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Correlation between the range of motion of the tibiotarsal joint and blood circulation in the lower limbs in diabetic individuals

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SUMMARY

OBJECTIVE: The aim of this study was to evaluate the relationship between the range of motion and lower-limb hemodynamic indices in the tibiotarsal joint of individuals with diabetic neuropathy.

METHODS: Twenty volunteers of both sexes, with a mean age of 61.45±7.05 years, were diagnosed with type 2 diabetes mellitus and diabetic peripheral neuropathy. Arterial blood flow was assessed using Doppler ultrasound, and the variables such as average velocity, pulsatility index, and resistivity index were also evaluated. A range of dorsiflexion and plantar flexion joint movements were assessed using digital goniometry before and after exercise. Data distribution was assessed using the Shapiro-Wilk test, followed by Pearson's correlation for normal data and Spearman's correlation for non-normal data, in order to verify the association between variables.

RESULTS: A moderate correlation was found between dorsiflexion and pulse rate on two occasions before (rs=0.497) and after initial evaluation (rs=0.511). A low correlation was found between plantar flexion and mean velocity (rs=-0.357), pulsatility index (rs=0.439), and resistivity index (rs=0.328); dorsiflexion and mean velocity (rs=0.374), pulse rate (rs=0.332), and resistance index (rs=0.327) before evaluation, and peak (rs=0.346) was observed after the evaluation of blood circulation.

CONCLUSION: There is a correlation between the range of motion of the tibiotarsal joint and the blood circulation of diabetics, ranging from moderate to poor for the different variables evaluated.

KEYWORDS: Physical therapy modalities. Diabetes mellitus. Ankle joint.

INTRODUCTION

Diabetes is a chronic disease whose complication causes damage to health and is the primary cause of cardiovascular disease and death today[1]. The number of people with diabetes mellitus worldwide is estimated to increase by 54%, from 285 million in 2010 to 439 million by 2030[2]. The high incidence can be explained by a rapid change in diet, coupled with sedentary habits, which increases the number of cases with chronic disease, highlighting obesity and type 2 diabetes[3].

Peripheral neuropathy, which affects the integrity of peripheral nerves, is one of the main complications of diabetes and is caused by high blood glucose levels that promote the accumulation of tissue metabolism end products[4]. This process leads to a loss of protective sensitivity and musculoskeletal function of the lower limbs[5].

Joint mobility and muscle function are impaired in diabetes due to the nonenzymatic collagen glycosylation process that damages the joint structure, ligaments, and tendons, thus compromising the elasticity and tensile strength of these structures[6]. The talofibular joint is the most affected joint due to the biomechanical changes related to multiple factors of neural and mechanical deficit which interfere with the function of intrinsic foot muscles, causing changes in balance, plantar pressure, and articular mobility with influence on gait, and on motor function, altogether in patients with neuropathic diabetes[7].

Peripheral arterial disease in diabetes is manifested by atherosclerosis, resulting from the harmful effect of hyperglycemia on the vascular endothelium, where atheromatous plaques cause limb artery blockage, especially in the lower limbs[8]. It is a disease where few patients are symptomatic. Of those with symptoms, intermittent discomfort is reported due to leg pain caused by physical effort, and this is relieved by resting[9].

Factors that directly influence the function of movement, and thus hinder the daily life of patients, are the reduced range of motion and lower-limb blood circulation[10].

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Given the above, the need to investigate the influence of joint mobility on the lower-limb blood circulation of individuals affected by diabetes, who developed peripheral neuropathy, is justified in order to substantiate clinical practice. This study aimed to evaluate the correlation between the range of motion of the tibiotarsal joint and lower-limb blood circulation in individuals with diabetic neuropathy.

METHODS

Ethical aspects

This study was conducted at the Ribeirão Preto Medical School (FMRP-USP) from February 2018 to March 2019. It was approved by the Research Ethics Committee of the Ribeirão Preto Clinical Hospital, Ribeirão Preto Medical School (protocol 808/2017). It was conducted by the National Health Council Resolution 466/12, and all patients agreed and signed a free and informed consent form.

Sample size

The sample size was calculated based on the study conducted by Marrón-Gómez et al.[11], considering the range of motion as an outcome variable, with a statistical power of 80% and significance level (alpha) of 5%, revealing n=18. Based on this, and predicting possible sample losses, a total of 20 patients were selected for this study.

