF/HF ratio: Ratio of low frequency to high frequency.

- Saliva sample

For saliva collection, participants were instructed to fast for one hour and brush their teeth. They rinsed their mouth with distilled water immediately before collection. Saliva was collected by spit method into 15mL plastic tubes (falcon) for two minutes, with the first 30 seconds for stimulating accumulated saliva production and the remaining one and a half minutes for spitting. The collected samples were immediately placed on ice. The samples were then centrifuged at 4°C, 3500rpm for 15 minutes, aliquoted into 2 microtubes (eppendorf) of 1.5mL, and stored at -80°C. The analysis of salivary nitrite (NO₂-) concentration was performed using the Griess colorimetric method (Green et al., 1982).

- 24-Hour dietary recall:

The participants responded to the 24-hour dietary recall administered by trained researchers. They were instructed to remember the foods and beverages they had consumed on the day preceding the HIIE and CON sessions. The total intake of energy, protein, fat, and carbohydrates was quantified using the Dietbox® software (Copyright © Dietbox 2023).

3.5 Statistical analysis

The statistical analysis of the collected data was performed descriptively, with values presented as mean, standard deviation, and delta. The Shapiro-Wilk normality test was used. The generalized estimating equation (GEE) was employed to compare sessions, times, and the interaction between sessions and times for absolute variables of BP up to 60 minutes and 24 hours post-exercise, HRV and nitrite. Linear (normal) and gamma (log) probability distributions were tested, and the latter showed better fit for all variables. Comparisons were made using the pairwise method, and adjustment for multiple comparisons was done by the Bonferroni test. The Wilcoxon test was used to compare participants' food intake between experimental sessions, and the paired t-test was used to compare mean BPV (SPSS version 22.0).

Additionally, from the delta of each variable (BP up to 60 minutes and 24 hours post-exercise, HRV, BP reactivity and nitrite), the area under the curve (AUC) was calculated, and the session areas were compared using the paired t-test. AUC was calculated using the trapezoidal method to analyze variable responses over time (GraphPad Prism 8.0.2). The Cohen's d effect size was calculated for significant results, where it is considered small = 0.2 to 0.49; medium = 0.5 to 0.79; and large = >0.8 (Cohen, 1988). For all assessments, the adopted significance level was $\alpha=0.05$.

4. RESULTS

One hundred and twenty women contacted us to participate in the study after the research was publicized on social media and television. Thirty-four were included according to the criteria, 12 had their data excluded as they did not complete all sessions, and 22 completed the study (Figure 3).

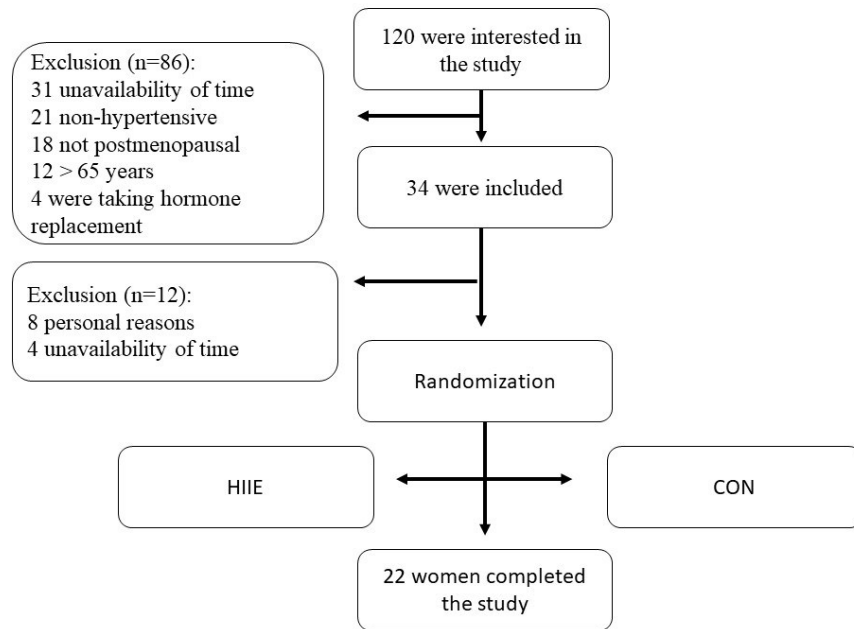


Figure 3. Flowchart of sample selection. HIIE: Interval Aquatic Exercise session; CON: Control session.

