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Systematic Review

Efficacy of Hydrotherapy on Arterial Blood Pressure, Systolic and Diastolic Blood Pressure, 6-Minute Walk Test, and Resting Heart Rate in Patients with Peripheral Artery Disease: A Systematic Review and Meta-Analysis

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Abstract: This systematic review aimed to investigate the effects of hydrotherapy on arterial blood pressure in patients with peripheral arterial disease (PAD). A systematic review was conducted using PubMed, Scopus, Physiotherapy Evidence Database (PEDro), and EBSCO databases from 2015 to 2023. The methodological quality was assessed using the PEDro scale to evaluate the risk of bias. A meta-analysis was conducted on six randomized control trials (214 patients, 204 patients with PAD, and 10 healthy subjects) to calculate the standardized mean difference (SMD) with 95% confidence interval (CI) and overall effect size (ES) of the ankle-brachial index (ABI), systolic blood pressure (SBP), diastolic blood pressure (DBP), 6-min-walk test (6 MWT) distance, and resting heart rate (RHR). The meta-analysis showed that hydrotherapy had non-significant effects on SBP (SMD 0.01 [95% CI -0.26-0.27]), DBP (SMD -0.18 [95% CI, -0.58-0.22]), ABI (SMD 0.08 [95% CI, -0.57-0.73]), 6 MWT (SMD 0.45 [95% CI, -0.19-1.08]), and RHR (SMD -0.19 [95% CI, -0.52-0.14]). The results of this review demonstrated non-significant effects of hydrotherapy in improving SBP, ABI, DBP, RHR, and 6 MWT distance in PA patients.

Keywords: hydrotherapy, peripheral arterial disease, systematic review

1. Introduction

The prevalence of peripheral arterial disease (PAD) is increasing continuously [1] and is characterized by reduced blood flow to the affected upper or lower limbs secondary to narrowing of the peripheral arteries. Patients with PAD suffer from frequent leg claudication pain that negatively impacts walking and functional abilities, as well as muscle strength and functional balance [2]. PAD-associated pain may progress from being exacerbated with activities to being elicited during rest, which, with other micro- or macrovascular disorders elsewhere, can predispose to elevated cardiovascular mortality risk [3]. PAD accelerates functional ability decline [4] and predisposes patients to deteriorated health-related quality of life [5]. Patients with PAD also manifest abnormally elevated blood pressure [6] and resting heart rate (RHR), which is related to reduced vagal tone and can cause adverse cardiac insults in patients with

PAD [7]. The ankle-brachial index (ABI) provides a clear diagnostic tool for PAD severity. The presence of PAD increases with increasing age [8]. Although it has beneficial effects, previous trials reported the absence of a significant effect of the exercise therapy on the ABI in patients with PAD [9, 10].

Various conservative therapeutic procedures are available for the treatment of PAD, and exercise is strongly recommended to control PAD-associated claudication [9]. Interventions targeting slowing down the resting heart rate will favorably reduce the potential for cardiac events in patients with PAD and can even ameliorate disease progression [11]. Supervised exercise in patients with PAD can effectively reduce arterial stiffness [12,13], control abnormally increased blood pressure [9], and increase exercise tolerance [14], walking capacity [15,16], and pain-free walking duration [10,16].

Although therapeutic exercise is effective in alleviating PAD disease burden, enhancing overall health, limiting the rate of disease progression, and enhancing functional capacity [17], the commonly encountered walk-induced intermittent claudication is a major barrier to exercise participation in patients with PAD [18]. Claudication-related limitations significantly contribute to the low treatment adherence rate in patients with PAD [18]; only about one-third of patients with PAD adhere to and complete the prescribed exercise program [19]. Unavoidable "weight bearing" during exercise training is another factor predisposing to increased claudication in patients with PAD during exercise training and thus further reduces adherence to exercise [11, 6, 14, 15, 20, 21], especially in patients with multiple comorbidities.

Any exercise done in water to help with recovery and rehabilitation after a serious disease or rigorous training session is known as hydrotherapy [22]. Hydrotherapy is an alternative therapeutic option for patients with PAD [18], where buoyancy eliminates weight-bearing stress [22,23], with a relatively higher adherence rate to the training program compared to on-land training [21]. Recent evidence supports the effectiveness of performing exercises in water as a therapeutic procedure during rehabilitation programs for patients with cardiovascular disorders and functional deterioration [24-27].

Performing exercise in warm water can ameliorate arterial stiffness [21], reduce pain, increase peripheral arterial blood flow [28], reduce RHR, and improve cardiopulmonary capacity, muscular strength, and physical function [21]. Moreover, patients with PAD benefit only from water immersion for improving exercise tolerance [9], blood flow, and controlling abnormally elevated blood pressure [29].

