Effect of Foot Reflexology on Capillary Blood Glucose, Tissue Temperature, and Plantar Pressure of Individuals With Diabetes Mellitus (Type 2): A Pilot Study

Natália C.M. Silva, PhD,[a] Érika C.L. Chaves, PhD,[b] Emília C. Carvalho, PhD,[c] Leonardo C. Carvalho, PhD,[d] and Denise H. Iunes, PhD[d]

Abstract

Objective: The purpose of this study was to assess the effect of foot reflexology on capillary blood glucose, feet tissue temperature, and plantar pressure of the feet of individuals with diabetes mellitus (type 2).

Methods: Forty-five individuals with type 2 diabetes mellitus were stratified into 2 groups: treated (n = 21), which received orientation about foot self-care and received 12 foot reflexology sessions; and control (n = 24), which received only orientations about foot self-care. A portable glucose meter, an infrared thermography camera, and a baropodometer evaluated the variables.

Results: The data indicate that, after 12 therapy sessions, there were no significant differences between the groups for producing effects on capillary blood glucose, feet tissue temperature, and plantar pressure.

Conclusion: No significant effect was observed after 12 foot reflexology sessions in the variables that were evaluated. (J Chiropr Med 2018;17:182-189)

Key Indexing Terms: *Massage; Diabetes Mellitus, Type 2; Lower Extremity*

Introduction

Individuals with diabetes mellitus are more susceptible to developing several complications, both acute and chronic.[1] Among the alterations caused by this pathology, the authors highlight the high risk of lower-limb complications.[2]

Complications caused to the nerves and peripheral blood vessels may lead to decreased foot temperature because thermal regulation is hindered.[3] When sensory nerve fibers are damaged, cold and heat perception are altered, and when blood flow is reduced, heat regulation through vasodilation and vasoconstriction is not effective, thus compromising tissue temperature.[4]

At the same time, high blood glucose levels contribute to reduced tissue elasticity and increased stiffness of the joints responsible for movement.[1] This leads to biomechanical gait dysfunction, which directly affects body weight distribution on the plantar surface, leading to increased pressure on some regions of the foot.[5]

Alteration of feet tissue temperature and plantar pressure make the individual vulnerable to trauma.[6] In light of this, it is necessary to implement actions to prevent and control plantar complications, with the aim of improving the health conditions of individuals with diabetes mellitus.[7]

In this sense, the use of integrative and complementary practices constitutes an option for health promotion and disease prevention and recovery, with possible effects on the development of illness.[8] Among integrative and therapeutic methods available, the authors highlight foot reflexology, which is characterized as being easy to apply and not greatly dependent on technology.[9]

Also known as pressure therapy, foot reflexology aims to promote relaxation and stimulate equilibrium.[8] It is based

[a] School of Nursing, Federal University of State of Rio de Janeiro, Rio de Janeiro, Brazil.
[b] Nursing School, Federal University of Alfenas, Minas Gerais, Brazil.
[c] Nursing School at Ribeirão Preto, University of São Paulo, São Paulo, Brazil.
[d] Course of Physiotheraphy/Nursing School, Federal University of Alfenas, Minas Gerais, Brazil.
Corresponding author: Natália C.M. Silva, PhD, School of Nursing, Federal University of State of Rio de Janeiro - UNIRIO, Rua Dr. Xavier Sigaud, 290, Urca, Rio de Janeiro RJ, Brazil, 22180290. Tel.: +55 031 993040364.
(e-mail: *naty_chantal@hotmail.com*).
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on the belief that all regions of the body are connected to specific points on the foot, so applying pressure to these points on the plantar surface stimulates the corresponding reflex area.[9]

Some researchers who are interested in investigating reflex therapy have proven its effects for controlling arterial blood pressure and heart rate and reducing anxiety.[10,11] Thus, with its goal of attaining mind and body homeostasis, foot reflexology can contribute to improving the population's health conditions.[9] However, it is necessary to conduct studies that ascertain the method's effects and ensure its use in the health care field. Thus, the goal of the present study is to evaluate the effects of foot reflexology on capillary blood glucose, plantar pressure, and feet tissue temperature of people with type 2 diabetes mellitus.

