THE EFFECT OF THE WARM WHIRLPOOL ON PERIPHERAL ARTERIAL INSUFFICIENCY IN LOWER LIMB

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ABSTRACT

Background and aim: to explore the warm whirlpool's influence on functions of the endothelium in type II diabetics with peripheral arterial insufficiency in the lower distal limb.

Materials and methods: In this study forty patients from both sex (aged from 40 to 55 years old) with Insufficiency of the Peripheral Arteries as an outcome of Type II Diabetes Mellitus, they were evenly split into 2 equal groups (A and B) randomly. Group (A) managed to receive warm whirlpool and treadmill walking sessions, group (B) received the treadmill walking sessions only. Data obtained from groups pre-and post-treatment regarding nitric oxide blood analysis (NO), maximum walking time (MWT), and the intermittent claudication questionnaire (ICQ) were statistically analyzed and compared.

Results: Statistical analysis used the Unpaired t-test to compare the mean values of characteristics in-between groups, comparisons within groups: Nitric oxide in blood levels and maximum walking time increased significantly, while intermittent claudication questionnaire in groups significantly decreased from pre- to post-treatment. Between groups, there was a substantial increase in maximum walking time following therapy, while the intermittent claudication questionnaire is significantly decreased; simultaneously, there was no significant difference in nitric oxide between 2 groups after the management plan.

Keywords: Peripheral Arterial Insufficiency, Type II Diabetes Mellitus, Warm Whirlpool Bath, Intermittent Claudication, Nitric Oxide.

I. INTRODUCTION:
The formation of atherosclerotic in the peripheral arteries is the defining feature of peripheral arterial disease (PAD), which affects 200 million individuals worldwide. Claudication is the prevalent manifestation of PAD and involves leg ache, cramps, exhaustion, pressure, and muscular weakness. These sensations are frequently triggered by physical exercise and subside with rest. Critical limb ischemia may develop in late-stage peripheral arterial disease (PAD) when tissue perfusion is not enough to satisfy the metabolic requirement of the tissues below an arterial blockage at rest. This frequently ends in persistent ischemia, discomfort, ulceration, and, in the worst-case scenario, amputation (1).

The patient's history, physical examination, and objective test findings should be considered while diagnosing peripheral arterial disease (PAD). The history should contain pertinent information, such as an accurate assessment of the patient's walking capacity. Many patients may not expressly mention the usual intermittent claudication (IC) symptoms of cramping calf discomfort that fades with rest after walking two blocks. Certain
patients may be unable to walk at all due to various physical problems or restrictions. Other patients may hide information regarding their walking abilities unless expressly asked. Additionally, cardiovascular risks such as smoking, high blood pressure, cholesterol, and diabetes are significant components of the history.

Diabetes mellitus is also related to more severe peripheral arterial disease (PAD) below the knee. In contrast, risk considerations such as smoking are linked to peripheral arterial disease (PAD) in the aorto-iliofemoral vasculature. Concurrent peripheral arterial disease (PAD) and diabetes mellitus are particularly prevalent in individuals with severe ischemia. More than fifty percent of patients with (CLI) also having Diabetes mellitus.

Cardiovascular events, including acute Myocardial infarction & stroke, occur at a rate of 20% in individuals with peripheral artery disease (PAD) over five years. In contrast, total mortality is 30%, and 30% of patients with critical limb ischemia (CLI) need to be amputated. The death rate is 20% within six months. Diabetic individuals account for 25% to 30% of coronary artery revascularization patients and up to sixty percent of the patients with myocardial infarction (MI). Cerebrovascular and Cardiovascular event rates, the fatal and nonfatal, are elevated in individuals with peripheral arterial disease and diabetes mellitus than people without diabetes who have peripheral arterial disease.

The primary mechanism behind the two kinds of diabetes mellitus, type I diabetes mellitus (T1DM) & type II diabetes mellitus (T2DM), is the loss of functional-cell mass. Type I diabetes mellitus (T1DM) is defined by the American Diabetes Association (ADA) as autoimmune-cell destruction that typically results in absolute insulin deficiency. In contrast, (T2DM) is defined as escalating loss of insulin secretion that frequently occurs in the context of insulin resistance.

When there is a lack of production on vasodilators, endothelial dysfunction ensues, and the vasculature is susceptible to pro-thrombotic and pro-atherogenic outcomes. This results in vasoconstriction, leukocyte adhesion, platelet activation, mitogenesis, pro-oxidation, impairment of coagulation, and NO production, as well as inflammation of the vessels, atherosclerosis & thrombosis. Endothelial abnormalities are emphasized because they may contribute significantly to the vascular problems in type II diabetes mellitus.

