REVIEW

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Effects of heated water-based exercise on blood pressure: a systematic review

Efeito do exercício em piscina aquecida sobre a pressão arterial: uma revisão sistemática

Efecto del ejercicio en piscina climatizada sobre la presión arterial: una revisión sistemática

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Abstract

Introduction: Systemic arterial hypertension is one of the main cardiovascular risk factors affecting several population. In this context, heated water-based exercise has emerged as a potential alternative to land-based physical exercise to reduce blood pressure (BP) in hypertensive patients. **Objective:** To systematically synthesize evidence for the lowering effects of heated water-based exercise on BP in a non-specific population.

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Methods: Scielo, Pubmed and Scopus electronic databases were searched for studies from 2005 to 2016, with the following descriptors in English: "blood pressure, exercise, immersion, blood pressure and hydrotherapy". A total of 10,461 articles were found and, after applying the inclusion and exclusion criteria, 13 articles were selected and included in the final analysis. All included articles evaluated individuals from different populations and age groups, submitted to a heated water-based exercise session and/or program. **Results:** The results suggest that both an acute single session and chronic training period (12 to 24 weeks) of heated water-based exercise may reduce BP in different populations (normotensive, hypertensive, postmenopausal women, and heart transplant populations). The magnitude and duration of acute and chronic hypotensive effect of exercise ranged substantially, which was probably due to the variety of exercise frequency, duration and intensity, as well as due to the studied population. **Conclusion:** These results suggest that heated water-based exercise may promote acute and chronic hypotensive effects in different populations. However, there is no homogeneity in the protocols used, which may have led to the heterogeneity in magnitude and duration of BP reductions.

Keywords: Blood Pressure. Exercise. Hydrotherapy. Hypertension. Immersion.

Resumo

Introdução: *A hipertensão arterial sistêmica (HAS) é um dos principais fatores de risco cardiovasculares que afeta diferentes populações. Sendo assim, o exercício físico em piscina aquecida tem surgido como uma potencial alternativa ao exercício físico em solo para a redução da pressão arterial (PA) de indivíduos hipertensos.* ***Objetivo****: Revisar a evidência dos efeitos do exercício físico em piscina aquecida na redução da PA em populações não especificas.* ***Métodos****: Foram pesquisadas as bases de dados eletrônicas Scielo, Pubmed e Scopus, de 2005 a 2016, com os seguintes descritores em inglês: "pressão arterial, exercício, imersão, pressão arterial e hidroterapia". Foram encontrados 10.461 artigos e, após a aplicação dos critérios de inclusão e exclusão, foram selecionados 13 artigos que fizeram parte da análise final. Todos os artigos incluídos avaliaram indivíduos de diferentes populações, em diferentes faixas etárias, submetidos a uma sessão e/ou programa de exercícios físicos em piscina aquecida.* ***Resultados****: Os resultados sugerem que uma sessão aguda de exercício físico em piscina aquecida, bem como um programa de treinamento de 12 a 24 semanas, pode reduzir a pressão arterial em diferentes populações (normotensos, hipertensos, mulheres na pós-menopausa e transplantados cardíacos). Houve uma grande variação na magnitude e duração do efeito hipotensivo do exercício, o que pode ter sido devido à grande variação de frequência, duração e intensidade das sessões, bem como de populações estudadas.* ***Conclusão****: Estes resultados sugerem que o exercício físico em piscina aquecida pode ter efeito hipotensivo agudo e crônico em diferentes populações. No entanto, não há homogeneidade nos protocolos utilizados, o que pode ter levado à heterogeneidade na magnitude e duração das reduções de PA.*

Palavras-chave: *Pressão Arterial. Exercício. Hidroterapia. Hipertensão. Imersão.*

Resumen

Introducción*: La hipertensión arterial sistémica es uno de los principales factores de riesgo cardiovascular que afecta diferentes poblaciones. Siendo así, el ejercicio físico en piscina calentada ha surgido como una alternativa potencial al ejercicio físico en suelo para la reducción de la presión arterial (PA) de pacientes hipertensos.* ***Objetivo****: Revisar la evidencia de los efectos del ejercicio físico en la piscina calentada en la reducción de la PA en poblaciones no específicas.* ***Métodos****: Buscamos las bases de datos electrónicas Scielo, Pubmed y Scopus, de 2005 a 2016, con los siguientes descriptores en inglés: "presión arterial, ejercicio, inmersión, presión arterial e hidroterapia". Se encontraron 10461 artículos y, después de la aplicación de los criterios de inclusión y exclusión, fueron seleccionados 13 artículos que fueron parte del análisis final. Todos los artículos incluidos evaluaron individuos de diferentes poblaciones en diferentes grupos de edad sometidos a programas de ejercicios físicos acuáticos.* ***Resultados****: Los resultados sugieren que el ejercicio físico realizado en una piscina calentada puede llevar a diferentes respuestas en la presión arterial, dependiendo de la frecuencia, la duración y la intensidad de* *las sesiones.* ***Conclusión****: Estos resultados sugieren que el ejercicio realizado en una piscina calentada durante 12 a 24 semanas de entrenamiento puede promover efectos benéficos sobre la reducción de la PA. Por otra parte, la sesión aguda no es suficiente para causar un efecto hipotensor. Sin embargo, no hay homogeneidad en los protocolos utilizados, lo que puede haber llevado la divergencia en los resultados.*

Palabras clave*: Presión Arterial. Ejercicio. Hidroterapia. Hipertensión. Inmersión.*

Introduction

Systemic arterial hypertension (HPT) is a highly prevalent disease associated with high risk for cardiovascular morbidity and mortality [1-3]. However, it is well known that cardiovascular disease risk may be reduced by physical exercise, which promote acute [4-6] and chronic [7-11] reductions on blood pressure (BP), and improves several mechanisms involved in HPT pathophysiology [8, 10, 12, 13]. Therefore, regular practice of physical exercise has been recommended for the prevention and management of HPT [1, 2, 14].