A recent systematic review assessed the effects of heat therapy on arterial shear rate, blood flow rate, systolic blood pressure (SBP), diastolic blood pressure (DBP), six-minute walk test (6 MWT) results, and ABI in patients with PAD and intermittent claudication. A recent review showed that there were no pooled data on whole-body outcomes in the intervention and control groups in this systematic review [30]. A recent randomized controlled trial (RCT) showed that the 6 MWT distance was improved only in whole-body immersion in patients with PAD. However, a recent randomized controlled trial (RCT) showed a non-significant difference in 6 MWT distance between supervised exercise and heat therapy procedures [9]. Therefore, the effect of hydrotherapy on patients with PAD remains unclear, contradictions exist, and no meta-analysis has been conducted in this area. Therefore, this systematic review and meta-analysis aimed to investigate the effects of hydrotherapy on arterial blood pressure in patients with PAD. The primary objective for this review is to investigate the effects of hydrotherapy on systolic blood pressure and diastolic blood pressure in patients with PAD and healthy subjects. The secondary objective for this review is to investigate the effects of hydrotherapy on arterial blood pressure, the 6-minute walk test, and the resting heart rate in patients with PAD and healthy subjects.

1. Materials and Methods

2.1 Study design

The current study design was a systematic review and meta-analysis, which was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, included in the supplementary material. The protocol of this systematic review was registered in the International Prospective Register of Systematic Reviews (PROSPERO) with registration number (CRD42022341815). A preprint version of this article is available in the European PMC [31].

2.2 Search strategy

A systematic search for original articles published between 2015 and 2025 was performed using the PubMed, Scopus, EBSCO, and Physical Therapy Evidence (PEDro) databases. The search was also performed using additional methods, including websites such as Google Scholar, ResearchGate, or the reference list from all full-text papers that were considered eligible for the current review.

The search included the following terms: hydrotherapy [MeSH], aquatic therapy, therapeutic irrigation, pool therapy, water exercise therapy, aquatic exercise therapy, whirlpool baths, peripheral arterial disease [MeSH], peripheral vascular diseases, peripheral arterial occlusive diseases, and PR chronic limb-threatening ischemia. Search filters were used: search keywords (abstract and title), article type (clinical trial, randomized controlled trial), species (humans), language (English), and year (2015-2025).

2.3 Eligibility study

Any article was eligible for inclusion if it was a randomized controlled study (RCT), clinical trial, or a full-text written in English, investigating the effect of hydrotherapy on patients with PAD and healthy subjects as a control group, with no restriction on sex or race. Only English-language studies were included. The primary outcome measures were SBP and DBP. Studies were excluded if they had non-RCT study designs (case studies and observational studies), any study with no control group, studies published before 2015, both treatment groups received hydrotherapy, or included participants with chronic diseases other than PAD.

2.4 Study selection

Two reviewers (AK and AA) independently completed the database search and selection of studies, including screening the title and abstract and then screening the full text. All studies that matched the inclusion criteria were carefully assessed for final decisions, and the selection process of the included studies is explained in the PRISMA flowchart (Figure 1). A third reviewer (MA) was consulted at the meeting if there was disagreement between the results of the two reviewers.

2.5 Data extraction

Data were extracted from all included studies as follows: population (disease), study author and date, participant data (age, sex, and sample size in both the experimental and control groups), the intervention and co-interventions used in the experimental and control groups, outcome measures used in the experimental and control groups, and the main findings of the study. To conduct the meta-analysis, the mean, standard deviation (SD), and sample size were reported for each variable for all the included studies in both the experimental and control groups.

2.6 Evaluation of methodological quality

The PEDro Scale was used to assess the methodological quality of the included studies, which are included in the supplementary material. The PEDro scale is widely used to assess the risk of bias in RCT studies [32]. The scale consisted of 11 items with yes/no answers. The first item evaluated the external validity and was not included in the total score. Items from two to 11 were used to rate the methodological quality with a total score of 10 [33]. The included study has a quality rating of high (≥6), fair (4-5), or low (≤3) [34]. Two reviewers (AK and MA) independently assessed the risk of bias by using the PEDro scale. A third reviewer (OK) reviewed any study if there was disagreement between the two reviewers.

2.7 Quality of evidence

Two reviewers (AK and OK) independently assessed the quality of evidence using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) system. A third reviewer (MA) reviewed any study if there was disagreement between the two reviewers. GRADE has five main categories that use three subscales to rate the quality of evidence. The five categories were study limitations, indirectness, impression, inconsistency, and publication bias. Each item is rated as very serious, serious, or not serious. The total score can be high, moderate, low, or very low. The total score may help ensure that the effect estimate is closely related to the true effect of the intervention [35-37].

2.8 Data Analysis

Qualitative analysis was applied and presented in tables, and quantitative synthesis was presented as a forest plot by performing a meta-analysis. The primary outcomes, SBP and DBP, were used in the meta-analysis to assess the effectiveness of hydrotherapy in PAD patients. The secondary outcomes were 6 MWT, ABI, and RHR.