Methods

The present research was a small-scale randomized clinical trial carried out in 2 primary health care services in a municipality in the south of the state of Minas Gerais, Brazil. The project was approved by the Federal University of Alfenas Ethics Committee, protocol CAAE: 07183512.1.00005142 and was entered into the Brazilian Clinical Trials Registry (RBR-8zk8sz). All participants in the study signed a free and informed consent form.

The study's representative population was composed of individuals aged 18 years or older who were diagnosed with type 2 diabetes for at least 5 years. Criteria for exclusion were as follows: the presence of foot ulcers, lower limb amputation, uncontrolled hypertension, thrombosis, cognitive deficits, and previous reflexology treatment.

The sample size was determined from a pilot test completed before the study began, which was conducted with 12 volunteers who met the eligibility criteria. The statistical software GPower 3.0.10 (Franz Faut, Universität Kiel, Kiel, Germany) was used, with a power effect of 0.80 and effect size of 0.68 ($\alpha = 0.05$). Thus, it was found that it would be necessary to have the allocation of 26 participants in each group.

A total of 214 individuals who were enrolled in the "System of Registration and Monitoring of Hypertensive/Diabetics," and had a diagnosis of type 2 diabetes mellitus fulfilled the eligibility criteria. Of these, 161 were excluded based on at least 1 exclusion criterion. After being contacted in their homes, only 53 agreed to participate in the study. Using simple stratification, participants were randomized into 2 groups according to age, sex, and length of time since diagnosis. The treated group comprised 26 participants who received orientation about foot care and 12 foot reflexology sessions, whereas the control group comprised 27 participants who received only orientation about foot self-care, which was considered a representative sample of the population.

During the follow-up, 5 participants in the treated group and 3 in the control group did not participate in all of the steps of the study and were, therefore, excluded. Thus, at the end of the study, the authors analyzed the data for 45 participants, as described in Figure 1.

The randomization process and the application of the reflexology intervention were carried out by the main researcher and were not disclosed to the assistant researcher, who was responsible for the evaluations. Participants were also instructed not to disclose which group they belonged to.

Evaluation

Participants from both groups were evaluated at the beginning of the study and after the 6th and 12th reflexology sessions. The assistant researcher was trained to analyze capillary blood glucose, feet tissue temperature, and plantar pressure. These procedures were carried out in a specific location, allowing for control of the environment and standardization of procedures. Capillary blood glucose was evaluated by measuring blood glucose at random using a Biocheck Gold portable glucose meter (Bioeasy, South Korea).

To measure feet tissue temperature, the authors used infrared thermography, a relatively new method in the health care field, which captures body temperature through an infrared thermal image, detecting subtle changes in dermal blood flow.[4,12] Foot temperature was measured according to norms established in the literature: the environment was thermally controlled, the temperature was constantly at 23°C; the number of individuals in the laboratory was restricted to 3, including the evaluator; participants were positioned in supine position and were barefoot, remaining in this position for 15 minutes (the time necessary for the body to attain thermal equilibrium with the environment).[12] The thermographic camera (FLIR E60, Porto Alegre, Rio Grande do Sul, Brazil) was positioned 95 cm above the ground at a standardized 98 cm away from the participant's feet. To prevent body heat from other regions from interfering with the plantar surface image, a cardboard support was used for thermal isolation.