Moderate intensity land-based exercise (LEx) training (i.e. walking, cycling, running and resistance exercise) is commonly recommended for hypertensive patients [9, 11, 13, 14]. However, heated water-based exercise (HEx) has been shown to promote important cardiovascular and muscular benefits in different populations [15-19]. For example, substantial BP reduction was found after 2 weeks (nearly 12/8 mmHg reduction on systolic/diastolic BP) [17] and 12 weeks (nearly 36/12 mmHg reduction on systolic/diastolic BP) [18] of HEx training in subjects with resistant systemic arterial hypertension, which were greater than the BP reductions observed after a LEx training of similar dose (duration, volume, frequency and intensity) [20].

In addition, the buoyancy effect during HEx reduces loading, facilitating the performance of individuals unable to perform high-impact dynamic exercises [16]. However, there is no consensus in literature on which HEx protocol is more appropriate to promote reductions in BP, since the depth of water immersion, exercise intensity and modality, water temperature, and body position during exercise [21-23] can influence the cardiovascular responses. Moreover, although there are systematic reviews and meta-analyses about the acute and chronic effects of LEx on BP [9, 11, 24, 25], none of them have distinguished the effects of HEx. Thus, the aim of this review is to systematically synthesize evidence for the lowering effects of HEx on BP in non-specific population.

Methods

Search strategy and study selection

PubMed (via National Library of Medicine), Scopus (Elsevier) and SciELO (Scientific Electronic Library Online) databases were searched for articles about the effects of HEx on BP. The following MeSH terms or keywords were used for the intervention type (immersion AND immersion exercise AND hydrotherapy AND aquatic exercise) and outcomes (blood pressure OR hypertension). The reference list of original articles within this field of study was also reviewed to identify potential eligible trials.

The present systematic review included only randomized clinical trials (RCTs) published between January 2005 and December 2016 that investigated the effects of HEx on BP in adults (age ≥ 18 years) with or without comorbidities. The inclusion of studies with hypertensive and normotensive individuals was in order to assess the hypotensive effect of HEx and its potential use as a therapeutic and preventive strategy for HPT. Reviews, short communications, letters, case studies, guidelines, theses, dissertations, qualitative studies, scientific conference abstracts, studies on animals, methodological or observational (descriptive only) articles, studies with HEx associated with other therapeutic interventions and clinical trials that did not have the full text available in English or Portuguese language were not included. Two independent reviewers (A. Y. N. and R. M. A.) performed the literature search and study assessment. The articles were initially screened based on their title and abstract, and were selected for full-text screening when any of the reviewers considered the abstract potentially eligible.

Data extraction and analysis

Data on study source, sample size, participants characteristics (i.e. age, sex, baseline BP and physical activity levels, comorbidities), method used to measure BP, characteristics of HEx (i.e. type, frequency, intensity and duration of exercise; water temperature; depth of water immersion), LEx (i.e. type, frequency, intensity and duration of exercise) and control interventions (i.e. type, frequency and duration), outcomes and limitations of the studies included were extracted independently by two authors (A. Y. N. and R. M. A.). The two reviewers also independently assessed methodological quality of included studies using the Physiotherapy Evidence Database (PEDro) scale[1]. When there were disagreements between reviewers on data extraction, data analyses and/or quality assessment, a third reviewer (E. G. C.) was consulted to solve the discrepancy. The results of the systematic review are presented descriptively (e.g. means, standard deviations, and minimum and maximum values).

Results

The electronic database search identified 10,461 articles. A total of 54 duplicate articles were removed, and 103,58 articles were excluded after screening by title and abstract. Full-text screening for eligibility of the remaining 49 articles removed 23 non-randomized clinical trials, five articles published before January 2005, six articles who did not present BP outcomes for all interventions, and two reviews. Finally, 13 clinical trials assessing acute (BP response to a single HEx session) [19, 21, 23, 26-28] or chronic (BP response to a HEx training program) [17, 18, 29-33] effect of HEx on BP were included in the present review (Figure 1).

Study and subject characteristics

General characteristics of each study included in the present review are displayed in Table 1. Six studies with sample size ranging from 14 to 20 subjects assessed the acute effect of HEx on BP in physically inactive hypertensive [21, 26, 28] and normotensive [23, 26] individuals, recreationally active normotensive [27], and sedentary heart transplant recipients [6], totaling 105 participants. Two studies included only young individuals [23, 27], two studies included only middle-aged individuals [26, 28] and one study included both middle-aged and older individuals [21]. All studies assessing acute effect of HEx on BP had randomized cross-over design with one [6, 21, 23, 27, 28] or two groups [26], and assessed the effect of HEx *versus* LEx session [23, 27], control session (CON) [28] or both LEx and CON [6, 21, 26]. One study further compared the BP response to HEx between hypertensive and normotensive subjects [26].

