Immediate Effects of Electrical Stimulation, Diathermy, and Physical Exercise on Lower Limb Arterial Blood Flow in Diabetic Women With Peripheral Arterial Disease: A Randomized Crossover Trial

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Abstract

Objective: The purpose of this study was to assess the effects of high-voltage electrical stimulation (HVES), continuous short wave diathermy, and physical exercise on arterial blood flow in the lower limbs of diabetic women with peripheral arterial disease.
Methods: A crossover study was carried out involving 15 diabetic women (mean age of 77.87 ± 6.20 years) with a diagnosis of peripheral arterial disease. One session of each therapeutic resource was held, with a 7-day washout period between protocols. Blood flow velocity was evaluated before each session and 0, 20, 40 and 60 minutes after the administration of each protocol. Two-way repeated-measures analysis of variance with Bonferroni post hoc test was used for the intragroup and intergroup comparisons.
Results: In the intragroup analysis, a significant reduction ($P < .05$) was found in blood flow velocity in the femoral and popliteal arteries over time with HVES and physical exercise and in the posterior tibial artery with the physical exercise protocol. However, no significant differences were found in the intergroup analysis ($P > .05$).
Conclusion: Proximal blood circulation in the lower limb of diabetic women with peripheral arterial disease was increased by a single session of HVES and physical exercise, whereas distal circulation was only increased with physical exercise. (J Manipulative Physiol Ther 2014;xx:1-8)
Key Indexing Terms: *Diabetes Mellitus; Short-Wave Therapy; Electrical Stimulation Therapy; Hyperthermia; Induced*

Peripheral arterial disease (PAD) is a limiting condition resulting from the narrowing or occlusion of an artery due to aneurysm, inflammation, atherosclerosis, or a thromboembolic event.[1] It is estimated that 20% of individuals aged 55 years or older have compromised arteries in the lower limbs, with the majority of cases asymptomatic.[1,2]

Diabetes mellitus is one of the major risk factors for developing PAD due to its association with atherogenesis.[3] Diabetes leads to a set of mechanisms that can cause harm to the vascular endothelium and are triggered by changes in levels of nitric oxide, angiotensin II, prostacyclin, endothelin 1, plasminogen activator inhibitor 1, and other substances.[2] According to Jude et al,[4] the most important abnormalities in this metabolic disease are chronic hyperglycemia, insulin resistance, and dyslipidemia, which render the arteries susceptible to atherosclerosis.

The literature reports different treatment protocols for PAD. Systematic reviews highlight the use of physical exercise,[5] stem cell therapy,[6] medication,[7,8] and revascularization.[9] However, few clinical trials involving physiotherapeutic treatment have been published. Tebbutt et al[10] and Castro-Sánchez et al[11] investigated the effects of exercise programs, Cousin et al[12] submitted volunteers to muscle strength and endurance training, and Castro-Sánchez et al[13] used connective tissue reflex massage. However, other

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Paper submitted September 30, 2013; in revised form July 24, 2014; accepted August 14, 2014.
0161-4754

http://dx.doi.org/10.1016/j.jmpt.2014.08.008

physiotherapeutic resources, such as electrotherapy and thermotherapy, have not been investigated in the rehabilitation of individuals with PAD. These protocols lack the proper scientific evidence for safe, effective use.

Among physiotherapeutic resources, *high-voltage electrical stimulation* (*HVES*) is defined as the percutaneous application of short-duration, high-tension, double-peak, monophasic electrical pulses.[14] Few studies have described the circulatory effects of HVES. In an experimental study, Mohr et al[15] found an increase in blood flow in the paws of rats following stimulation. According to Bélanger,[14] HVES increases blood flow in muscles due to the induction of contractions and offers the benefit of being more comfortable than other excitatory motor currents.

Continuous short wave diathermy (*CSWD*) is defined as using electromagnetic energy to heat up soft tissues.[16,17] When biological tissues are exposed to CSWD, part of the energy is absorbed, which triggers reactions on the atomic and molecular levels, causing the tissue to warm and a consequent increase in blood flow.[17]

Besides the previously mentioned therapies, physical exercise is the therapeutic resource with the best scientific foundation. Through exercise, the increase in blood flow to muscles occurs due to several physiological mechanisms, especially the release of nitric oxide[18] and the thermal effect that stems from muscle contraction and the partial consumption of adenosine triphosphate.[19]

Therefore, the aim of this study was to assess the effects of HVES, CSWD, and physical exercise on arterial blood flow in the lower limbs of diabetic women with peripheral arterial disease. Considering the therapeutic potential and physiological effects of these resources, the hypothesis tested was that a change in blood flow in the lower limbs will occur with the administration of such protocols.

Methods

Ethical Considerations

The procedures used in this study received approval from the Human Research Ethics Committee of the Methodist University of Piracicaba under process number 57/06. This study is registered with ClinicalTrials.gov (NCT01868698). Recruitment and data collection were performed at the Methodist University of Piracicaba (Piracicaba, SP, Brazil) between March 2009 and January 2010. Data processing and statistical analysis were performed at the University of São Paulo (Ribeirão Preto, SP, Brazil) in June 2012. All participants signed consent forms.

Study Design

A crossover study was carried out in which the 3 treatment protocols were applied, with the order randomly determined by simple lots and washout period of 7 days between protocols. Opaque envelopes were used to conceal the allocation. The physiotherapists in charge of the evaluations, data processing, and statistical analysis were blinded to the resource applied to the volunteers.

Sample

The calculation of the sample size was based on the results of a clinical trial conducted by Castro-Sánchez et al[11] and performed using the Ene program, version 3.0 (Barcelona, Spain). The outcome was Doppler flow velocity after physiotherapeutic treatment. The calculation was based on the detection of a 6.8 cm/s difference among groups, assuming an SD of 4.94 cm/s, an 80% statistical power, and α of .05. The minimum sample was estimated to be 11 volunteers.

Twenty women with a diagnosis of type II diabetes mellitus were initially recruited. Excluding 5 individuals was due to the practice of regular physical activity (3 women) and smoking habit (2 women). Thirteen volunteers with mild PAD and 2 with moderate PAD participated in the study (mean age of 77.87 ± 6.20 years, mean body mass index of 30.47 ± 4.99 kg/m^2, right side dominance). Peripheral arterial disease was classified using the ankle-brachial index (ABI). The following were the exclusion criteria: practice of regular physical exercise, smoking habit, active thrombosis, or severe occlusive arterial disease (based on the ABI).

Evaluations

Clinical and physical examinations were performed through a visual inspection and functional test to determine the eligibility of the volunteers. The degree of physical activity was determined using the International Physical Activity Questionnaire, version 8.[20,21]

The ABI was used to identify and classify PAD. This index correlates with symptoms and functional status and is useful for determining the severity of arterial impairment and abnormalities in the lower limbs.[22] Ankle-brachial index values were obtained from the ratio between systolic blood pressure of the ankle and arm, determined by analyzing the brachial and posterior tibial arteries, respectively.[23] Measures were taken 3 times, with the highest reading used for the analysis.[24] For each sample, the probe was removed and repositioned over that artery, at intervals of 1 minute. Systolic pressure was measured on all 4 limbs, and the ratio between the higher systolic pressure in the lower limbs and higher systolic pressure in the upper limbs was used for the estimation of the ABI.[25]

Data collection for the calculation of ABI was performed with the volunteer in the supine position after 5 minutes of rest.[26,27] A duly calibrated aneroid sphygmomanometer (Missouri brand, Embu, SP, Brazil) with a scale from 0 to 300 mm Hg and portable Doppler ultrasound device