Patients with cutaneous lesions or lower-limb fractures in the past 6 months, plantar malformations, severe postural changes, and/or a real difference in lower-limb length were excluded from the study.

Evaluation procedures

Evaluations were performed in the morning, on a single day, to limit the effects of daily hormonal variations[12]. The measurements were taken before and immediately after the exercise. All participants underwent standard anamnesis. The characterization of the sample in relation to the risk of peripheral arterial disease was quantified by calculating the ankle/brachial index (ABI) using the SONARA/Tek® Doppler ultrasound (Nicolet Vascular, Madison, USA). The measurements were performed in the supine position after 5 min of rest. The values considered were between 0.90 and 1.40, with indices >1.40, representing an increase in arterial resistance, and indices £0.90, demonstrating the presence of peripheral arterial disease[13].

For the range of motion analysis of the ankle joint, a digital goniometer (Richmeters®) was used in the supine position with slight knee flexion and the feet at 90º. Dorsiflexion and plantar flexion movements of each foot were analyzed, and the average of three repetitions was recorded[14]. For thermographic analysis of vasomotor aspects (points), the FLIR® model T300 W/25 térmica thermal camera (FLIR® Systems, Wilsonville, OR, USA), with a sensitivity of 0.1°C and focal plane matrix of 320/240, was used. Skin temperature (solar) was assessed after 15 min of acclimatization at environmentally controlled temperature of 22±2°C[15], in a place illuminated by fluorescent lamps, without the presence of heat-generating electrical equipment and light. To evaluate the blood flow, the SONARA/Tek® Doppler ultrasound (Nicolet Vascular, Madison, USA), calibrated with an 8 MHz probe, was used at 45º to the blood vessel and on skin greased with water-soluble gel[16]. The measurements were performed in the supine position with the lower limbs in extension, and the blood vessels analyzed were the posterior tibial artery and the dorsal artery of the feet.

Neurological impairment was assessed using the diabetic distal polyneuropathy diagnostic scale and was translated into Portuguese and tested for reliability by Moreira et al.[17]. This is a tool used for assessing neurological symptoms such as muscle weakness, sensory disturbances, and autonomic symptoms. The scale has a score ranging from 1 to 10, with 1 indicating no neuropathic symptoms, 3–4 indicating mild neuropathic symptoms, 5–6 indicating moderate neuropathic symptoms, and 7–10 indicating severe symptoms. To evaluate a circulatory response after mobilization, an exercise protocol was used in which the patient in supine position with supported lower limbs performed plantar flexion and dorsiflexion (3 sets of 15 repetitions), and circular movements of the ankle (3 sets of 15 repetitions)[18].

Statistical analysis

The Shapiro-Wilk test was used to verify the distribution of the data. The range of motion and the surface temperature of the skin had a normal distribution, which was analyzed using Pearson's correlation coefficient. The association between blood flow and range of motion had a non-normal distribution, which was analyzed using the Spearman's correlation coefficient.

To interpret the magnitude of the correlations, we used the following classification established by Munro[19]: low, 0.26–0.49; moderate, 0.50–0.69; high, 0.70–0.89; and very high, 0.90–1.00.

RESULTS

Neurological symptoms in the lower limbs, such as sensory disturbances and autonomic symptoms, were determined using the Diabetic Distal Polyneuropathy Diagnostic Scale.

Severe symptoms and peripheral obstructive arterial disease were predominant. The ABI values of all volunteers remained between 0.90 and 1.40, which are considered normal.

The sample characterization of 20 patients was done on average, followed by the standard deviation of the patients' age of 61.45±7.05 years, body mass index of 32.47±5.70 kg/cm^2, and time of diabetes diagnosis of 11.6±6.64 years.

Correlations were low (from 0.26 to 0.49) between right plantar flexion and temperatures of the right lower limb both before and immediately after dynamic assessment, and also between left plantar flexion and temperatures of the left-leg regions at the post-immediate moment (Table 1).

The correlations were low (from 0.26 to 0.49) between joint movement (plantar flexion and dorsiflexion) and the values of mean velocity, peak, pulsatility index, and resistivity index of arterial blood circulation of both arteries, i.e., posterior tibial artery and dorsal artery of the right leg, were analyzed at the pre- and post-immediate moments (Table 2).