After capturing the thermographic image of the foot, computer thermal analysis was conducted on 18 points pre-established by the researchers. An electronic baropodometer (Footwork, Brazil) was used to analyze plantar pressure. This instrument allowed us to evaluate plantar pressure distribution during static and body sway analysis, in orthostatic position, and during dynamic analysis, while in movement.[5]

For the static and body sway analysis, participants were asked to remain barefoot on the baropodometer platform, with their arms alongside their body, for 20 seconds. During this period, the machine captured pressure points on the left and right feet and the body's dislocation around its supporting axis. Afterward, in the dynamic analysis, participants were asked to walk 5 meters along an ethylene

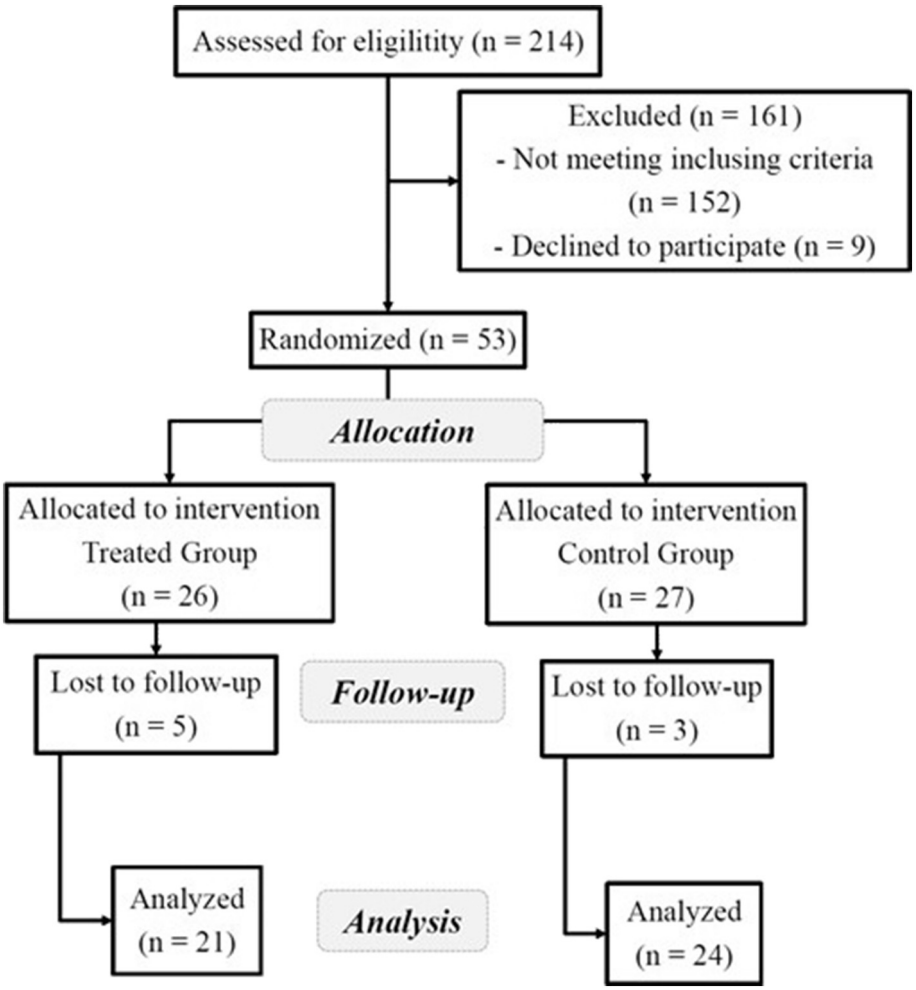

Fig 1. *Flow diagram consort.*

vinyl acetate strip, with the baropodometer positioned in the middle of the strip in such a way that, upon stepping on the modular platform, it was possible to verify the pressure points on the participant's left and right feet during gait.

Interventions

After the initial evaluation and sample randomization, the researcher went to each participant's home and provided them with orientation about the following self-care topics: wearing closed shoes,[13,14] not walking around barefoot,[7,13] proper technique for trimming toe nails,[7] using a mirror for self-examination,[14,15] how to dry feet properly,[13] wearing cotton socks,[16] applying moisturizer on legs, not applying moisturizer between the toes,[7,13] and not using abrasives or sandpaper.[13]

Three therapy sessions per week were provided, which totaled 12 sessions during a period of 30 days. These sessions took place in a systematic and previously scheduled manner, on set days and at set times, in an attempt to reduce possible interference caused by daily routine habits. The therapy was applied on a bed, with the participant remaining in a supine position and with the head resting on a pillow throughout the entire session. The application followed the principles set forth by Eunice Ingham, the first reflexologist to map out the foot's pressure points and their corresponding effects on the rest of the organism.[9]