Most patients with diabetes illustrate variations from the norm of endothelial work. Hyperglycaemia pieces the work of endothelial NO synthase, and free fatty acids may have various harmful impacts on normal vascular homeostasis. Diabetes leads to a hypercoagulable state and anomalies in platelet science.

Nitric oxide (NO) is known as a functional controller of the cardiovascular structure that extends beyond its well-known role as a dilator for vessels. It regulates smooth muscle cell proliferation and migration, fibrinolysis, platelet and white blood cell adhesion, and angiogenesis and is secreted by endothelial nitric oxide synthase.

Today, patients with PAD have various therapy choices, including pharmaceutical, revascularisation, and exercise therapy. Treadmill walking training under supervision is an effective therapy for patients with PAD.

According to a recent study, hydrotherapy is just as effective as exercise in managing peripheral arterial disease (PAD), a common ailment affecting blood flow to the arms and legs. The results may be beneficial to patients who suffer from PAD.

Whirlpool application stimulates superficial vascular vasodilation, which improves oxygenation and nourishment to surface tissues and nerves. Additionally, it has been shown that pleasant heating of the foot tissue improves local sensations and superficial blood flow in individuals with DPN. These enhancements are attributed to the generation of nitric oxide.

Heat treatment, or the use of an external source of heat to raise local or systemic body temperatures, is proving to be an effective strategy for patients with PAD. Heat treatments encompass a broad range of techniques, including submersion in warm water or external heating via water-circulating pants. In general, exercise improves cardiac output and lowers peripheral vascular resistance due to vasodilation and autoregulation of the local vasculature.
II. THE MATERIALS & METHODS:

Study Design: This study was done at the Hydrotherapy Lab at Physical Therapy faculty, Modern University, from August 2020 to May 2021. A moral agreement was obtained from Cairo University Ethical Committee of Physical Therapy faculty, Egypt no: (012-002799)

Subjects: forty patients of both sex with arterial insufficiency in both limbs secondary to Type II Diabetes Mellitus (DM), all subjects Managing Type II Diabetes for more than five years, moreover, Suffering from Intermittent claudication due to vascular disease. There Ankle Brachial Index (ABI) of (0.6) to (0.9) And body mass index (BMI) less than (34.9). Before participating in this study, each subject signed an informed consent according to Faculty Ethical Committee. Subjects were excluded if their Ankle Brachial Index greater than 0.9 or lower than 0.6, Body mass index (BMI) is greater than 34.9 moreover if they had Cerebrovascular, musculoskeletal diseases, Angina, and Cardiac arrhythmias that were poorly managed or are caused by exertion.

Randomization: Written informed consents were obtained from the subjects after explaining the nature, purpose, and benefits of the study, informing them of their right to withdraw or refuse at any time, and the confidentiality of any obtained information. The subjects were placed into two equal groups, (A) & (B) with respect to age, weight, height and BMI

Interventions: Group (A): Twenty patients were randomly assigned, had 12 physical therapy sessions in the form of a supervised program that included hydrotherapy in the form of a warm whirlpool bath in addition to the regular treadmill walking sessions. Group (B): Twenty patients who participated were randomly assigned to typical physical therapy sessions (treadmill walking exercise) only. Both groups would continue taking their medication prescribed by the physician and followed nutritional advice that includes:

- Choose healthier carbohydrates
- Eat few salts
- Eat more fruit and veg
- Choose healthier fats
- Cut down on added sugar
- Be smart with snacks
- drink at least 3 liters of water daily
- Do not smoke
- Get minerals and vitamins from foods.

1.1 Instrumentation and Tools:

For Assessment:

- Standard weight and height scale (made in China). to take the measurements of each patient & to compute the (BMI)
- Doppler Ultrasound; for noticing the ankle-brachial pressure index: (made in China) A handheld Doppler probe used to determine the systolic pressure in the right and left brachial, dorsalis pedis & posterior tibial arteries.

For Treatment:

- Electronic Treadmill: Samson Fitness created the original design (made in New Delhi, India). It is electronically controlled and equipped with a display panel that allows for adjusting the height and speed.
• Limb whirlpool: (1110E Whirlpool for the Lower Extremities) This type is intended to treat the foot, ankle, and shank. Four wall-mounted jets deliver the whirlpool massage. This low-capacity 40-liter tank is optionally outfitted.

1.2 Evaluation procedures:
The demographic and clinical features of patients were thoroughly gathered Arterial of Peripheral to determine the origin of their insufficiency, its severity, the chronicity of their diabetes, and their medicines. Before the start of the evaluation process, the whole process was thoroughly described to all patients.