The characteristics of the participants will be presented in Table 1. Body assessment indicated obesity ($BMI = 30,7 \pm 4,99 \text{ kg/m}^2$), high risk of developing cardiovascular diseases ($WHR = 0,99 \pm 0,09\text{cm}$), and a very high percentage of body fat ($42,4 \pm 5,98\%$). In addition, (40,9%) participants were active, and only one (4,5%) was sedentary according to the IPAQ.

Table 1. Sample characterization, n=22.

Variables	Mean $\pm$ SD or n(%)
Age (years)	58.05 ± 4.5
Time in postmenopause (years)	8.28 ± 6.4
Hypertension history	20 (90.9%)
Resting SBP (mmHg)	116 ± 12
Resting DBP (mmHg)	72 ± 6

Resting HR (bpm)	69 ± 12
Body composition	
BMI (kg/m ²)	30.7 ± 4.99
WHR (cm)	0.99 ± 0.09
Muscle mass (kg)	25.0 ± 3.52
Fat mass (kg)	33.8 ± 9.53
Fat-free mass (kg)	44.5 ± 5.29
% fat (%)	42.4 ± 5.98
Antihypertensives	
Diuretics	16 (72.7%)
Angiotensin receptor blockers	15 (68.2%)
Angiotensin-converting enzyme inhibitors	4 (18.2%)
Calcium channel blockers	4 (18.2%)
β-blockers	6 (27.3%)
Other diseases	
Pre-diabetes	7 (31.8%)
Musculoskeletal diseases	5 (22.7%)
IPAQ classification	
Sedentary	1 (4.5%)
Irregularly active	12 (54.5%)
Active	9 (40.9%)

BMI: body mass index; WHR: waist-to-hip ratio; IPAQ: International Physical Activity Questionnaire.

There was no difference in absolute responses of SBP (p time = 0.14; p session = 0.96; p session*time = 0.15) and DBP (p time = 0.81; p session = 0.96; p session*time = 0.19) up to 60 minutes after exercise. The area under the curve for both SBP and DBP was lower during the 60 minutes after the HIIE session compared to the CON session (p=0.04) (Figure 4, letter B and D). The effect size was moderate for both SBP (Cohen's d = 0.70) and DBP (Cohen's d = 0.56).