The meta-analysis was performed using Review Manager (version 5.4, Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014) software, and forest plots were constructed by calculating the effect size by collecting the mean, standard deviation, and sample size for the experimental and control groups of the included studies. The standardized mean difference (SMD) was presented as the effect size (ES), and the corresponding 95% CI was computed. The estimated effect size was rated as small (0.2), medium (0.5), or large (0.8) ES [38]. The I^2 test was conducted to test and quantify the heterogeneity among the studies. To categorize the heterogeneity in the I^2 test, small ($I^2 \leqslant 25\%$), medium (I^2 26%-50%), and high ($I^2 \geqslant 75\%$) heterogeneity were used [39]. Sensitivity analysis was used to assess the consistency of the results if heterogeneity was high.

2. Results

3.1. Study selection

A total of 141 studies were identified from these five databases. After removing the duplicates, 114 studies remained. Of the 114 studies, only 21 studies were initially eligible after abstract screening, and only eight studies were eligible after full-text screening, with two of them excluded because the patients had not only PAD; therefore, the final studies in this systematic review also included six studies. The PRISMA flow diagram presented in Figure 1 explains the steps involved in the search and the study selection procedures.

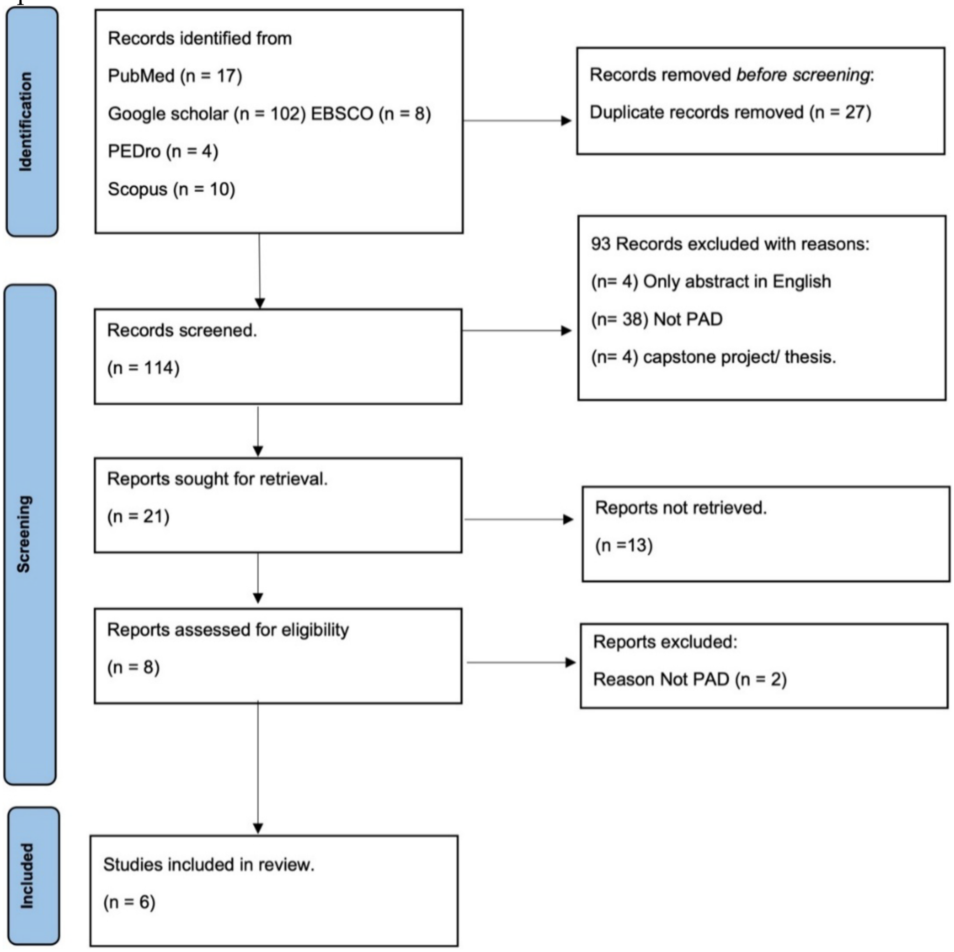

Fig 1. PRISMA Flow diagram of the selected studies.

3.2. Study characteristics

Six studies were published after 2015, including 214 patients: 204 with PAD and 10 healthy subjects. A total of 105 and 99 patients and 10 healthy subjects were included in the experimental and control groups, respectively. Conflicting results were observed regarding the effects of hydrotherapy on SBP, DBP, ABI, RHR, and 6 MWT results.