Six RCTs with an initial sample size ranging from 26 to 60 subjects assessed the chronic effect of HEx on BP in normotensive [30], pre-hypertensive [32] and hypertensive [29, 31] individuals, in patients with resistant hypertension

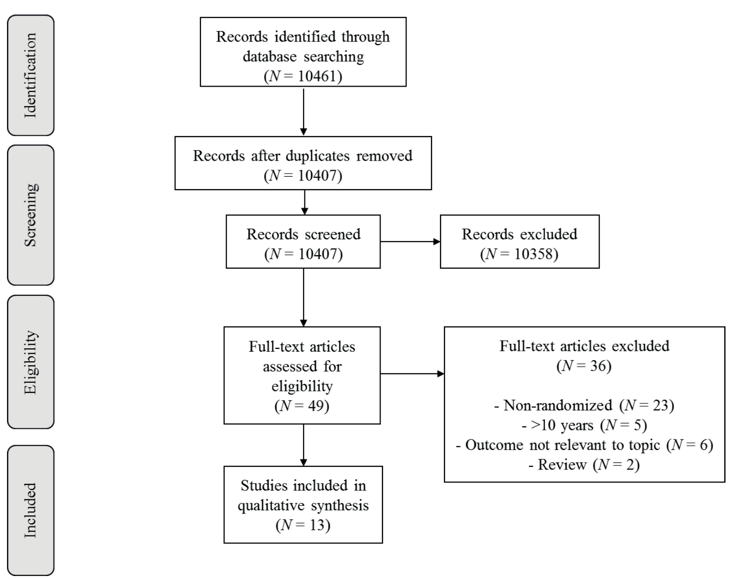

Figure 1 - Flowchart of the process of screening and selection of articles for inclusion in the review.

1 See <http://www.pedro.org.au>.

[17, 18], and in postmenopausal women [33], totaling 292 randomized participants. Six studies included only middle-aged subjects [17, 18, 30-33] and one study included only older subjects [29]. All chronic studies had parallel design and assessed the effect of HEx *versus* LEx [30], CON [17, 18, 31, 32] or both LEx and CON [29, 33].

Finally, the study quality using PEDro-scale is shown in Table 2. The median PEDro score of studies assessing the acute effect of HEx on BP was 6, with a range from 3 to 8. In the studies assessing the chronic effect of HEx on BP, the median PEDro score was 7, with a range from 5 to 9.

Table 1 – Characteristics of included studies

(To be continued)

First author (Country) / Design	Population assessed	HEx intervention	LEx intervention	Control intervention	Water temperature	BP and secondary outcomes assessment
Studies assessing acute response to HEx						
Cunha *et al.* (Brazil) / cross-over [28]	18 overweight (mean age 54.4 ± 7.9 yrs.) and obese hypertensive women (mean age 56.4±6.6 yrs.) were randomly assigned to HEx and CON intervention.	The water aerobics exercise session consisted of a 45-minute training at the intensity of 70%–75% of maximum heart rate adjusted for the aquatic environment.	NR	The control group did not enter the pool and did not perform any exercise.	28.5 ºC	Systolic and diastolic BP was measured before, immediately after, and every 10 min up to 30 min after HEx and CON intervention, using a semiautomatic device (Omron 705-CP).
Castro *et al.* (Brazil) / cross-over [6]	18 heart transplant patients (12 male/6 female, mean age 45.7 ± 2.7 yrs.) were randomly assigned to HEx, LEx and CON.	30 min moderate-intensity (11-13 in the 6-20 RPE) aerobic exercise (walking inside the pool immersed up to the xiphoid process).	30 min moderate-intensity (11-13 in the 6-20 RPE) aerobic exercise (walking on a motorized treadmill).	30 min of resting quietly in the seated position.	30-32 ºC	Ambulatory BP (systolic and diastolic) was measured during 24h after HEx, LEx and CON intervention, using an automatic device (Dyna-Mapa ABP monitor).
Garzon *et al.* (Canada) / cross-over [23]	20 healthy normotensive (18 male/2 female, mean age (32 ± 7 yrs.) were randomly assigned to HEx and LEx.	Pedaling immersed on immersible ergocycle (Hydrorider®)-(immersion to the chest level). External power output on immersible ergocycle was controlled by pedaling rate (rpm). Initial rpm was set at 40 rpm and was increased by 10 rpm until 70 rpm and thereafter by 5 rpm until exhaustion.	Pedaling on dryland ergocycle (Ergoline 800S; Bitz, Germany). Initial external power output of dryland ergocycle protocol was set at 25W and increased by 25W every minute until exhaustion.	NR	30 ºC	Central hemodynamic parameters were measured continuously during exercise and a 5-min recovery period using a sphygmomanometer (WelchAllyn, USA). Central hemodynamic was measured continuously at rest, during exercise and after exercise cessation using impedance cardiography.