Table 1. Results of correlation between range of motion and surface temperature at the pre- (PRE) and post-immediate (POST) moments of dynamic evaluation.

Region	PRE				POST			
	R PF (r-value)	p	R DF (r-value)	p	R PF r-value)	p	R DF (r-value)	p
Front	0.302	0.196	-0.224	0.342	0.213	0.367	-0.08	0.736
Side	0.283	0.227	-0.153	0.520	0.281	0.230	-0.03	0.902
Medial	0.252	0.283	-0.223	0.344	0.268	0.253	-0.074	0.757
Back	0.296	0.204	-0.126	0.597	0.331	0.154	-0.145	0.541
Region	L PF (r-value)	p	L DF (r-value)	p	L PF (r-value)	p	L DF (r-value)	p
Front	0.113	0.635	-0.318	0.172	0.283	0.227	-0.100	0.676
Side	0.132	0.579	-0.181	0.444	0.278	0.235	-0.082	0.730
Medial	0.179	0.449	-0.311	0.181	0.249	0.290	-0.110	0.643
Back	0.141	0.553	-0.294	0.208	0.148	0.534	-0.255	0.279

Values presented in correlation index (r-value) and p-value. Right plantar flexion (R PF), right dorsiflexion (R DF), left plantar flexion (L PF), left dorsiflexion (L DF), front region leg (Front), side region leg (Side), medial region leg (Medial), back region leg (Back). Positive value: >0; negative value: <0.

Table 2. Results of correlation between range of motion and blood circulation of the right lower limb at the pre- (PRE) and post-immediate (POST) moments.

Right tibial	PRE				POST			
	R PF (r-value)	p	R DF (r-value)	p	R PF r-value)	p	R DF (r-value)	p
MEAN	-0.203	0.390	-0.390	0.089	-0.334	0.150	-0.129	0.354
PEAK	-0.049	0.838	-0.150	0.528	-0.287	0.220	-0.130	0.586
PI	0.283	0.227	0.096	0.688	0.032	0.892	0.394	0.086
RI	0.015	0.950	-0.006	0.980	0.016	0.946	-0.110	0.645
Right dorsal	R PF (r-value)	p	R DF (r-value)	p	R PF r-value)	p	R DF (r-value)	p
MEAN	-0.357	0.122	0.374	0.104	0.102	0.670	-0.134	0.573
PEAK	-0.234	0.321	0.162	0.495	0.326	0.160	-0.005	0.833
PI	0.020	0.935	-0.335	0.148	0.439	0.053	0.014	0.955
RI	-0.091	0.703	0.164	0.489	0.328	0.158	-0.017	0.943

Values presented in correlation index (r-value) and p-value. Right plantar flexion (R PF), right dorsiflexion (R DF), right posterior tibial artery (RIGHT TIBIAL), right dorsal artery (RIGHT DORSAL), mean arterial flow velocity (MEAN), peak arterial flow (PEAK), pulsatility index of arterial flow (PI), resistivity index of arterial flow (RI). Positive value: >0; negative value: <0.

In the left lower limb, low correlations (from 0.26 to 0.49) were observed between joint (both plantar flexion and dorsiflexion) movements and the values of mean velocity, peak, and resistivity index of the blood circulation of both tibial posterior and dorsal arteries were analyzed. There was a moderate correlation (from 0.50 to 0.69) between dorsiflexion and the left dorsal artery pulsatility index in the moments before and after dynamic evaluation, with significant values for the lower dorsiflexion and the lower pulsatility index (Table 3).

DISCUSSION

This study involved the evaluation and correlation of the range of motion of the ankle joint with the cutaneous surface temperature of the leg and the circulation of the posterior and dorsal tibial arteries before and after dynamic evaluation in which a series of motion repetitions were performed to verify joint mobility. A low correlation between the tibiotarsal range of motion and cutaneous surface temperature, and a moderate correlation between the range of motion and arterial blood circulation of the lower limb were identified.

Regarding the detrimental effects of diabetes on body structures, morphological changes in the tendons can be identified which cause decreased mobility of the ankle joint[4] and may impair the efficiency of muscle contraction, thereby interfering with movement stabilization and acceleration and consequently decreasing the functionality of these individuals[20]. The restriction of joint mobility interferes with the adequate contraction of the musculature and consequently with the blood circulation of the lower limb, with a decrease in the speed of blood flow[21], which corroborates the findings of the present study, in which reduced values of joint range of motion and arterial blood flow were observed.