A previous RCT showed a significant reduction in SBP and DBP, with a significant increase in HR during (all $p < .001$) and 30 min post hot water immersion (all $p \leq .03$). Furthermore, there were significant reductions in ambulatory SBP ($p = .001$) and DPB ($p = .047$) in patients with PAD [29]. Another RCT reported that SBP responded favorably and was significantly reduced (-7 mmHg, $p < .001$) in response to hot water immersion (spa bathing and calisthenics exercises), more than ($p = .049$) the land-based (supervised walking and gym-based exercise) training program (-3 mmHg, $p = .078$). DBP responded favorably to both interventions (-4 mmHg, $p = .002$ for both groups), with non-significant between-group differences ($p = .229$). No significant changes in peak HR were recorded in either group ($p = .363$), with non-significant differences between groups ($p = .154$), and there were still non-significant differences between groups ($p = .668$) in the covered 6 MWT distance [9].

In another study, the effects of aquatic exercise training (AQET) on HR, BP, ABI, and 6 MWT in patients with PAD reported conflicting results, contradicting previously reported findings. The post-study mean values of the resting HR were significantly reduced (-2.3 beat/min, $p < .05$) in the AQET group compared to the non-significant decrease (-1 beats/min, $p > 0.05$) in the control group. The 6 MWD was significantly increased (+50 m, $p < .05$) in the AQET group compared to the non-significant decrease (-2 m, $p > .05$) in the control group, where there were non-significant differences in SBP, DBP, and ABI ($p > .05$) in patients with PAD [21]. A single session of 90 min of leg heat therapy using warm water decreased SBP (-7 mmHg, $p < .05$) but not DBP in patients with PAD compared to sham treatment [40].

Six weeks of leg heat therapy using heated water significantly decreased SBP (-6 mmHg, $p = .0042$) and DBP ($p = .0168$) in the heat therapy group. Post-hoc analysis detected significant differences between groups (treatment versus sham) in SBP ($p = .0178$), but not DBP. Furthermore, the results did not indicate significant group differences in mean changes in SBP or DBP. Leg heat therapy did not increase the 6 MWT distance ($p = .80$) and did not reduce the ABI ($p = .75$) in the six intervention weeks [41]. A randomized controlled study examined the effectiveness of performing 12 weeks of exercise training in heated water on BP, RHR, ABI, and 6 MWT distance compared with land-based exercise training in patients with PAD. The results revealed a significant reduction in SBP, DBP, and RHR and a significant increase in 6 MWT ($p < .05$), with a non-significant increase in ABI in the heated water group ($p > .05$). The results did not indicate significant differences in ABI ($p > .05$) (Table 1) [42].

Table 1: Summary of included RCT intervention studies.

Study	Sample characteristics	Intervention and co-intervention	Measured variable	Summary of results
Thomas, 2017 [29]	21 participants	Participants randomized to 11 PAD patients performed 1 week to 3 weeks, 30 min exercise including 3 min treadmill walk at 3km/h under waist level (Active and passive sessions) and 10 control subjects for passive immersion with only 3 min treadmill exercise and passive immersion.	BP HR	Elderly individuals to reduce blood pressure and rising heart rate significantly ($p = .001$) in both groups except the SBP was higher in PAD group and significantly different than control group ($p = .04$).
Akerman, 2019 [9]	22 PAD patients	22 PAD patients randomized to 11 in the heat therapy group and 11in the supervised exercise group for 12 weeks each. The exercise time was: For supervised exercise 90 min including 30 min walking and 60 min circuit exercise for 2 days/week. For heat therapy group 3-5 days per week for 30 min, followed by 30 min of calisthenics in spa bath including resistance exercises.	ABI BP 6MWT	Systolic BP was reduced more following heat (7 mmHg, $p = .001$) than following exercise (3 mmHg, $p = .078$), and diastolic BP decreased by 4 mmHg in both groups ($p = 0.002$). There were no significant changes in, ankle-brachial index ($p = .459$), or measures of vascular health. There were no differences in the improvement in functional or BP outcomes between heat and exercise in individuals with PAD.
Park, 2019[21]	72 Female PAD	72 female PAD patients randomized to 35 in the aquatic therapy group and 37 in the control group (no treatment). Participants in the intervention group participated in an aquatic walking exercise-training program for 12 weeks, 4 days/ week, for 60 min/day.	ABI BP 6MWT RHR	The HR significantly decreased, whereas 6MWD significantly increased, compared with pre-exercise program and control group. There were no significant differences for BP ($p = .63$) and ABI after 12 weeks.