(To be continued)

First author (Country) / Design	Population assessed	HEx intervention	LEx intervention	Control intervention	Water temperature	BP and secondary outcomes assessment
Studies assessing acute response to HEx						
Luza *et al.* (Brazil) / cross-over [26]	8 sedentary normotensive (1 male/7 female, mean age 62 ± 3.7 yrs.) and 12 sedentary hypertensive (3 male/9 female, mean age 59 ± 2.6 yrs.) were randomly assigned to HEx, LEx and CON intervention.	Heating; aerobic exercises; fortification; And stretching and relaxation, lasting 45 minutes [moderate-intensity (83-85% of HRMAX)].	The exercise was performed in athletics track, where the subjects were instructed to walk for 45 minutes in the heart rate intensity measured at the intensity corresponding to the anaerobic threshold [moderate-intensity (83-85% of HRMAX)].	In the ground rest protocol, the participants remained sitting for 45 minutes. In the rest protocol in the water, participants were immersed for 45 minutes in the pool. (The immersion occurred up to shoulder height.)	30-32 ºC	Systolic and diastolic BP (standard mercury sphygmomanometer Sankey), and Heart Rate were measured before and after (30, 60 and 90 min) each intervention.
Pugh *et al.* (Australia) / cross-over [27]	15 recreationally active healthy normotensive (8 male/7 female, mean age 26 ± 4 yrs.) were randomly assigned to HEx and LEx intervention.	Once immersed in water, participants remained in the resting upright position for 5 min, which was followed by a 20-min bout of low-intensity exercise consisting of a repetitive stepping protocol (approximately 100 bpm). Upon completion of the exercise bout, participants remained in the resting upright position for a further 5 min, after which, the pumps were reversed to empty the tank-30 min low-intensity (HR = 100 bpm).	Participants remained in the upright standing position and avoided movement for 5 min. This was followed by a 20-min bout of low-intensity exercise consisting of a repetitive stepping protocol (approximately 100 bpm). Upon completion of the exercise bout, participants remained in the resting upright position for a further 5 min.	NR	30 ºC	Finometer PRO (Finapres Medical Systems, Amsterdam, the Netherlands) was used to monitor relative changes in mean BP, cardiac output, and stroke volume, before, during, and 20 min after HEx and LEx intervention.

(To be continued)

First author (Country) / Design	Population assessed	HEx intervention	LEx intervention	Control intervention	Water temperature	BP and secondary outcomes assessment
Studies assessing acute response to HEx						
Sosner *et al.* (Canada) / cross-over [21]	42 hypertensive adults (22 male/20 female, mean age 65 ± 7 yrs.) were randomly assigned to HEx, LEx and CON intervention.	30 min High-intensity interval exercise in up-to-the-chest immersed condition was performed on a mechanically-braked cycle ergometer (Hydrorider, DIESSE, San Lazzaro di Savena, Italia). Each exercise session was preceded by a 5-min warm-up consisting in pedaling at 40 rpm and followed by a 5-min passive recovery period in a sitting position that began immediately after exercise cessation.	Moderate-intensity continuous exercise in dry land were performed on a stationary bicycle ergometer -- 24-min at 50% peak power output. High-intensity interval exercise in dry land were performed on a stationary bicycle ergometer-- two sets of 10-min with phases of 15-sec 100% peak power output interspersed by 15-sec of passive recovery.	NR	30 ºC	The 24h Ambulatory BP (Systolic and Diastolic) was measured with a brachial cuff-based oscillometric device Mobil-O-Graph PWA Monitor (I.E.M. GmbH, Stolberg, Germany)- The monitor was programmed to measure BP every 20 min during the overall 24h. Arterial stiffness was automatically assessed, using the same oscillometric device Mobil-O-Graph PWA Monitor (I.E.M. GmbH, Stolberg, Germany), at rest with the patient in supine position in a quiet atmosphere for the first measurement, and every 20 min during the following 24h.
Studies assessing chronic adaptation to HEx						
Arca *et al.* (Brazil) / Parallel [29]	52 hypertensive women (mean age 64 ± 7 yrs.) randomly assigned to HEx (n = 19), LEx (n = 19) or CON (n = 14) groups.	50-minute sessions on a three-time per week basis during 12 weeks. The heart rate was maintained around 50% to 60% of heart rate reserve.	50-minute sessions on a three-time per week basis during 12 weeks. Dry land exercise was performed in stationary bikes. In the land dry exercise program, the heart rate was maintained around 50% to 60% of heart rate reserve.	Did not change his eating habits and remained without practicing physical activity in the period	33-33.5 ºC	BP measurements were performed with a mercury sphygmomanometer Premium G-tech®, adequately calibrated. In every one of the 12 weeks of intervention in aquatic and land, BP and heart rate were measured before subjects begun exercising, so respectively before immersion in water or before they had a walk on land.

(To be continued)