The authors found no references regarding the proper sequence to be followed when administering foot reflexology. However, it is recommended that all reflex points be stimulated because the goal is to balance out the organism and apply pressure to the areas that correspond to the human body.[8] To maintain uniformity and standardization of technique, the left foot was massaged first, followed by the right foot, stimulating pressure points according to the following pre-established sequence: joints, lateral portion, medial portion, and plantar surface.

Statistical Analysis

Statistical analysis was conducted using R software,[17] version 2.15.3, with a 5% significance level. Regarding the analysis of the qualitative variables of characterization, the

Table 1. *Comparison of Capillary Random Blood Glucose Levels in the Treated Group and Control Group, by Applying the Log-Linear Regression Test*

Analysis	Treated Group (mg/dL)	Control Group (mg/dL)	B	SE (β)	*P* Value
Intercept	————————	————————	5.28	0.09	<.001 [a]
First assessment	196.80 SD 94.13	230.15 SD 107.37	0.16	0.13	.219
Second assessment	232.85 SD 92.12	226.92 SD 104.06	-0.14	0.10	.166
Third assessment	222.62 SD 109.23	241.90 SD 115.05	-0.09	0.09	.354

SD, standard deviation; *SE*, standard error.
[a] $P < .05$.

χ^2 test and, when necessary, Fisher's exact test were used. In the analysis of the quantitative variables, the Mann-Whitney test was used.

In relation to the analysis of the effect of the tested intervention, to verify if there was a significant difference between the 3 evaluations in each group, the Wilcoxon test was used, both for the qualitative and quantitative variables. However, the Wilcoxon test does not evaluate if the behavior of the variables between the 2 groups was different throughout the 3 evaluations. Thus regression analysis was performed, which accounts for the correlation between the groups among the existing variables; in the ordinal variables, logistic regressions were used and in the quantitative variables, log-linear regressions.

Results

In the treated group, 65% of participants were female. The average age was 63.0 ± 9.1 years, average weight was 73.2 ± 14.4 kilos, and average height was 1.63 ± 1.15 meters. In the control group, 62% were women with an average age of 60 ± 10.5 years, an average weight of 76.6 ± 11.0 kilos, and an average height of 1.61 ± 0.88 meters. No significant differences were found between the groups regarding these variables, race, marital status, schooling, occupation, smoking, alcoholism, physical activity, presence of chronic illness, presence of an acute illness, or type of treatment for diabetes mellitus.

The treated group displayed a greater number of hypertensive individuals (92.31%) and a lower number of retirees (30.77%) in relation to the control group (66.67% hypertensive and 92.59% retirees). The differences between the groups for these variables were statistically significant (arterial blood pressure, $P = .039$ and retirees, $P = .021$).

Regarding risk of incapacity, verified with Semmes-Weinstein 10g monofilament, portions of the treated group (65.4%) and control group (46.15%) presented sensory neuropathy in 1 of the 2 points indicated by the American Diabetes Association. Thus participants displayed a moderate level of risk of incapacity because the authors detected no signs of peripheral vascular disease or foot deformities.[2]

When verifying the effect of foot reflexology on capillary blood glucose, the authors observed that even though the treated group displayed lower blood glucose levels than the control group at the end of the study, there were no significant differences between groups, as described in the Table 1.

Upon comparing treated group and control group feet tissue temperature, no significant differences were identified. The authors also noticed that both groups presented a temperature reduction throughout the study.

No significant differences were found between groups throughout the evaluations upon analysis of the following plantar pressure variables: static analysis (average pressure, maximum pressure, surface, and center of gravity distribution), body sway, and dynamics analysis (average pressure, maximum pressure, time of contact, and surface). However, when comparing the 3 evaluations within the same group, differences were found, as described in Table 2.