Monroe, 2021[39]	16 PAD patients	90 min of single leg heat therapy for 16 patients randomized cross over to leg heat therapy and shame treatment. Leg heat therapy was applied for 90 min, 3 times/ week for 6 weeks for a total of 18 sessions. Cardiopulmonary exercise test done after leg heat therapy.	BP	A single session of 90 min of leg heat therapy reduced SBP (p = .05) but not DBP in patients with PAD compared to shame treatment.
Monroe ,2020[40]	30 PAD patients.	PAD patients randomly to 15 in the control /sham group and 15 in the leg heat therapy group	ABI BP 6MWT	6 weeks of supervised leg HT increased physical functioning but had no effect on vascular reactivity and 6-min walk distance and in patients with PAD. Leg HT did not improve 6-min walk distance (p = 0.80), ABI (p = 0.75) and BP in 6 weeks.
Park, 2020[41]	53 Female PAD patients	The HWET group participated in a supervised heated-water exercise therapy program for 12 week, 4 days/ week, for 60 min/day. The LBET group participated in supervised treadmill therapy program for the same period.	ABI BP RHR 6MWT	Walking distance increased and systolic and diastolic blood pressure decreased in both groups and the change in HWET was greater than LBET, which indicate that HWET better then LBET in walking distance, blood pressure and resting heart rate but not in ABI.

PAD = Peripheral artery disease; ABI = Ankle-brachial index; BP = Blood pressure; RCT = randomized controlled trial; HWET = heat-water exercise therapy; LBET = land-based exercise therapy; RHR = Resting heart rate; HR = Heart rate; 6 MWD= 6 Minute Walk Distance; HT= Heat therapy.

3.3. Evaluation of methodological quality

Assessment of methodological quality using the PEDro scale revealed four high-quality studies [9, 40, 21, 29] and two fair-quality studies [39, 41]. The reason for lowering the score for the PEDro scale was that most of the included studies did not mention concealed allocation, blind subjects, blind therapists, and intention-to-treat analysis (Table 2).

Table 2. Methodological quality assessment of included studies (PEDro scale).

Study, Year	**Eligibility criteria** [a]	**Random allocation**	**Concealed allocation**	**Baseline comparability**	**Blind subjects**	**Blind therapists**	**Blind assessors**	**Adequate follow-up**	**Intention-to-treat analysis**	**Between-group comparisons**	**Point estimates and variability**	**Total score for each study (10)**	**Level of Quality**
Thomas, 2017	Y	Y	Y	Y	N	N	N	N	Y	Y	Y	6	High
Akerman ,2019	Y	Y	Y	Y	N	Y	Y	Y	N	Y	Y	8	High
Park, 2019	Y	Y	N	Y	N	N	Y	Y	N	Y	Y	6	High
Monroe ,2020	Y	Y	N	Y	Y	N	N	Y	N	Y	Y	6	High
Monroe, 2021	Y	Y	N	Y	N	N	N	N	N	Y	Y	4	Fair
Park, 2020	Y	Y	N	Y	N	N	Y	N	N	Y	Y	5	Fair

[a] Not included in the final score.

3.4. Quality of evidence

The GRADE assessment showed an overall very low level of evidence score with a small effect size on SBP, DBP, RHR, and ABI, and a medium effect size on the 6 MWT (Table 3). The causes of downgrading were related to the study limitations, inconsistencies, and imprecision. The reason for the serious score in the study limitation was the lack of allocation concealment, blinding of participants or therapists, and attrition bias due to incomplete outcome data regarding the intention-to-treat analysis procedures [43]. The significant heterogeneity among the included studies was the main cause of the serious downgrading of the score for the inconsistency [44]. A small sample size (less than 400 participants) with a wide confidence interval was responsible for downgrading the imprecision score [45].

Table 3. Quality of evidence (GRADE)

Outcome measured	N. of part. (studies)	Study limitation	Inconsistency	Indirectness	Imprecision	Publication bias	Overall quality of evidence	Effect Estimate SMD [95% CI]	Effect size	Direction
SBP	230 (6)	Serious [a]	Serious [b]	Not serious	Serious [c]	Not serious	Very Low [d] OOO	0.01 [-0.26, 0.27]	Small	No favour
DBP	230 (6)	Serious [a]	Serious [b]	Not serious	Serious [c]	Not serious	Very Low [d] OOO	-0.18 [-0.58, 0.22]	Small	Hydrotherapy
6-min walk test	124 (3)	Serious [a]	Serious [b]	Not serious	Serious [c]	Not serious	Very Low [d] OOO	0.45 [-0.19, 1.08]	Medium	Hydrotherapy
Resting heart rate	146 (3)	Serious [a]	Serious [b]	Not serious	Serious [c]	Not serious	Very Low [d] OOO	-0.19 [-0.52, 0.14]	Small	Hydrotherapy
Ankle brachial index	177 (4)	Serious [a]	Serious [b]	Not serious	Serious [c]	Not serious	Very Low [d] OOO	0.08 [-0.57, 0.73]	Small	No favour

GRADE, Grading of Recommendations Assessment, Development and Evaluation; SMD, Standard Mean Difference; CI, Confidence Interval.
[a] Allocation concealment was not clearly reported; lack of blinding of participants, assessors, and therapists; attrition bias due to incomplete outcome data.
[b] Significant heterogeneity in meta-analysis, $I^2 > 75\%$,
[c] Small sample size with wide confidence intervals, (sample size less than 400 participants).
[d]: Very low-quality of evidence. The true effect might be different from the estimated effect with very limited confidence in the estimated effect.