First author (Country) / Design	Population assessed	HEx intervention	LEx intervention	Control intervention	Water temperature	BP and secondary outcomes assessment
Studies assessing chronic adaptation to HEx						
Colado *et al.* (Spain) / Parallel [33]	46 postmenopausal women randomly assigned to HEx (n = 15, mean age 54.7 ± 2 yrs.), LEx (n = 21, mean age 54 ± 2.8 yrs.) or CON (n = 10, mean age 52.9 ± 1.9 yrs.) groups.	Training was performed twice per week in the first 12 weeks and three times per week for weeks 13–24. The total duration of the training session ranged from 35 to 60 min depending on the phase of periodization of the training program.	Training was performed twice per week in the first 12 weeks and three times per week for weeks 13–24. The total duration of the training session ranged from 35 to 60 min depending on the phase of periodization of the training program.	Did not change his eating habits and remained without practicing physical activity in the period.	NR	BP were taken at the same physician's office within 1 week prior to and after the physical pre and post-testing, respectively. A resting BP measurement was taken after 10 min of quiet sitting. The BP measurement was repeated in the same manner after 48 h to ensure reliability.
Farahani *et al.* (Iran)/ Parallel [34]	40 men with stage 1 or 2 essential hypertension were assigned to HEx (n=12, mean age 48.33 ± 10.74 yrs.) or CON (n = 28, mean age 46.96 ± 11.58 yrs.) groups.	Subjects in the intervention group participated in a supervised 10-week water aerobic training program of 55 min sessions, 3 days per week on alternate days. The exercise intensity was set at 60-65% of the maximal heart rate and increased gradually up to 70-75% during the program.	NR	The control group were not involved in any regular training program during this period.	31-32 °C	Blood pressures were measured using mercury sphygmomanometers (Richter, Germany). Blood pressure was measured at baseline and 48 hours after the last exercise session to avoid the acute effects of a single bout of exercise.
Guimarães *et al.* (Brazil) / Parallel [18]	32 patients with resistant hypertension (15 male/17 female, mean age 53.7 ± 6 yrs.) randomly assigned to HEx (n = 16, 8 male/8 female, mean age 55±5,9 yrs.) or CON (n = 16.6 male/10f emale, mean age 52.4 ± 5.9 yrs.) groups.	60 min of moderate-intensity (11-13 in the 6-20 RPE) aerobic (walking inside the pool immersed up to the xiphoid process) and callisthenic exercise (immersed up to the xiphoid process) performed 3 times a week.	NR	The control group was asked to maintain habitual activities.	32 ºC	Systolic and diastolic BP were measured before, and after 2 and 12 weeks of HEx and CON intervention, using a standard mercury sphygmomanometer. Ambulatory BP (systolic and diastolic) was measured during 24 h before, and after 2 and 12 weeks of HEx and CON intervention, using an automatic device (Spacelabs model).

(Conclusion)

First author (Country) / Design	Population assessed	HEx intervention	LEx intervention	Control intervention	Water temperature	BP and secondary outcomes assessment
Studies assessing chronic adaptation to HEx						
Lambert *et al.* (USA) / Parallel [30]	60 normotensive subjects (30 male/30 female) randomly assigned to HEx (n = 36.19 male/17 female, mean age 41 ± 2 yrs.) or LEx (n = 24.11 male/13 female, mean age 42 ±2 yrs.) groups.	Exercise training included three sessions per week for 12 weeks with sessions progressively increasing from 250 kcal per session, 60% $\dot{V}O_2$max during the first week, to 500 kcal per session, 85% $\dot{V}O_2$max during weeks 6–12.	Exercise training included three sessions per week for 12 weeks with sessions progressively increasing from 250 kcal per session, 60% $\dot{V}O_2$max during the first week, to 500 kcal per session, 85% $\dot{V}O_2$max during weeks 6–12.	NR	33 ºC	BP measured before, at the end of each stage, and for 5 min after exercise testing. Serial BP measurements were obtained using standard sphygmomanometric procedures with subjects resting in the supine position during the last 30 s of each 3-min stage of the graded exercise stress tests and at 1, 3, and 5 min during recovery.
Silva *et al.* (Brazil) / Parallel [31]	26 hypertensive subjects (11 male/15 female) randomly assigned to HEx (n = 13.4 male/9 female, mean age 38.40 ± 8.24 yrs.) or CON (n = 13.7 male/6 female, mean age 38.36 ± 8.96 yrs.) groups.	Regular swimming program consisting of three weekly fifty-minute sessions of training for 10 weeks. The initial sessions had an intensity of around 40% of HRmax.	NR	Did not change his eating habits and remained without practicing physical activity in the period.	27-28 ºC	BP was measured with a digital arterial pressure monitor (Omrom® HEM-741C model, Japan). The measurements were taken always at the same time of day. Before training, the subjects were at rest for at least 10 minutes prior to the measurement of BP. Soon after the training session, the subjects remained at rest again for about 10 minutes before measurement.
Silva *et al.* (Portugal) / Parallel [32]	36 pre-hypertensive men randomly assigned to HEx (n = 24, mean age 40.60 ± 9.36 yrs.) or CON (n = 12, mean age 40.57 ± 8.05 yrs.) groups.	A regular swimming program was conducted, with three weekly sessions of 45 minutes for 12 weeks. The initial sessions had an intensity of around 40% to 50% of HR max.	NR	Did not change his eating habits and remained without practicing physical activity in the period.	27-29 °C	BP was measured according to the recommendations of the ACSM hypertension diagnosis, and was measured using an oscillometric device (Omrom, model HEM-741C, Japan).

Note: Exercise in heated pool (HEx), Exercise in land based (LEx), Control without exercise (CON), Years (yrs.), Scale of 6-20 in perceived exertion (RPE), Pedaling Rate (rpm), Heart Rate (HR), Heart rate maximal (HRmax), Beats per minute (bpm), Blood Pressure (BP), American College of Sports Medicine (ACSM), Not reported (NR).

Table 2 – PEDro score of the included studies

First Author, Year	Criteria PEDro											
	Eligibility	Subjects were randomly allocated	Allocation was concealed	Similar groups	Blinding of all subjects	Blinding of all therapists	Blinding of all assessors	Key outcome in more than 85% of the subjects	Intention to treat	Between-group statistical comparison	Point measure	Total
Arca, 2013 [29]	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	7/10
Castro, 2016 [6]	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8/10
Colado, 2009 [33]	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	7/10
Cunha, 2016 [28]	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	7/10
Farahani, 2010 [34]	Y	N	N	Y	N	N	N	N	Y	Y	Y	4/10
Guimarães, 2014 [18]	Y	Y	Y	Y	N	N	Y	N	Y	Y	Y	7/10
Garzon, 2014 [23]	Y	Y	Y	N	N	N	N	Y	Y	Y	Y	6/10
Lambert, 2014 [30]	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	9/10
Luza, 2011 [26]	Y	Y	N	Y	Y	N	N	N	Y	Y	Y	6/10
Pugh, 2014 [27]	Y	Y	N	N	N	N	N	N	N	Y	Y	3/10
Silva, 2009 [31]	Y	Y	Y	N	N	N	N	N	Y	Y	Y	5/10
Silva, 2015 [32]	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6/10
Sosner, 2016 [21]	Y	Y	N	Y	N	Y	Y	Y	Y	Y	Y	8/10

Note: Y = yes; N = no.