Haemoglobin A1c test: (alternatively referred to as the glycated hemoglobin test or HbA1c) offers information about the glucose levels in the blood over the preceding three months. To ascertain the degree to which diabetes is managed(12). As shown in Table 1.

<table>
<thead>
<tr>
<th>HbA1c less than 42 mmol/mol (6.0%)</th>
<th>Not a diabetic patient</th>
</tr>
</thead>
<tbody>
<tr>
<td>HbA1c level between 42 and 47 mmol/mol (6.0–6.4%)</td>
<td>Prediabetic patient</td>
</tr>
<tr>
<td>HbA1c level of 48 mmol/mol (6.5%) or greater:</td>
<td>Diabetes patient</td>
</tr>
</tbody>
</table>

The Body Mass Index (BMI) calculation: is the body mass divided by a square of the body height. It is given in kilograms per square meter and is calculated by multiplying the mass in kilograms by the height in meters.

Nitric Oxide blood test (NO): the serum Nitric Oxide compared pre-and post-treatment in both groups.

Doppler Ultrasound Ankle Brachial Pressure Index: Calculate the (ABI): Using a calculator, divide the highest value of the left ankle arteries by the result of the left brachial artery. Record and interpret the result:(13)

• ABI<0.40 value which means the patient suffers from severe peripheral arterial disease.
• ABI of 0.41-0.60 value which means the patient suffers from moderate PAD
• ABI of 0.60-0.90 value which means the patient suffers mild PAD
• ABI of 0.91-1.30 pointing to normal vessels.
• ABI>1.3 pointing to non-compressible and severely calcified vessels.

The maximal graded walking Test: It was carried out on the motorized treadmill at a steady pace of 2.7 kilometers per hour. Initially, the gradient of the treadmill put on 0% for the first five minutes and then raised by two percent every three minutes till the patient was unable to do the job painlessly. (14). It was used to determine: The maximum walking time.

The Intermittent Claudication Questionnaire (ICQ): It is a questionnaire that is self-administered. The Maximum amount of points y is 80. all questions presented on a grade of 0 to 100, zero means (the best quality of life/best health condition) and 100 means (worst quality of life/worst result of health examination)(15) representing Question number and Intermittent Claudication Questionnaire: as shown in Table 2.

<table>
<thead>
<tr>
<th>1. Severity of leg pains</th>
<th>9. Had to stop walking because of leg pains</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. aching limits crossing the road</td>
<td>10. Time spent thinking of leg aching</td>
</tr>
<tr>
<td>3. aching limits traveling by bus, train</td>
<td>11. Feel down and low because the pain</td>
</tr>
<tr>
<td>4. aching limits climbing ≥ a flight of stairs</td>
<td>12. Time spent worrying that pains worsen</td>
</tr>
<tr>
<td>5. aching limits climbing a flight of stairs</td>
<td>13. Interfere with ordinary work</td>
</tr>
<tr>
<td>6. aching limits walking more than 1 km</td>
<td>14. Interfere with hobbies</td>
</tr>
<tr>
<td>7. aching limits walking 100 meters</td>
<td>15. Interfere with social life</td>
</tr>
<tr>
<td>8. aching limits leaving the house</td>
<td>16. Interfere with errands</td>
</tr>
</tbody>
</table>
2.7 Rehabilitation procedures:

**Traditional treadmill exercise:** Exercise prescription: (16) Intensity of exercise: According to the maximal graded walking test, Frequency: 3 days/week. Duration: the time spent exercising in total (including rest periods) should be 50 min/day. Five minutes warming, 40 minutes active phase with rest intervals, five minutes cooling down.

**Programmed Warm Whirlpool:** twenty patients underwent warm whirlpool therapy three times a week for twelve weeks. Temperature: Mild warmth between 35.5°C and 37°C (96°F and 98°F) (17) Leg immersion time: Immersion of the whole leg in a whirlpool for 20-30 minutes every session. (18).

**III. RESULTS:**

**Statistical Analysis:**

A chi-squared test was used to analyze the gender distributions between groups; the Shapiro-Wilk correlation was done to check out the normal distribution of the data. To ensure group homogeneity, Levene's test for variance homogeneity was used. The mean values of nitric oxide, maximum walking distance, and the intermittent claudication questionnaire were compared across the groups (A) & (B) by an unpaired t-test. Each group's pre- and post-treatment data were compared using a paired t-test. All statistical tests were conducted with a significance threshold of p > 0.05. All the analyses were done on Windows by the statistical program for social studies (SPSS) version 25. (IBM SPSS, Chicago, IL, USA).