3.5. Data synthesis

A descriptive synthesis was performed, and the data are presented (Table 1). Six studies were included in this meta-analysis [9, 42, 21, 29, 40, 41]. All the included studies (six studies) measured SBP and DBP, while only three studies measured the 6 MWT [9, 41, 21], and only three studies measured the RHR [21 ,29, 40], and four studies measured the ABI [9, 21, 29]. The forest plot showed favorable results for hydrotherapy in DBP, 6 MWT, and RHR. The estimated effect size was medium in the 6 MWT, with a small effect size on the remaining variables (Table 3). The test for the overall effect of hydrotherapy on outcome-measured variables showed a non-significant effect (p >. 05). Heterogeneity was significant for the SBP (I^2= 64%) and ABI (I^2=76%). For the other measured outcomes, heterogeneity reported a percentage of I^2=53% in the DBP and I^2=61% in the 6 MWT, with non-significance (Figures 2-5).

Figure 2 explained the forest plot of the systolic blood pressure as it pooled with non-significant (p = .95). Figure 3 showed the forest plot of diastolic blood pressure (non-significant pooled result (p = .37)). Figure 4 revealed the forest plot of the 6-minute walk test with non-significant results (p = .17). Figure 5 showed the forest plot of the resting heart rate (non-significant (p = .26)). Figure 6 showed the forest plot of the ankle brachial pressure index with non-significant results (p = .81).

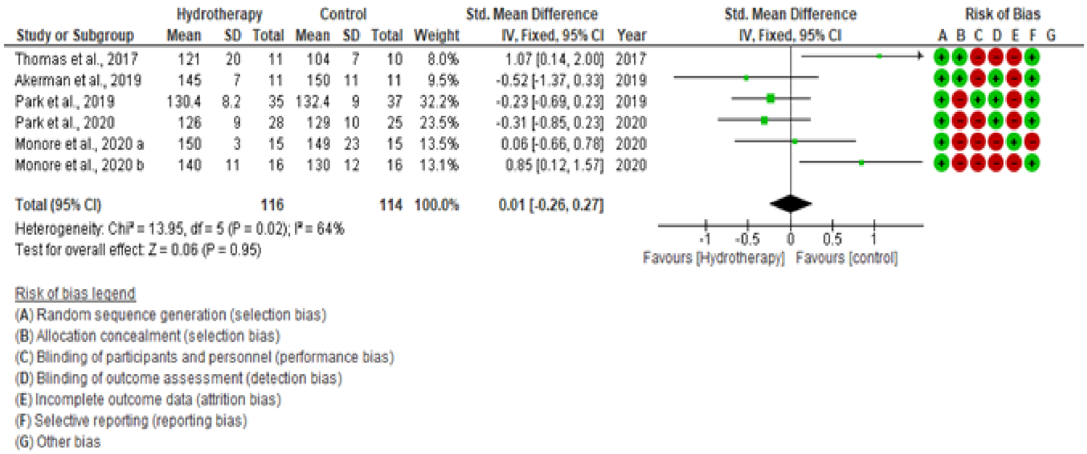

Figure 2. Forest plot to the effect of hydrotherapy on Systolic Blood Pressure.

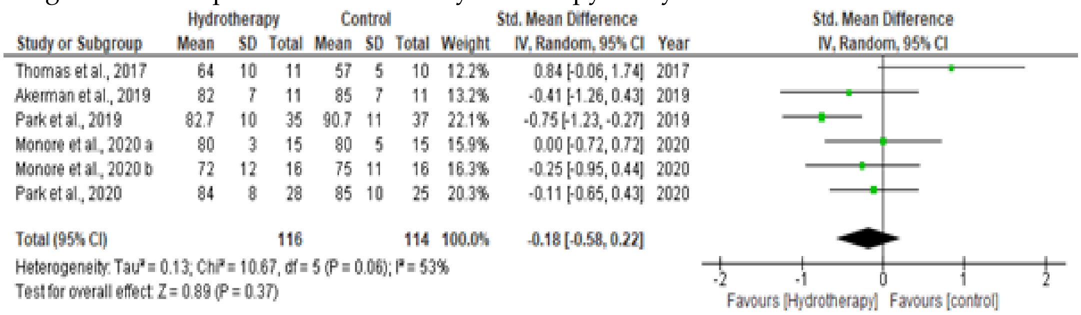

Figure 3. Forest plot to the effect of hydrotherapy on Diastolic Blood Pressure.