BP and secondary outcomes assessment

The studies evaluating the acute and chronic effect of HEx measured BP by means of standard mercury sphygmomanometer [18,23,26,29,30,33,34], semiautomatic devices [28], brachial cuff-based oscillometric automatic device (24h) [6, 18, 21, 32], Finometer PRO to monitor BP beat-to-beat [27] and digital arterial pressure monitor [31].

Characteristics of HEx

The studies assessing the acute effect of HEx on BP reported low-intensity [27], moderate-intensity [6, 26, 28], and high-intensity aerobic exercise sessions [21, 23], with 30 min [6, 21, 27] or 45 min [26, 28] of duration; however, one study did not report exercise duration [23]. The water temperature ranged from 28.5°C to 32°C. The studies assessing the chronic effect of HEx on BP reported low-intensity [31, 32] and moderate-intensity [17, 18, 29, 30] exercise sessions, with 35 to 60 min of duration; however, one study did not report exercise session duration [30]. The exercise sessions were performed three times a week in six studies [17, 18, 29-32], and progress from two to three times a week in one study [33]. The water temperature ranged from 27°C to 33.5°C; however, the water temperature during HEx was not reported in one study [33].

Effects of HEx on BP and secondary outcomes

The main results and conclusions of acute and chronic water-based exercise on BP are described in Table 3. Five studies showed significant acute BP reduction (systolic and/or diastolic) after HEx [6, 21, 26-28]. On the other hand, one study did not observe acute hypotensive effects after HEx [23]. Considering the chronic effects, six studies showed significant BP reduction after HEx training when compared to control group and/or land-based exercise group [18, 29, 30, 32-34], and only one study showed no effect of HEx training in BP [31]. Indeed, one study observed similar BP reduction in both HEx and LEx group, which were greater than in CON group [29]. Therefore, the results of this review demonstrated some divergent effects in chronic or acute approach post-HEx in BP.

Table 3 – Main results on blood pressure variables, other hemodynamic parameters, secondary measurements and the conclusions of the acute and chronic studies

(To be continued)

Studies assessing the acute response to heated water-based exercise			
Luza et al. [26]	In the hypertensive group, the exercise protocol on the ground caused an average reduction of 16.5 ± 3.7 mmHg ($P = 0.01$) in SBP at 90 minutes post-exercise. In the normotensive group, the protocol of rest in the water caused an average reduction of 14 bpm ($P < 0.01$) in HR.	The volume of diuresis was increased when compared with the protocols accomplished on the ground ($P < 0.01$).	The results suggest that when a physical exercise lasts 45 minutes, at submaximal intensity, it causes reduction of SBP in hypertensive individuals.
Pugh et al. [27]	The HEx and LEx bouts were closely matched for mean arterial BP in 106 mmHg (95% CI) vs 101 mmHg (95% CI), and heart rate (95 bpm (95% CI, 90–101) vs 96 bpm (95% CI, 91–102, $P = 0.65$).	The oxygen consumption was similar between the groups (13.3 mL.kg.min (95% CI, 12.2–14.6) vs 13.5 mL.kg. min (95% CI , 12.1–14.8), $P = 0.89$). Compared with land-based exercise, water-based exercise induced an increase in middle cerebral artery blood flow velocity 74 cm/s (95% confidence interval, 66–81) vs 67 cm/s (95% CI , $P = 0.001$), posterior cerebral artery blood flow velocity 47 cm/s (95% CI) vs 43 cm/s (95% CI , $P = 0.001$), and partial pressure of expired CO_2 ($P = 0.001$).	Water based exercise induces greater increase in cerebral blood flow velocity than land-based exercise of matched intensity. The water immersion may enhance the recurrent episodic increases in cerebral blood flow and shear stress that occur during exercise and, subsequently, amplify cerebrovascular health benefits associated with exercise training.
Cunha et al. [28]	Overall ($n = 18$), DBP did not change after the HEx and CON, and SBP decreased at 10 and 20 min post exercise compared to the CON. Among overweight women, SBP decreased at 10 and 20 minutes post exercise. In contrast, among obese women, SBP decreased only at 10 minutes post exercise. SBP variation was 2.68 mmHg in overweight and 2.4 mmHg in obese women.	NA	The HEx session leads to a reduction in SBP, but not in DBP, during 10 and 20 minutes post exercise recovery.
Castro et al. [6]	No significant differences between interventions were found in 24h and nighttime BP. However, daytime DBP was significantly lower after HEx than CON (-4 ± 1.6 mmHg, $P = 0.03$), and daytime DBP tended to be lower after LEx than CON (-2.3 ± 1.1 mmHg, $P = 0.052$). Hourly analysis showed that SBP and DBP values were lower after HEx (average reductions of 6.6 to 12.3 mmHg, $P < 0.01$) and LEx (average reductions of 5 to 8.3 mmHg, $P < 0.05$) than after CON in several hours. No significant differences between HEx and LEx were found in any ambulatory BP data.	NA	HEx and LEx promoted similar reductions in ambulatory BP of heart transplant recipients. This post exercise hypotension occurred even though the heart transplant recipient patients had lower control ambulatory BP levels (average 24h of 122/81 mmHg), which does not occur in non-heart transplant recipient populations. These results suggest that both exercises may be tools to counteract hypertension in this high-risk population.