The results of static plantar pressure analysis demonstrated that after 12 reflexology sessions, individuals who received intervention presented a significant reduction in average pressure in both the right and the left foot and a reduction in maximum pressure in the left foot. The authors also verified that after 6 therapy sessions, the average pressure for the right foot was significantly reduced.

Concerning center of gravity distribution, the treated group displayed significant differences after 6 sessions in the left region, and the same result was observed in the right region after 12 intervention sessions.

The results of dynamic analysis show that treated patients displayed significant increase in foot-ground contact time, during gait, after 12 therapy sessions. Thus, although there were no significant differences between groups with regard to plantar pressure variables, individuals who received foot reflexology presented a reduction in average and maximum pressure and an improvement with respect to center of gravity distribution in the static analysis. The dynamic analysis showed improvements regarding increased foot-ground contact time, results which were not observed in the control group.

Discussion

Because it is a cutaneous stimulation therapy, reflex massage may produce slow effects because its goal is to attain

Table 2. *Comparison of Plantar Pressure in the Treated Group and Control Group, by Means of the Wilcoxon Test*

		Treated Group			Control Group		
Indicators		First Assessment	Second Assessment	Third Assessment	First Assessment	Second Assessment	Third Assessment
Static analysis							
Medium pressure (kgf/cm^2)	L	0.36 SD 0.08	0.35 SD 0.08	0.34 SD 0.08 [a]	0.36 SD 0.07	0.35 SD 0.06	0.35 SD 0.05
	R	0.38 SD 0.07	0.34 SD 0.06 [c]	0.34 SD 0.07 [a]	0.35 SD 0.06	0.34 SD 0.06	0.33 SD 0.06 [a]
Maximum pressure (kgf/cm^2)	L	1.19 SD 0.34	1.18 SD 0.42	1.12 SD 0.32 [a]	1.24 SD 0.41	1.15 SD 0.32	1.14 SD 0.26 [a]
	R	1.25 SD 0.35	1.16 SD 0.29	1.26 SD 0.37	1.18 SD 0.28	1.12 SD 0.26	1.10 SD 0.25
Surface (cm^2)	L	100.4 SD 16.3	96.9 SD 17.3	98.1 SD 17.4 [a]	110.5 SD 19.3	106.8 SD 18.2 [c]	99.4 SD 26.6 [a,b]
	R	100.4 SD 15.9	98.7 SD 16.1	96.4 SD 18.0 [a,b]	110.2 SD 17.1	107.9 SD 18.8	106.0 SD 19.4 [a,b]
Distribution center of gravity (%)	L	48.0 SD 5.7	50.2 SD 6.3 [c]	50.4 SD 5.0 [a]	50.4 SD 6.4	51.6 SD 5.2	51.7 SD 4.7 [a]
	R	51.8 SD 6.2	49.7 SD 6.3 [c]	49.5 SD 5.0 [a]	49.5 SD 6.4	48.3 SD 5.2	48.6 SD 4.8
	A	43.4 SD 9.4	44.0 SD 8.0	44.1 SD 7.9	41.7 SD 7.1	43.7 SD 8.4	44.4 SD 9.5 [a]
	P	56.7 SD 9.0	55.9 SD 8.0	55.8 SD 7.9	58.2 SD 7.1	56.2 SD 8.4	55.9 SD 9.5 [a]
Oscillation of the body (cm)							
Lat		1314.7 SD 812.3	1648.7 SD 702.3	1421.5 SD 1138.5	786.0 SD 878.0	861.3 SD 1044.9	1179.9 SD 1017.8
AP		1689.4 SD 1134.9	2160.9 SD 575.0	2321.2 SD 1054.7	1753 SD 621.7	1980 SD 680.8	1947.2 SD 1035.1
Dynamic analysis							
Medium pressure (kgf/cm^2)	L	1.3 SD 0.2	1.3 SD 0.2	1.2 SD 0.2	1.1 SD 0.2	1.1 SD 0.2	1.1 SD 0.1
	R	1.3 SD 0.2	1.2 SD 0.2	1.2 SD 0.2	1.1 SD 0.2	1.8 SD 0.2	1.2 SD 0.2
Maximum pressure (kgf/cm^2)	L	2.6 SD 0.4	2.6 SD 0.4	2.6 SD 0.4	2.5 SD 0.4	2.5 SD 0.4	2.6 SD 0.5
	R	2.7 SD 0.4	2.6 SD 0.3	2.7 SD 0.5	2.5 SD 0.5	2.6 SD 0.4	2.6 SD 0.4
Contact time (ms)	L	1065 SD 647.8	1006.1 SD 295.6	106 SD 505.4	1014.2 SD 982.1	982.2 SD 234.8	1057.5 SD 522.6
	R	984.2 SD 405.4	989.6 SD 349.8	1149.5 SD 709.5 [a]	958.6 SD 310.2	1026 SD 313.8	1122.8 SD 719.1
Surface (cm^2)	L	107.9 SD 12.1	104.0 SD 14.4 [c]	107.8 SD 18.2	120.1 SD 19.7	120.2 SD 31.1	113.6 SD 20.0 [a]
	R	107.8 SD 18.2	107.8 SD 12.4	110.1 SD 23.1	119.6 SD 19.7	116.1 SD 21.9	113.2 SD 19.0