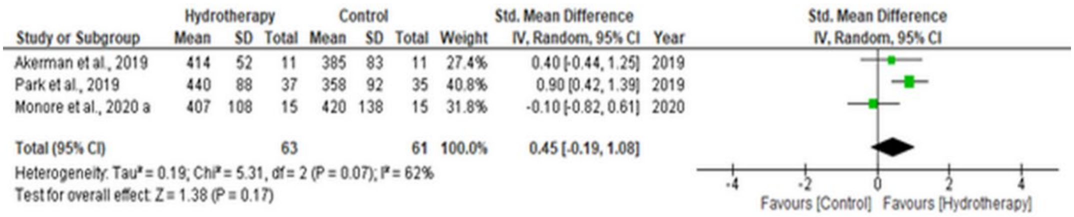

Figure 4. Forest plot to the effect of hydrotherapy on 6-minute walk test.

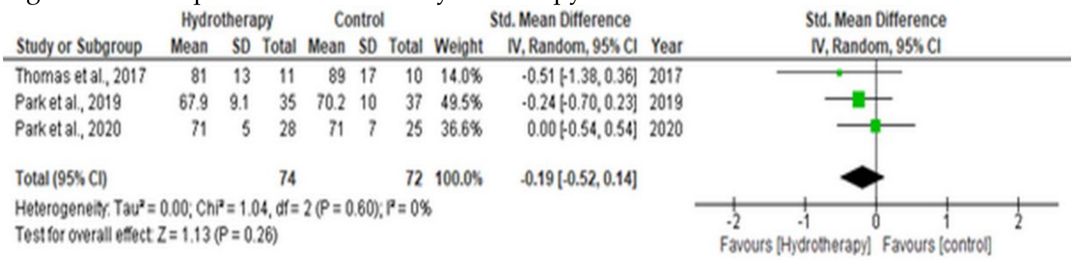

Figure 5. Forest plot to the effect of hydrotherapy on Resting heart rate.

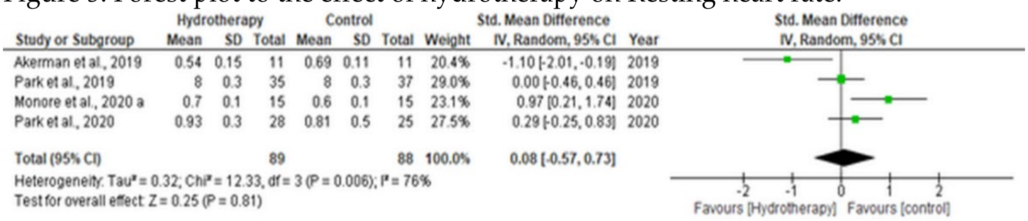

Figure 6. Forest plot to the effect of hydrotherapy on Ankle Brachial pressure Index.

3. Discussion

This is the first systematic review and meta-analysis to investigate the effects of hydrotherapy on the SBP, DBP, RHR, ABI, and 6 MWT distance in patients with PAD. The results of the current systematic review showed that there were no significant differences between the patients with PAD and the control group in response to hydrotherapy on SBP (SMD 0.01 [95% CI -0.26-0.27]; p = .95; very low-quality evidence), increasing ABI (SMD 0.08 [95% CI -0.57-0.73]; p = .81; very low-quality evidence), reducing DBP (SMD -0.18 [95% CI -0.58-0.22]; p = .37; very low-quality evidence), increasing the 6 MWT distance (SMD 0.45 [95% CI -0.19-1.08]; p = .17; very low-quality evidence), and reducing RHR (SMD -0.19 [95% CI -0.52-0.14]; p = .26; very low-quality evidence).

The results of the current review regarding the effects of hydrotherapy on SBP by approximately 11 mmHg contradict the previously reported results. **Neff et al.** reported a significant reduction in SBP in response to an aquatic-based thermotherapy program [37]. The observed SBP reduction was 7.3%, and no change was observed in DBP in response to a 25-min moderate-intensity aquatic walking program [46-48]. They also reported that the average reductions in SBP and DBP were 5 mmHg and 1 mmHg, respectively, in response to moderate-to-high-intensity aquatic exercise programs in older women [48].

According to the current systematic review and meta-analysis, no significant reduction in SBP was observed in response to hydrotherapy. The current review findings were in accordance with those of Park et al. (2019), who reported non-significant differences in BP (p = .63) and ABI after 12 weeks between the AQWET and control groups [21]. The non-significant SBP reduction in response to hydrotherapy, especially warm water therapy, can be explained by the moderate and significant heterogeneity among the studies included in this review. Therefore, it is important to conduct more research with less heterogeneity, high quality, and a large sample size to draw a conclusion on the effect of hydrotherapy on SBP in patients with PAD. On the other hand, the current study findings contradict those of Tomas et al. (2017), who reported significant hemodynamic and cardiovascular responses to hot water in PAD patients, which can be resolved when considering that they evaluated the acute post-immersion responses [29].