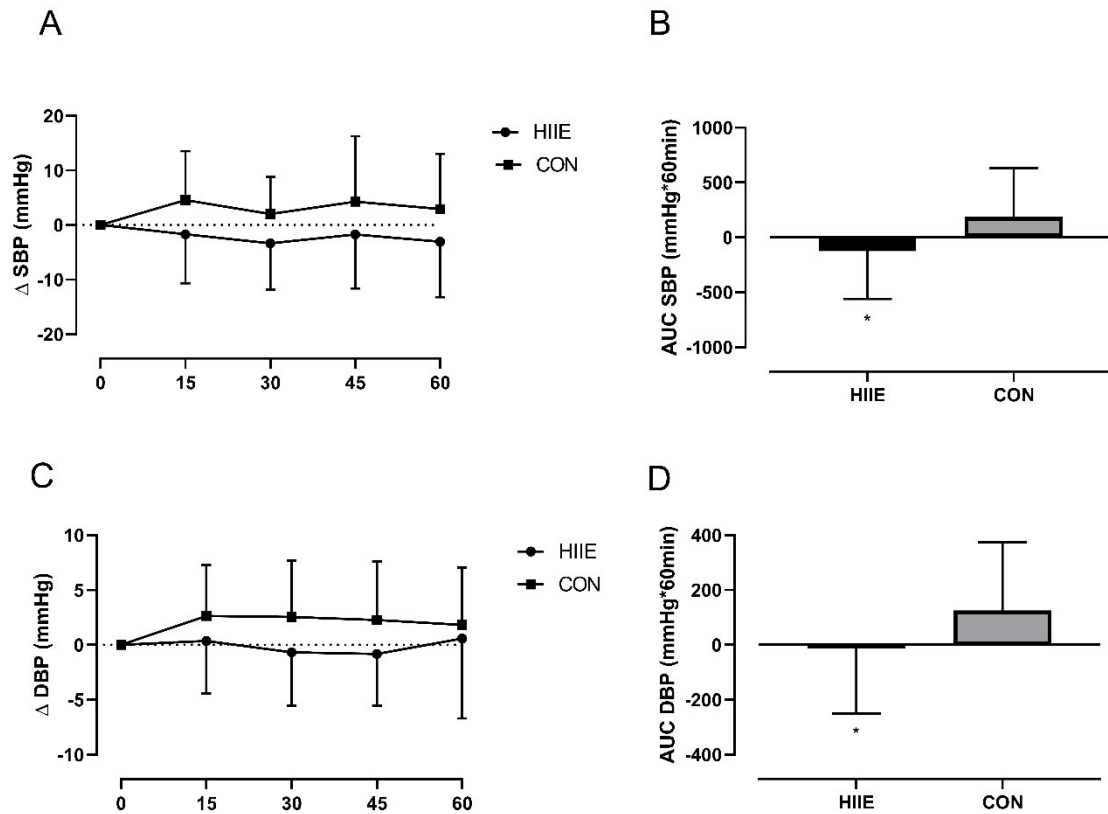


Figure 4. Responses of SBP and DBP after 60 minutes of HIIE and CON sessions. A and C: delta of SBP and DBP, respectively; B and D: area under the curve (AUC) of SBP and DBP, respectively. HIIE: high-intensity interval exercise session; CON: control session; SBP: systolic blood pressure; DBP: diastolic blood pressure; *Significant p-value (<0.05).

There was no difference in the mean 24-hour BP in SBP ($p = 0.74$) and DBP ($p = 0.86$), in wakeful SBP ($p = 0.72$) and DBP ($p > 0.99$), and finally, there was no difference in sleep BP, SBP ($p = 0.77$) and DBP ($p = 0.51$) between HIIE and CON sessions. The AUC of SBP after 24h of the HIIE session was lower ($p = 0.04$) than the area after the CON session, and there was no difference in the AUC of DBP ($p = 0.29$) (Figure 5, letters B and D). The effect size was moderate for SBP (Cohen's $d = 0.50$).