A, anterior; *AP*, anteroposterior; *P*, posterior; *Lat*, lateral; *L*, left; *R*, right; *SD*, standard deviation.
[a] Significant difference in the third assessment vs the first assessment.
[b] Significant difference in the third assessment vs the second assessment.
[c] Significant difference in the second assessment vs first assessment.

the equilibrium of all the organs and regions that make up the organism.[8] In the literature, there is no consensus about the number of foot reflexology sessions needed to produce some kind of effect upon the organism. Some researchers state that 1 session alone is enough to intervene in certain variables, such as heart rate, systemic arterial blood pressure, and pain intensity during labor in childbirth.[10-12] The greatest number of foot reflexology sessions administered in scientific research was

found in a study[18] with the objective to test the effects of the therapy on the incidence and intensity of dysmenorrhea. The researchers administered 12 foot reflexology sessions to a group of women.

The authors found few nonpharmacologic therapeutic approaches for controlling diabetes mellitus. Only 1 study, conducted in China, tested the effects of reflex therapy on blood glucose levels. It detected that after administering foot reflexology daily for a period of 30 days, fasting capillary blood glucose levels were significantly reduced in individuals who received the intervention. The same result was not found in the current study because there were no alterations in randomly measured capillary blood glucose. This difference may be due to the methodology used for therapy administration; in the Wang study,[19] the technique was administered daily, and in the present study it was administered 3 times a week on alternate days.

Because diabetes is a metabolic pathology, therapies aimed at its control, be they dietary reeducation, physical exercise,[20] pharmacologic and nonpharmacologic interventions (as is the case for reflex therapy), the therapies must be implemented daily, for the metabolism constantly changes based on activity.[21] Thus, in light of the study conducted in China,[19] and because glucose levels are influenced by intrinsic and extrinsic factors,[22] perhaps daily sessions of foot reflexology and systematic supervision of factors that influence blood glucose levels could help control capillary blood glucose.

In the present study, the groups were equivalent in most of the characterization variables analyzed. Only in the variables "arterial hypertension" and "retirement," were there significant differences in the composition of the treated group and the control group. However, these aren't considered determinant variables for the development of plantar alterations.[1,7]

It is established that heat conduction to the skin is influenced by internal and external factors and is detected mainly by the peripheral sensory nerves.[6] Low temperature in the feet of people with diabetes can, therefore, be attributed to lower limb innervation complications.[3,4,6]

In this study, most participants reported being diagnosed with diabetes for 10 years and, in these cases, there is an increased chance of peripheral nerve damage.[3,4] The majority of participants from both groups presented with sensory neuropathy in some region of the plantar surface. This might explain the low foot temperature experienced by the participants and the absence of significant differences between groups. Besides thermoregulation alternations in the lower limbs, people with diabetes mellitus display a higher propensity for gait alterations, which modifies the pattern of plantar pressure distribution.[5,6]