**Characteristics of the subjects:**

Table 3 summarizes the subject features of the 2 groups. No significant variation appears in the mean of age, weight, height, body mass index, diabetes chronicity, HbA1c, ankle-brachial index, and gender distribution (p > 0.05).

<table>
<thead>
<tr>
<th></th>
<th>Mean ± SD</th>
<th>p-value</th>
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<tbody>
<tr>
<td><strong>Group (A)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>48.85 ± 3.86</td>
<td>0.28</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>85.7 ± 5.36</td>
<td>0.46</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>171.8 ± 7.44</td>
<td>0.7</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>29.13 ± 2.5</td>
<td>0.84</td>
</tr>
<tr>
<td>Chronicity of diabetes (years)</td>
<td>7.7 ± 1.14</td>
<td>0.71</td>
</tr>
<tr>
<td>HbA1c (%)</td>
<td>8.58 ± 0.94</td>
<td>0.22</td>
</tr>
<tr>
<td>ABI</td>
<td>0.76 ± 0.06</td>
<td>0.51</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td>7 (35%)</td>
<td>0.73</td>
</tr>
<tr>
<td>Males</td>
<td>13 (65%)</td>
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</tbody>
</table>

standard deviation; p-value, the probability value

**Effect of treatment:**

**Within-group comparison:** nitric oxide, maximum walking time was increased significantly, and there was a significant decrease in intermittent claudication questionnaire in the groups post-treatment compared to the pre-treatment (p > 0.001). The percent of change in group (A) was 37.07, 102.99, and 38.93%, respectively, and that in group (B) was 30.5, 69.32, and 25.71%, respectively. As shown in Table 4.

**Between groups comparison:** no significant variation in all variables between groups pre-treatment (p > 0.05). In Comparing the two groups, post-treatment exposed a significant increase in maximum walking time, and the intermittent claudication questionnaires significantly decreased in group (A) compared with that of the group (B) (p > 0.001). Simultaneously, there was no any significant difference in nitric oxide between 2 groups post-treatment (p > 0.05). As shown in Table 4.
<table>
<thead>
<tr>
<th>Pre</th>
<th>Post</th>
<th>Mean ± SD</th>
<th>Mean ± SD</th>
<th>MD</th>
<th>% Of change</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NITRIC OXIDE (u/ml)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>group (A)</td>
<td>110.61 ± 8.68</td>
<td>114.25 ± 9.28</td>
<td>9.64</td>
<td>2.51</td>
<td></td>
<td>0.2</td>
<td>0.53</td>
</tr>
<tr>
<td>Group (B)</td>
<td>151.61 ± 12.51</td>
<td>149.1 ± 12.88</td>
<td>-1.27</td>
<td>0.62</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>MAXIMUM WALKING TIME (sec)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>group (A)</td>
<td>72.81 ± 4.5</td>
<td>72.5 ± 5.25</td>
<td>0.31</td>
<td>25.04</td>
<td></td>
<td>0.84</td>
<td>0.001</td>
</tr>
<tr>
<td>Group (B)</td>
<td>147.8 ± 12.9</td>
<td>122.76 ± 9.12</td>
<td>-2.26</td>
<td>7.08</td>
<td></td>
<td></td>
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<tr>
<td><strong>INTERMITTENT CLAUDICATION QUESTIONNARE (%)</strong></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>group (A)</td>
<td>66.01 ± 5.3</td>
<td>64.12 ± 7.1</td>
<td>1.92</td>
<td>11.56</td>
<td></td>
<td>0.34</td>
<td>0.001</td>
</tr>
<tr>
<td>Group (B)</td>
<td>40.31 ± 6.13</td>
<td>51.87 ± 5.6</td>
<td>-6.22</td>
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</table>

SD, Standard deviation; MD, Mean difference; p-value, Probability value

### IV. DISCUSSION:

The study's objective was to conclude the Efficiency of hydrotherapy via warm whirlpool on endothelial function in type II diabetics with peripheral lower limb arterial diseases. In **group A and B**: The result is revealed a significant increase in the Nitric Oxide, Maximum Walking Time statistically, and a Substantial Reduction in Intermittent Claudication Questionnaire in post-treatment in comparison with pre-treatment. **In comparing the improvement percentage in the group (A) & (B) post-treatment**: the was no any significant difference in (NO) improvement between two groups, that improvement percentage was 37.07% in group A, and the percent of change was 30.5% in group B., but There was a significant increase in the (MWT) in the study with improvement percentage 102.99% than that of the control group with improvement percentage 69.32%. In the (ICQ), There was a significant change in the study group with an improvement percentage of 38.93% compared with the control group (19.1%) post-treatment.