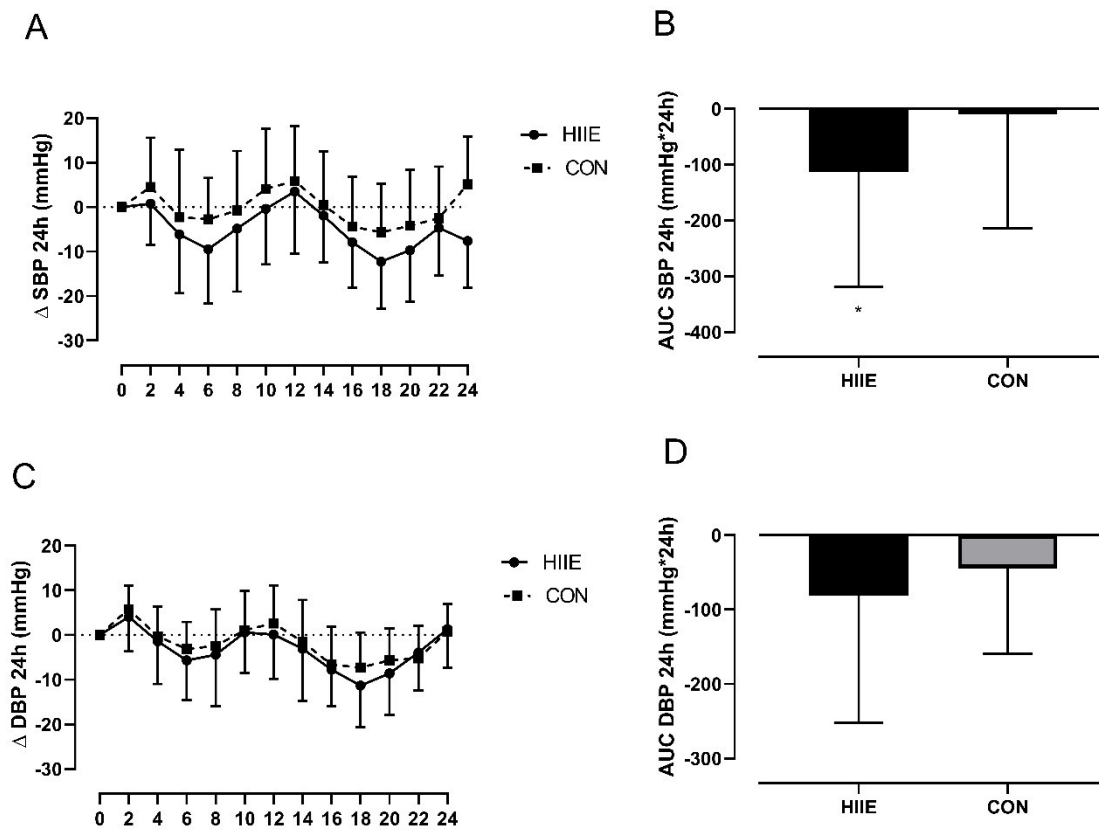


Figure 5. Responses of SBP and DBP during 24 hours after HIIE and CON sessions. A and C: delta of SBP and DBP, respectively; B and D: area under the curve (AUC) of SBP and DBP, respectively. HIIE: high-intensity interval exercise session; CON: control session; SBP: systolic blood pressure; DBP: diastolic blood pressure; *Significant p-value (<0.05).

The absolute values of 24-hour SBP showed a significant reduction over time ($p < 0.001$) in both sessions. There was no difference between the sessions ($p = 0.99$). However, SBP showed an interaction between sessions and time ($p < 0.001$) after 24 hours, being lower after the HIIE session compared to the CON session (d Cohen = 0.80 large). DBP also decreased over time in both sessions ($p < 0.001$) but showed no differences between sessions ($p = 0.96$) and no interaction between sessions and time ($p = 0.30$) (Table 2).

1 Table 2. 24-hour blood pressure responses after HIIE and CON sessions, n=22.

Hours	HIIE mean±SD	CON mean±SD	p time	p session	p session*time
SDP (mmHg)					
Pre	119±11	114±12			
2	119±14	119±14			
4	112±12	112±15			
6	109±9	111±10			
8	114±12	113±11			
10	118±13	118±12	<0.001	0.99	<0.001
12	122±17	120±12			
14	117±12	114±10			
16	111±10	110±14			
18	106±10	108±14			
20	119±11	110±11			
22	114±11	111±11			
24	111±10 [#]	119±10			
DBP (mmHg)					
Pre	73±7	71±7			
2	77±11	77±10			
4	71±10	71±10			
6	67±9	68±10			
8	68±9	69±10			
10	73±9	73±10			
12	73±9	74±10	<0.001	0.96	0.30
14	70±9	70±11			
16	65±9	65±10			
18	62±10	64±11			
20	64±9	66±11			
22	69±9	66±10			
24	74±8	73±9			

2 HIIE: High-intensity interval exercise session; CON: Control session; SBP: Systolic Blood Pressure, DBP:
3 Diastolic Blood Pressure; # p<0.05 between sessions at time 24.

4

5 There was no difference in the variability of SBP and DBP (p>0.05) during the 24 hours
6 after the HIIE and CON sessions (Table 3).

7

8

9

Table 3. Blood Pressure Variability during 24 hours after HIIE and CON sessions, n=22.

Variables	HIIE mean±SD	CON mean±SD	p
SBP (mmHg)			
DP 24h	12 ± 4	12 ± 2	0.51
SDdn	11 ± 3	11 ± 2	0.31
ARV	9 ± 3	10 ± 2	0.56
DBP (mmHg)			
DP 24h	10 ± 2	9 ± 2	0.42
SDdn	9 ± 2	8 ± 1	0.32
ARV	7 ± 2	7 ± 2	0.86

HIIE: High-intensity interval exercise session; CON: Control Session; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; SD 24h: Standard Deviation of 24-hour Blood Pressure; SDdn: Standard Deviation of Blood Pressure weighted by day and night duration; ARV: Average Real Variability of Blood Pressure over 24 hours.

The reactivity of blood pressure did not differ between HIIE and CON sessions for both SBP and DBP in relation to the resting, peak, and delta measurements ($p > 0.05$) (Table 4).