There is evidence of the effect of cutaneous stimulation for preventing adherences between skin and bone and increasing skin layer elasticity.[23] However, the authors did not find evidence that proved the effectiveness of reflex therapy on plantar pressure. In a quasi-experimental study developed in Spain, statistical analysis showed a significant reduction in average and maximum pressures observed after participants received foot massages.[11] These data match that of the present study; static plantar pressures, both maximum and average, were reduced in the treated group after 12 reflexology sessions, despite the lack of a significant difference between groups.

Analysis of static pressure also evaluated the distribution of the body's center of gravity, which corresponds to the regions where body mass is concentrated.[5] A 50% distribution of the center of gravity among the left, right, anterior, and posterior regions of the foot is expected, for intense asymmetry over long periods of time can cause anatomic and functional disorders, leading to spinal cord and lower limb complications.[23]

Although there was no significant difference between groups, participants who received the tested therapy presented significant differences in the left and right regions of center of gravity distribution after 6 foot reflexology sessions. After the therapy was completed, distribution approached 50%. This result was not observed in the control group and remained constant after the 12th therapy session.

The treated group presented an increase in foot-ground contact time, which did not occur in the control group. It is understood that the longer the foot-ground contact time, the greater the area of body weight distribution on the plantar surface.[5] Also, the increase in foot-ground contact time effectively contributes toward improved mobility and reduced incidence of ulcerations in the diabetic population.[11]

Limitations and Future Studies

The frequency and period of administration of the tested therapy and the absence of daily supervision of factors, which influence metabolism, were limitations of the present study. To produce an effect upon capillary blood glucose levels, feet tissue temperature, and plantar pressure of the feet, these items should be controlled. This study only included a small number of participants. More participants should be included in future studies.

The absence of significant differences between groups may have been related to time. Because they are clinical variables, which require longer for alterations to occur, 12 intervention sessions, on alternate days, may have proved insufficient time for producing therapy-related results. Thus, the authors recommend that future studies be carried out for longer periods, in which the intervention is administered more frequently and with a larger sample, allowing for detection of small differences between groups. In this manner, it will be possible to confirm the effects of reflex therapy and certify its application for type 2 diabetes foot care.

Conclusion

In this small-scale, randomized clinical trial, no significant differences were observed between groups with respect to the following analyzed variables: capillary blood glucose, feet tissue temperature, and foot plantar pressure (static analysis, body sway, and dynamics analysis). However, the authors observed that after 12 sessions of the tested therapy,

participants in the treated group presented more "normal" results than those of the control group regarding subvariables of the static analysis (average pressure, maximum pressure, and center of gravity distribution) and the foot-ground contact time subvariable of the dynamics analysis. These findings may provide fertile ground for future studies.

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Contributorship Information

Concept development (provided idea for the research): N.C.M.S., E.C.L.C., E.C.C., L.C.C., D.H.I.
Design (planned the methods to generate the results): N.C.M.S., E.C.L.C., D.H.I.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): N.C.M.S., E.C.L.C., E.C.C., L.C.C., D.H.I.
Data collection/processing (responsible for experiments, patient management, organization, or reporting data): N.C.M.S.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): N.C.M.S., E.C.L.C., E.C.C., L.C.C., D.H.I.
Literature search (performed the literature search): N.C.M.S.
Writing (responsible for writing a substantive part of the manuscript): N.C.M.S.
Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): N.C.M.S., E.C.L.C., E.C.C., L.C.C., D.H.I.

Practical Applications

- The data indicate that 12 therapy sessions were insufficient to significantly differentiate the groups and for producing effects on capillary blood glucose, feet tissue temperature, and plantar pressure.
- It was observed that after 12 sessions, the treated group presented different results compared to the control group regarding subvariables of the plantar pressure (average pressure, maximum pressure, and center of gravity distribution of the static analysis and the foot-ground contact time of the dynamics analysis).

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