Non-significant results regarding the hydrotherapy can be related to some physiological effects on the evaluated variables; there is some evidence showing that heat is associated with variations in the endothelium and smooth muscle activity [49], reduction in the systematic vascular resistance [50,51], control of the baroreflex and renin-angiotensin system activation [52,53], blood flow shift from the core towards the peripheral arteries [54,51], and transient increase in the concentrations of anti-inflammatory chemokines and cytokines, such as IL-10 and IL-6 [55].

Immersion-related hydrostatic effects can also increase venous return, with approximately 700 mL of blood directed from the periphery towards the thorax, [56,57], which, cumulatively with the previously mentioned alternations, leads to better vascular compliance, which results in reduced peripheral arterial resistance [58]. The significant heterogeneity among the studies included in the current review can explain the absence of these alternation-related effects in the current review.

The results of the current review regarding the effects of hydrotherapy on DBP and RHR contradict those of **Neff et al.,** who reported a significant reduction in DBP in response to the aquatic-based thermotherapy program by approximately 6 mmHg and a significant increase in RHR [46]. This response is an acute post-intervention response (within two hours post-treatment) to a single (90 min) session treatment; therefore, the results cannot be generalized as a long-standing chronic effect. **Park et al. (2019)** showed that RHR was significantly reduced after 12 weeks; however, a clear conclusion was still unclear because the results were obtained from only a single study with a small sample size [21].

The 6 MWT distance results clarified non-significant differences between the study and control groups, in accordance with Neff et al., who reported no differences between the intervention (327 m) and control (325 m) groups [46]. Previously published RCTs have reported the same conclusion [59, 60].

The current review results of the 6 MWT contradict those of **Kapusta and Irzmanski (2022)**, who reported a significant increase in the 6 MWT distance in patients with chronic lower limb arterial disorders after a 3-week supervised rehabilitation program. The significant improvement in the covered 6 MWT distance can be attributed to the combined effects of the individually tailored exercise training program and 10 whirlpool treatment sessions [61].

The current review clarified the non-significant effect of hydrotherapy on DBP, RHR, ABI, and the 6 MWT, which is consistent with the results of the Akreman study [9], which reported that blood pressure and functional performance responses were not significantly different in response to either heat or supervised exercise for 12 weeks, suggesting that heat therapy can be used as an alternative to the supervised land-based exercise program, and it is useful to use it particularly in patients with PDA who cannot adhere to supervised exercise programs.

Moreover, **Park et al. (2019)** showed that there were no significant differences in SBP, DBP, and ABI ($p > .05$) between the AQWET and control groups after 12 weeks in patients with PAD [21], which agrees with the results of the current review. **Monroe et al. (2020)** reported that leg heat therapy can significantly improve SBP but not DBP ($p > .05$), 6 MWT distance ($p = .80$), or ABI ($p = .75$) after six intervention weeks [41], which mostly came in alignment with the current review results, but other results contradict the current review results.

The results of a quiet recent systematic review [30] were not aligned with the current review results, as they suggested significant differences in the 6 MWT. A possible reason is that they pooled the studies together, and one or two studies could not be sure about the results; they did not measure the difference between the PAD and control groups, and they reported that their results could not provide clear conclusions for patients with PAD due to the small number of studies and large heterogeneity between the types of interventions in the intervention and control groups.

Future research is warranted to clarify the optimal details and criteria required to obtain significant effects on the dependent variables in patients with PAD. Future research with well-defined treatment parameters (mode, intensity, frequency, and duration) and inclusion and exclusion criteria, with a longer treatment time (more than 12 weeks), is needed to objectively assess the effectiveness of the hydrotherapy treatment programs and to determine the optimal hydrotherapy treatment parameters for patients with PAD. Finally, further comparative studies with sufficient sample sizes are required to objectively draw a clear conclusion and clarify the degree of effectiveness of the hydrotherapy treatment program when delivered to patients with PAD.

4.1. Study limitations

Although the strength of the current systematic review is that it included a meta-analysis and pooled the data, a few limitations were encountered. First, there was moderate heterogeneity in most of the obtained results, and the control group (which included healthy subjects) differed from the intervention PAD group in some of the studies. The variability of the hydrotherapy program parameters across the screened studies (which differed from one study to another) and the length of treatment (which varied from 30 min in a single session to 12 weeks) were other limitations.

5. Conclusion

The results of this review demonstrated the non-significant effects of hydrotherapy in improving SBP, ABI, DBP, RHR, and 6 MWT distance in patients with PAD. A few studies showed significant effects on the 6-minute walk test, systolic and diastolic blood pressure, and ankle brachial pressure index, but most of the studies showed non-significant effects on the previous outcomes, so the pooled results showed non-significant results. Also, the high heterogeneity is another factor that explained why the pooled results were non-significant. Heat is associated with variations in the endothelium and smooth muscle activity and a reduction in the systematic vascular resistance, as this could lead to the non-significant pooled results. Call for better-designed, longer-duration, and larger RCTs with standardized protocols.

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