Table 4. Blood pressure responses during the reactivity test after HIIE and CON sessions, n=22.

Variables	HIIE mean±SD	CON mean±SD	p
SBP (mmHg)			
Rest	115 ± 15	113 ± 15	0.61
Peak	123 ± 15	121 ± 13	0.50
Delta	8 ± 7	8 ± 8	0.91
DBP (mmHg)			
Rest	74 ± 9	73 ± 7	0.45
Peak	82 ± 8	79 ± 9	0.11
Delta	8 ± 4	6 ± 7	0.45

HIIE: High-intensity interval exercise session; CON: Control session; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; Delta: Peak - Rest.

Table 5 presents the participants' perception of stress after the blood pressure reactivity test. It is noticeable that the stress level after HIIE and CON sessions was similar.

Table 5. Stress level after blood pressure reactivity test after HIIE and CON sessions, n=22.

Stress Level	HIIE n (%)	CON n (%)
Not stressful	1 (4.5%)	0 (0%)
Slightly stressful	2 (9.1%)	2 (9.1 %)
Stressful	7 (31.8%)	8 (34.4%)
Very stressful	6 (27.3%)	7 (31.8%)
Extremely stressful	6 (27.3%)	5 (22.7 %)

HIIE: Interval Aquatic Exercise session; CON: Control session

In relation to HRV, there was no difference between the sessions in the time domain:

RMSSD (p=0.13) and SDNN (p=0.09), and in the frequency domain: LF (p=0.06), HF (p=0.06), and LF/HF (p=0.74) during 60 minutes after the sessions.

The analyzes found no interaction between sessions and times in the RMSSD (p=0.26), SDNN (p=0.13), LF (p=0.82), HF (p=0.83), LF /HF (p=0.83). However, the SDNN index, which is related to a global HRV response, showed an average difference of 7 ± 4 ms (p session=0.04) after the CON session compared to the HIIE session (Table 6).

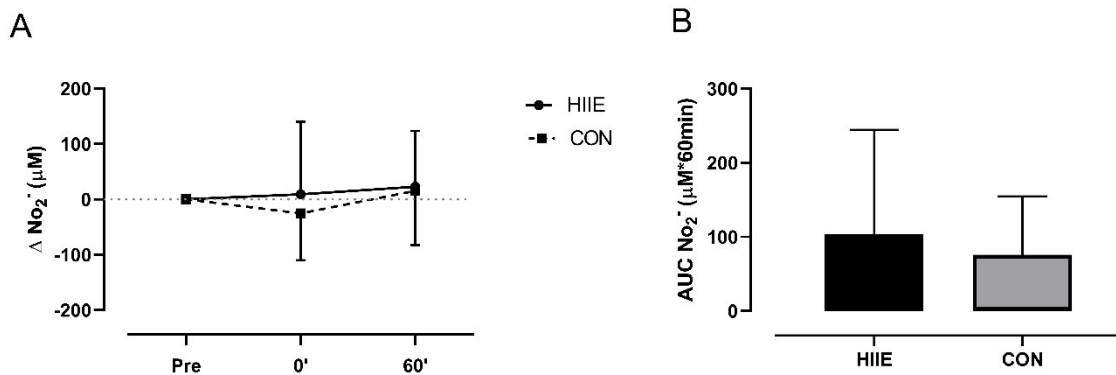
Table 6. Heart rate variability responses after HIIE and CON sessions, n=22.

Variables	HIIE mean±SD	CON mean±SD	p time	p session	p session*time
RMSSD (ms)					
Pre	21±14	26±17			
15min	23±22	32±18			
30 min	21±15	32±19	0.67	0.13	0.26
45 min	23±24	31±23			
60 min	22±16	29±16			
SDNN (ms)					
Pre	22±10	26±13			
15min	21±15	31±13			
30 min	22±10	31±15	0.25	0.04	0.13
45 min	24±14	32±18			
60 min	23±10	29±12			
LF (n.u.)					