The present study demonstrated a limitation in the range of articular movement of diabetic neuropathic individuals, as shown in the studies by Fernando et al[20]. that found a decrease in the range of ankle joint movement, resulting in a change in plantar distribution during gait, which can be identified as a risk factor for ulcers and lower quality of life in these patients.

Diabetic individuals often present with vascular calcification that increases arterial wall stiffness and systolic pressure[22], which is supported by the findings of the present study based on the pulsatility and resistivity data of the evaluated arteries. The lower the values of both indices, the slower the flow within the vessels, with the slower continuous flow being found in diabetic individuals[23].

The superficial cutaneous temperature of the skin of diabetic individuals is higher compared to that of healthy individuals due to an increase in heat emission caused by the thermoregulatory mechanisms present in the blood flow of cutaneous vessels, and being related to the presence of peripheral arterial disease[24].

The study by Weigert et al.[25] evaluated the body composition referring to the accumulation of fat in tissues in obese individuals and also observed a long time to change the skin surface temperature after resistance training. Body fat acts as a

Table 3. Results of correlation between range of motion and blood circulation of the left lower limb at the pre- (PRE) and post-immediate (POST) moments.

	PRE				POST			
Left tibial	**L PF (r-value)**	**p**	**L DF (r-value)**	**p**	**L PF (r-value)**	**p**	**L DF (r-value)**	**p**
MEAN	-0.333	0.152	-0.258	0.272	-0.271	0.248	-0.181	0.444
PEAK	-0.236	0.316	0.005	0.982	-0.047	0.845	0.065	0.786
PI	-0.015	0.950	0.332	0.153	0.420	0.065	0.325	0.163
RI	-0.133	0.575	0.049	0.838	0.047	0.842	0.144	0.545
Left dorsal	**L PF (r-value)**	**p**	**L DF (r-value)**	**p**	**L PF (r-value)**	**p**	**L DF (r-value)**	**p**
MEAN	-0.159	0.503	-0.132	0.579	-0.192	0.418	-0.096	0.688
PEAK	-0.264	0.260	0.283	0.227	-0.261	0.266	0.346	0.135
PI	-0.135	0.571	0.497*	0.026	-0.124	0.603	0.511*	0.021
RI	-0.219	0.353	0.327	0.159	-0.308	0.186	0.217	0.357

Values presented in correlation index (r-value) and p-value. Left plantar flexion (L PF), left dorsiflexion (L DF), left posterior tibial artery (LEFT TIBIAL), left dorsal artery (LEFT DORSAL), mean arterial flow velocity (MEAN), peak arterial flow (PEAK), pulsatility index of arterial flow (PI), resistivity index of arterial flow (RI). Positive value: >0; negative value: <0.

thermal insulator by reducing thermal conductivity and thus hindering heat exchange with the environment. Thus, the average surface temperature depends on the body fat[25]. The patients in the present study had a mean body mass index between 30 and 34.99, and were categorized as type I obesity. This may explain the results found in relation to the skin surface temperature, which did not change after the dynamic evaluation since it would take a longer time for the skin surface temperature to change, and the evaluation was performed immediately after exercise.

The results obtained in this study reveal a correlation between the tibiotarsal range of motion and peripheral blood circulation in diabetic individuals which interferes with the health of these individuals, thus reinforcing the importance of evaluating these parameters in clinical practice to preserve functionality and prevent related comorbidities throughout the disease.

CONCLUSION

The results of the present study point to a moderate correlation between the range of motion of the tibiotarsal joint and blood circulation and low temperature, demonstrating a reduction in the range of motion of the ankle and in the arterial blood flow of the lower limb of patients with diabetic neuropathy.

AUTHORS' CONTRIBUTIONS

CCZ: Conceptualization (equal), Data curation (equal), Writing – original draft (equal), Writing – review & editing (equal). **AG:** Data curation (equal), Formal Analysis (equal), Writing – review & editing (equal). **ATS:** Data curation (equal), Formal Analysis (equal). **GC:** Data curation (equal), Formal Analysis (equal). **RRJG:** Methodology (equal), Writing – review & editing (equal). **ECOG:** Conceptualization (equal), Writing – review & editing (equal).

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