This study's feedback is consistent with Akerman et al. (2019) conducted a 12-week randomized controlled experiment comparing heat treatment to exercise under supervision treatment for peripheral artery disease. Twelve weeks of heat or exercise were assigned to volunteers with PAD. Heat included 30 minutes of spa bathing at 39°C three to five days a week, followed by 30 minutes of calisthenics. The exercise consists of 90 minutes of supervised walking and gym-based exercise performed once or twice a week. Following the treatments, overall walking distance improved by 41 meters (from 350 m) during a 6-minute walk test, independent of the group, and walking distance free of pain increased by 43 meters (from 170 m). In both groups, systolic pressure was lessened more significantly (-7 mmHg) than exercise (-3 mmHg), while diastolic and mean arterial blood pressures fell by four mmHg. There were no statistically significant changes in blood volume (BV), ankle-brachial index (ABI), or vascular health markers. In patients with PAD, there were no differences in improving functional or blood pressure results from heat and exercise.

Januszek et al. (2014) The objectives of this research were to test the impact of twelve weeks of intermittent treadmill walking under supervision on endothelial function and maximum walking duration. Three times per week, exercise sessions were done at a speed of 3.2 km/h and a grade that causing claudication within 3-5 minutes for each patient. At the outset of the program, intermittent walking was employed for 35 minutes, with session duration steadily increasing by five minutes every two weeks. The results revealed that the maximum walking length increased by 90% following the training program, and the Flow Mediated Dilation (FMD) values increased by 43%.
Aziz Alimul Hidayat et al. (2021) identify the relationship between foot peripheral blood circulation and ankle-brachial index (ABI) indicators in type II diabetes mellitus patients with a diabetic foot spa. The study used a trial design with a one-group pre-test & post-test design. Sixty-two respondents were included in the sampling. The intervention took the form of providing a diabetic foot spa technique that included foot exercises, skin washing, and foot massage that were performed for 45 minutes daily for five days. The Ankle Brachial Index (ABI) measuring tool compares the ankle temperature measurement (right or left) to the highest systole measurement value on the right or left. This indicates the effectiveness of diabetic foot spas in increasing peripheral blood circulation in persons with diabetes. Thus, the diabetic foot spa may be utilized in lieu of surgery to improve peripheral blood circulation in type 2 diabetics. (21)

Brunt et al. (2016) tested the influence of passive heat treatment on the function of the endothelium, arterial stiffness, and blood pressure in sedentary adults. According to a new prospective study, lifelong sauna use is connected with a relief of cardiovascular and causes of death. However, the specific circulatory alterations underlying this continuous protection remain unknown. They viewed the impact of eight weeks of immersion in warm water ('heat treatment') on various cardiovascular indicators in young people, sedentary adults. They observed that heat treatment promoted flow-mediated dilatation, decreased the stiffness of the arteries, reduced mean arterial and diastolic blood pressures, and inhibited carcinogenesis compared to a sham group that received thermoneutral water immersion. For the first time, the findings demonstrate that heat therapy has a broad and robust effect on vascular function, implying that it may be a realistic therapy strategy for enhancing cardiovascular health in a diverse patient group and the patients with low exercise tolerance and capability. (22)

Kapusta et al., (2019) published a study. The Effect of hydrotherapy and regulated physical exercise on the temperature of the lower extremities of individuals with atherosclerotic peripheral vascular disease. The research enrolled 50 patients, both males, and females, in age from thirty-nine to seventy-nine years and suffering from poor circulation in the distal lower extremities. Subjects were assigned to two groups of twenty-five patients each. In group A, ten vortex massage techniques were employed, as well as an individually chosen training program that included breathing, relaxation, and active lower limb activities. Individually selected instructions were conducted in Group B. The temperature of each subject's lower extremities was determined by an infrared thermometer (IR). The measurements were taken prior to and following the start of the management plan. The temperature of the lower limbs increased statistically significantly in group A. (23)

V. CONCLUSION:
The study concluded that a warm whirlpool is significantly effective for improving endothelial function and decreasing symptoms in peripheral arterial diseases. As a result, incorporating both warm whirlpool and treadmill walking exercise into a management program for lower limb peripheral arterial insufficiency yielded remarkable outcomes.

Source of funding: Nil.

Conflict of interest: The writers say with authority that they have none

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21. Aziz Alimul Hidayat, A. et al. (2021) Improving Foot Peripheral Blood Circulation with Indicators of Ankle Brachial Index (ABI) through Diabetic Foot Spa in Diabetes Mellitus Patients of Type 2, Systematic Reviews in Pharmacy.