Pre	56±20	59±15			
15min	61±23	57±21			
30 min	59±22	57±21	0.58	0.74	0.82
45 min	62±22	59±20			
60 min	58±20	56±21			
HF (n.u.)					
Pre	43±20	40±15			
15min	38±23	42±21			
30 min	40±22	42±21	0.66	0.73	0.83
45 min	37±22	40±20			
60 min	40±20	42±21			
LF/HF					
Pre	2.6±4.4	2.1±2.0			
15min	2.8±2.3	2.4±2.7			
30 min	3.2±4.0	2.4±2.8	0.41	0.20	0.83
45 min	3.2±3.5	2.2±1.8			
60 min	2.5±2.8	2.0±1.8			

1 HIIE: High-intensity interval exercise session; CON: Control session. RMSSD: Root Mean Square of Successive
2 Differences; SDNN: Standard Deviation of all NN intervals; HF: Power in the high-frequency range; LF: Power
3 in the low-frequency range; LF/HF ratio: Ratio of low frequency to high frequency.
4

5 There was no difference in salivary nitrite concentration during 60 minutes after the
6 sessions ($p = 0.39$) (Figure 6). Furthermore, the absolute values of nitrite concentration did not
7 differ concerning time ($p = 0.10$), session ($p = 0.60$), and time*session interaction ($p = 0.45$).



8
9 Figure 6. Nitrite (NO_2^-) concentration after HIIE and CON sessions. A: delta of nitrite concentration after the
10 session. B: area under the curve (AUC) of nitrite concentration. HIIE: High-intensity interval exercise session;
11 CON: Control session.

The analysis of the food recall showed that there was no difference in protein ($p=0.85$), carbohydrate ($p=0.88$), lipid ($p=0.42$) consumption, and total calories ($p=0.83$) on the day before the HIIE and CON sessions.

5. DISCUSSION

The present study aimed to evaluate the acute effects of interval aquatic exercise on cardiovascular and salivary nitrite responses in postmenopausal women with hypertension. The main results showed that the interval aquatic exercise session was able to reduce both SBP and DBP for 60 minutes post-session and decrease SBP over a 24-hour period. There were no significant differences in blood pressure variability, reactivity and nitrite concentration after the sessions. Additionally, the SDNN index was higher after the CON session compared to the HIIE session.

HIIE has been studied as an alternative for cardiac rehabilitation, showing beneficial effects superior to continuous moderate-intensity exercise in the short to long term. This includes improvements in endothelial and vascular function, which are crucial for the prevention and treatment of cardiovascular diseases. Additionally, individuals practicing HIIE report higher adherence to the exercise programs (Guiraud et al., 2012). Regarding BP, the exercise "dose" is an important variable that still requires further investigation.

A previous study found that low-intensity, prolonged-duration exercise produces the same effect on ABPM in normotensive men as land-based HIIE (Jones et al., 2007). In water, HIIE (2 bouts of 10 minutes) led to a greater reduction in ABP in hypertensive elderly individuals compared to continuous moderate-intensity exercise and land-based HIIE (Sosner et al., 2019). In the present study, a 16-minute session (2 bouts of 8 minutes) of interval aquatic exercise was able to reduce the BP of postmenopausal hypertensive women for 60 minutes and SBP for 24 hours.

1 So far, few studies have investigated the BP response of hypertensive individuals after
2 a session of aquatic HIIE compared to a control session in water. Júnior et al. (2018) conducted
3 aquatic HIIE with 12 hypertensive women (66 ± 4 years) and found a reduction in SBP and
4 DBP after 45 minutes; the control session involved participants standing and immersed.
5 Meanwhile, Marçal et al. (2022) assessed ambulatory BP after an acute session with 20 men
6 and women (67 ± 7 years), with the control session involving participants sitting in water. In
7 this study, BP was evaluated over 24 hours, revealing a reduction in SBP at 45 minutes, and
8 over 24 hours, the BP returned to baseline levels. It is important to note that the effects of BP
9 in the aquatic environment depend on various factors, such as immersion depth and body
10 position, which should be consistent in both sessions for better comparison.

11 From this study, it was found that interval aquatic exercise did not induce changes in
12 24-hour BPV, displaying a well-defined circadian rhythm and not generating reactivity in BP,
13 indicating that it was not a stressful activity for the participants. The lack of variation in BPV
14 observed in the study may be related to the use of antihypertensive medications, as these are
15 responsible for normalizing the circadian variation of BP in hypertensive patients, thereby
16 improving cardiovascular prognosis (Kario, 2004). It was found that different classes of
17 antihypertensive medications have varying effects on BPV, with a greater reduction in
18 variability observed in patients treated with diuretics and calcium channel blockers, which were
19 predominantly used by the participants in this study (Levi-Marpillat, et al., 2014).