(To be continued)

Studies assessing the acute response to heated water-based exercise			
Garzon et al. [23]	BP and systemic vascular resistance were not different in exercise on HEx and LEx in ergocycle. The stroke volume and cardiac output were significantly higher during exercise on immersible ergocycle ($P < 0.05$, $g = 0.59$ and 0.20 respectively). The stroke volume, ejection fraction and contractility index were higher ($P < 0.05$, $g = 0.64$, 0.71 and 0.19 respectively).	Both oxygen uptake and arteriovenous difference were significantly lower during exercise on immersible ergocycle ($P < 0.001$, $g = -0.25$ and -0.87 respectively). During recovery, oxygen uptake and arteriovenous difference were significantly reduced in water ($P < 0.001$, $g = -0.41$ and -0.67).	During exercise and recovery in immersion, arteriovenous differences were reduced in healthy young participants, while stroke volume and cardiac output were increased for the same external power output. During the recovery, central hemodynamic responses remained higher in immersible ergocycle. BP and systemic vascular resistance were not different between the two conditions.
Sosner et al. [21]	Dryland high intensity interval exercise induced a significant decrease in both SBP and DBP measures during the 24h period (SBP: -3.6 ± 5.7 mmHg, P = .04; DBP: -2.8 ± 3.0 mmHg, P = .00) and the daytime period (SBP: -4.4 ± 7.5 mmHg, P = .046; DBP: -2.9 ± 4.0 mmHg, P =.02) but not during the nighttime period. High intensity interval exercise immersed resulted in a greater decrease from baseline in systolic measures during the 24h period SBP: -6.8 ± 9.5 mmHg, P = .02) and the daytime period (SBP: -7.5 ± 11.2 mmHg, P = .03). There was also a decrease in diastolic measures during the 24h period (DBP: -3.0 ± 4.5 mmHg, P = .03) and the daytime period (DBP: -3.9 ± 4.5 mmHg, P = .006).	NA	In individuals with a baseline office BP ≥ 130/85 mmHg, the 24h BP load decreased significantly following a bout of high intensity interval exercise performed on a stationary cycle in immersed condition.
Studies assessing the chronic response to heated water-based exercise			
Guimarães et al. [18]	12 weeks of HEx significantly decreased SBP and DBP in the 24-hour period (19.5 ± 11.0 and 11.1 ± 3.1 mmHg), daytime (22.3 ± 12.6 and 13.0 ± 3.6 mmHg) and nighttime (17.4 ± 9.1 and 8.5 ± 2.1 mmHg). SBP office was reduced from 162 to 144 mmHg ($P < 0.004$) after HEx. After Hex, during 24-h ambulatory BP, SBP decreased from 135 to 123 mmHg ($P = 0.02$), DBP decreased from 83 to 74 mmHg ($P = 0.001$), daytime SBP decreased from 141 to 125 mmHg ($P = 0.02$), DBP decreased from 87 to 77 mmHg ($P = 0.009$), night-time SBP decreased from 128 to 118 mmHg ($P = 0.06$) and DBP decreased from 77 to 69 mmHg ($P = 0.01$). In addition, BP cardiovascular load was reduced significantly during the 24-h daytime and night-time period after the HEx. HEx reduced office BP and 24-h daytime and night-time ambulatory BP levels.	NA	HEx induced beneficial effects on BP in patients with resistant hypertension, and there were no signs of adverse reactions. These effects suggest that HEx may have a potential as a new therapeutic approach to resistant hypertensive patients.