20 Postmenopausal hypertensive women exhibit a reduction in HRV, which is associated
21 with a higher risk of cardiovascular complications (Brockbank et al., 2000). Despite physical
22 training being known to increase variability (Schuit et al., 1999), a session of both aquatic and
23 land-based moderate-intensity exercise did not alter HRV in hypertensive elderly individuals
24 under pharmacological treatment (Ngomane et al., 2019), as observed in the present study.
25 Thus, hypertensive patients under treatment showed a nonsignificant trend toward altering HRV

parameters (Bocalini et al., 2017). On the other hand, a meta-analysis suggested that relaxation exercises may decrease blood pressure and increase HRV (Sangthong & Pickler, 2004). In the present study, it was observed that the SDNN index was higher after the CON session compared to the HIIE session.

Another crucial factor for the cardiovascular health of postmenopausal hypertensive women is the bioavailability of NO. Although the present study did not find a difference in salivary NO₂- concentration, Chikara et al. (2007) found that a 30 minutes session of moderate-intensity aerobic exercise promoted vasodilation through an increase in NO concentration in healthy young men, while intense exercise led to increased oxidative stress. In postmenopausal hypertensive women, moderate-intensity aerobic training resulted in a 30.4% increase in NO concentration and a reduction in blood pressure (Khalid et al., 2013). A meta-analysis found that both HIIE and moderate-intensity training increased serum nitrite/nitrate levels, regardless of exercise duration (Arefirad et al., 2022). Despite land-based exercise and aerobic training leading to an increase in NO and nitrite/nitrate concentration, there is a lack of studies assessing endothelial responses after high-intensity aquatic exercises.

As a limitation, the study was carried out with a small sample size, which may have impacted the results. However, to minimize this limitation, the effect size of the outcomes was calculated, where we found a moderate effect in relation to the reduction in SBP and DBP up to 60 minutes after the session and a high effect in relation to the reduction in SBP during 24 hours. On the other hand, the study's strength lies in its methodological rigor, demonstrated through a well-conducted study design, the use of validated equipment, and, additionally, the control session conducted under the same conditions as the exercise session. The 24-hour dietary intake of the participants was also assessed to minimize the influence of diet on our findings. The study holds significant clinical implications as it reinforces that interval aquatic exercise is both safe and effective for individuals with hypertension.

The Brazilian Hypertension Guideline (2020) indicates physical activity as an important factor for the primary prevention of the disease, recommending at least 150 minutes per week of moderate-intensity physical activity or 75 minutes per week of vigorous physical activity, which can progress to 300 minutes and 150 minutes, respectively (Barroso et al., 2021). The present study demonstrated that a 24-minute session of interval aquatic exercise was able to reduce BP, with an effect on SBP lasting up to 24 hours. This suggests a quick and cost-effective alternative that could be implemented in the Health System for the prevention and treatment of hypertension. Finally, to our knowledge, this is the first study to conduct an interval aquatic exercise session with postmenopausal hypertensive women.

Therefore, it is suggested that future studies assess the chronic effects of interval aquatic exercise in postmenopausal hypertensive women to examine the hypotensive effect of this modality. Additionally, it is recommended that these studies include a water-based control group and a land-based control group, as immersion may induce cardiovascular changes due to the properties of water.

6. CONCLUSION

The high-intensity interval aquatic exercise was able to acutely decrease resting SBP and DBP during 60 minutes and SBP during 24 hours after this exercise performance in hypertensive postmenopausal women. Otherwise, this session did not change blood pressure reactivity, blood pressure variability, heart rate variability, and salivary nitrite concentration. The present study is of great clinical relevance, as aquatic exercise is widely sought after and recommended for postmenopausal women. Furthermore, the results showed that the intense and interval method promoted an acute reduction in BP, this response promotes immediate effects on cardiovascular health, such as relief of symptoms associated with hypertension and the risk of adverse cardiovascular events. Therefore, the findings of this study may contribute to the

1 recommendation of aquatic exercises as a treatment and prevention measure for hypertension,
2 thus promoting the health of this population.

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