(Conclusion

Studies assessing the chronic response to heated water-based exercise			
Arca et al. [29]	Reduction on SBP in water group from 136 ± 16 mmHg at week zero to 124 ± 15 mmHg at week 12. In LEx, there was a reduction from 138 ± 15 mmHg at week zero to 126 ± 9 mmHg at week 12. SBP has no changes in CON.	NA	The lowering of BP in hypertensive women submitted to HEx was similar to the one obtained with LEx and more intense than in the inactive CON. This controlled study addresses the antihypertensive effect of HEx in post-menopausal women.
Lambert et al. [30]	HEx decreased resting DBP (-3.2 mmHg, $P < 0.05$) significantly when compared to LEx, SBP (-9.0 to 18.2 mmHg, $P < 0.05$), mean arterial pressure (-4.8 to 8.3 mmHg, $P < 0.05$), pulse pressure (-7.5 to 15 mmHg, $P < 0.05$), and rate pressure product (-1.8 to 3.9 bpm.mmHg.103, $P < 0.05$). Under exercise stress, HEx, but not LEx, demonstrated reductions in HR (range 6.5–7.9 bpm lower for each stage, $P < 0.05$).	NA	The HEx preferentially ameliorates blood pressure reactivity to exercise stress, which would then be predicted to prevent or delay the onset of chronic diseases such as essential hypertension.
Silva et al. [32]	The SBP and DBP significantly reduced only in HEx (5.89 mmHg for SBP and 5.15mmHg for DBP).	NA	The results show that regular HEx causes significant decreases in systolic and diastolic pressures in pre-hypertensive men.
Silva et al. [31]	Comparisons of the BP levels observed before and after the intervention revealed no statistically significant differences.	NA	Despite evidence demonstrating the benefits of swimming for arterial pressure, it is necessary to emphasize the need for further studies to determine the optimal parameters for the prescription of physical activity for hypertensive individuals. Thus, the activities or forms of exercise can be selected to meet the personal characteristics of each individual in order to enhance the prevention, treatment, and control of hypertension.
Colado et al. [33]	The DBP significantly reduced ($P \leq 0.01$) in both exercise groups (6.8 mmHg in HEx group and 4.8 mmHg in the elastic band group).	NA	Training with aquatic resistance exercises is a viable alternative to traditional resistance with elastic bands, and may provide more benefits to individuals who would be more sensitive to heavier loads or to impact, which may occur when training on LEx with certain devices and exercises.
Farahani et al. [34]	Exercise lowered SBP and mean arterial pressure by 11.71 (95% confidence interval: 5.07 to 18.35) and 5.90 (95% confidence interval: 1.17 to 10.63) mmHg respectively. The lowering effect of exercise on DBP was neither statistically significant nor clinically important (0.55 mmHg; $P = 0.8$).	There was no significant effect of age, baseline body mass index and stage of hypertension on the exercise-induced changes in BP.	A 10-week course of HEx markedly reduced the systolic and mean arterial BP of patients with essential hypertension and is especially recommended for the obese and the elderly who have orthopedic problems or bronchospasm.

Note: Exercise in heated pool (HEx), exercise in land based (LEx), Control group (CON), systolic blood pressure (SBP), diastolic blood pressure (DBP), blood pressure (BP), not assessment (NA), confidence interval (CI).

Discussion

The present systematic review evaluated the effect of HEx on BP in different populations. Although HEx failed to reduce BP levels after an acute [23] and a chronic [31] intervention study, the present systematic review identified significant acute [6, 21, 26-28] and chronic [18, 29, 30, 32-34] hypotensive effect of HEx in different populations.

There are several physiological mechanisms triggered by the aquatic environment which benefits the neurohumoral control of BP [22, 35, 36]. The physical properties of water, such as the hydrostatic pressure, are responsible for facilitating venous return, which stimulates baroreceptors to trigger the increase in cardiac filling volume and stroke volume, reflexively reducing heart rate and BP [6, 35-37]. In addition, heated water ranging from 30 to 32°C triggers a reduction in peripheral vascular resistance due to dilatation of arterioles [6, 18, 38].

Moreover, HEx reduces circulating levels of adrenergic neurotransmitters epinephrine and norepinephrine, renin and endothelin-1, as well as increases circulating levels of nitric oxide, which may results in reduced peripheral vascular resistance [38]. Regarding neurohumoral regulation, the improved renal system undergoes inhibition of renin-angiotensin-aldosterone system, increases factors that excrete sodium (atrial natriuretic peptide), and favors diuresis, which reduce blood volume [9, 18, 38]. Other hypothesis is that there are improvements in sympathomodulatory and arterial baroreceptors after HEx, which reduce BP.

In contrast to the beneficial results of HEx, two studies did not identify differences in BP values in patients with hypertension [31] and healthy normotensive individuals [23]. These effects can be attributed to methodological differences in relation to training protocols, when compared with the other studies that found reduction of BP in the same populations [18, 21, 26-30, 32]. One possible explanation for the lack of hypotensive effect in the above mentioned studies is that the exercise protocol did not follow the recommendations for dynamic exercises, such as an exercise intensity between 50% and 80% of peak oxygen consumption [2].

Muscle mass is another important factor that may contribute to the post-exercise hypotension after HEx. The larger muscle mass involved in HEx may result in larger production of vasodilatory agents, such as adenosine, potassium, lactate, nitric oxide and prostaglandin [24]. Although some land-based exercises (e.g. walking, running, cycling) require the participation of large muscle groups, it appears that HEx requires a greater activation of major muscle groups due to the resistance imposed by the water, thus triggering hypotension. In this context, heart failure patients who underwent an exercise program associating LEx and HEx (water temperature of 31ºC) showed substantial reduction in diastolic BP (11 mmHg) after 24 weeks of training, which did not occur in patients who underwent LEx only for the same period [25]. This result supports the superior effects of HEx due to the mechanisms previously mentioned.

Therefore, the present systematic review identified a variety of training protocols that make it difficult to identify the best dose response of training to promote changes in BP effectively. However, HEx can be an optional exercise tool for reducing BP, isolated or in association with other exercise interventions. HEx also allows the practice of exercise for those individuals who are unable to perform LEx due to some physical limitation.

Study limitations

The present review was limited by the heterogeneity and degree of the pathological conditions among the studied populations, associated with the inclusion of both gender in the same samples, and the variety of training protocols, which made it impossible to carry out a meta-analysis.

Conclusion

Although negative findings exist, the present review suggests that HEx training performed for 12 to 24 weeks may reduce BP in normotensive, prehypertensive, hypertensive, postmenopausal women populations, whereas a HEx session may be efficient to acutely reduce BP in normotensive, hypertensive and heart transplant individuals. However, there is no homogeneity in the protocols used, which may have led to the heterogeneity in magnitude and duration of HEx-induced BP reductions.

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