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Effect of combined ankle exercise and self foot massage on ankle-brachial index and diabetic peripheral neuropathy symptoms

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Abstract

Background: Buerger Allen Exercise (BAE) and Self-Thai Foot Massage (STFM) are strongly recommended ameliorating Diabetes Peripheral Neuropathy (DPN) symptoms. Nevertheless, there is lack of evidence on the combination of both on alleviating DPN symptoms and Ankle-Brachial Index (ABI).
Aims: This study aimed to examine the combination effect of BAE and STFM on symptoms of diabetic peripheral neuropathy and ABI among individuals with DPN.
Methods: The research design used an experimental one-group with pre-test and post-test design. In total, 36 eligible individuals with DPN with a seven-day received combination of BAE and STFM implementing ankle exercise and foot massage. DPN scores were measured using the Michigan Screening Instrument (MNSI) questionnaire and foot perfusion was measured using the ABI. An analysis of the research data was conducted using the Paired *t*-test and effect size with Cohen's d with a significance threshold of p >0.05.
Results: There are a significant finding combination of BAE and STFM on MNSI subjective (mean diff=-2.78, p=>.001, d=0.71), MNSI objective (mean diff=-1.60, p=>.001, d=0.38), ABI left (mean diff= 0.01, p=>.001, d=0.51), and ABI right (mean diff=0.07, p=>.001, d=0.59).
Conclusion: The finding of this study indicates that a combination of BAE and STFM is a feasible alternative therapy for ABI and MNSI in patients with DPN.

Keywords: Ankle-Brachial index; Buerger allen exercise; Diabetes peripheral neuropathy; Self-Thai foot massage.

INTRODUCTION

Diabetes mellitus is a chronic condition that imposes a significant burden on the global healthcare system, including in Indonesia (1, 2). The International Diabetes Federation forecast the prevalence of diabetes mellitus will increase to 700 million by 2045, affecting 578 million individuals worldwide in 2030. In Indonesia, the estimated number of individuals with diabetes will rise from 10.7 million in 2019 to 16.6 million in 2045 (3). The incidence of complications is also on the rise as a result of the increasing prevalence of diabetes (1, 4). Interesting fact, the diabetic peripheral neuropathy (DPN) is one of the most common complications of diabetes mellitus, with a global prevalence of 30% due to elevated glucose resistance (4). Nevertheless, Southeast Asian countries including Philippines (58%), Malaysia (54.3%), Thailand (34%), and Singapore (33%), exhibit a higher prevalence of DPN (5). DPN occurs when peripheral nerves are damaged. This can include oxidative stress damage, the buildup of sorbitol and other advanced glycosylation end products, and problems with the hexosamine pathway and protein kinase-C (6). Consequently, these factors exacerbate neurovascular conditions and induce endothelial dysfunction.

DPN is a progressive degradation of peripheral nerves, particularly in the lower limbs, that impacts the sensory, motor, and autonomic aspects of the nerves. This leads to an increase in DPN symptoms, such as a

diminished sense of protection, dysfunction of the intrinsic foot muscles, and foot anhidrosis (7, 8). In DPN, neuropathic pain is a prevalent symptom, with a prevalence of 20%, particularly at night (8). Additionally, tingling, numbness, burning sensations (9), and impaired foot perfusion or capillary blood flow in the dorsum of the foot are common (10). Individuals with DPN are 10-20 times more likely to undergo an amputation, which is a distinctive characteristic. Therefore, a person with DPN undergoes the amputation of a portion of their lower extremity every 30 seconds (10). Consequently, to gain a more comprehensive comprehension of the mechanism, it is necessary to identify symptoms of DPN and foot perfusion The ankle-brachial index (ABI) is a key indicator and an established method for evaluating ankle perfusion in patients with DPN (11). Due to its ease of use, lack of invasiveness, and low cost, an ABI assessment is the best way to find out if someone with diabetes has perfusion circulation disorders (12). Yasa's research indicates that a reduction of one value from the standard ABI value can increase the incidence of DPN by 1.45 times (13). Moreover, a study conducted in Japan demonstrated a correlation between the symptoms of DPN and ankle perfusion as assessed by ABI in individuals with diabetes (11). In fact, endothelial dysfunction of the vasa nervorum causes a reduction in blood flow in DPN and perfusion circulation in the ankle. This leads to hypoxia, which in turn can establish functional nerve morphology, and oxidative stress. Ultimately, this damage to the ankle perfusion can lead to the development of DPN (14).

Effective pharmacological treatment is crucial for preventing comorbidities and managing DPN (9). Nevertheless, because of substantial adverse effects of pharmaceutical treatment, non-pharmacological methods and alternative medicine remain options (15). Nevertheless, engaging in moderate to high-intensity exercise, while it may alleviate pain, has minimal impact neuropathic symptoms and might lead to negative consequences, including hypoglycemia, muscular soreness, dizziness, and limb distress (16). A systematic review and meta-analysis studies have shown that ankle exercise such as BAE significantly improves ABI and Oxyhemoglobin (HbO2) values in people with DM (17). In line with several studies stating that BAE can increase ABI, HbO2 and reduce DPN symptoms (18).

Several research results show that TFM is a simple and easy-to-apply therapeutic and integrative therapy for individuals with DPN (9, 19, 20). TFM is a form of massage using thumb pressure applied along the meridian lines of the legs and feet (21, 22). STFM can improve blood flow to the skin of the feet, pulse pressure, range of motion of the feet and ankles in people with DPN, so it can be indicated that it can improve DNP symptoms, HbO2, and ABI values. Furthermore, STFM is recommended as an alternative treatment that is easy to apply, does not cost anything, and is done independently at home (23). Therefore, STFM can likely increase blood flow, thereby increasing foot perfusion, reducing DPN symptoms.

The benefits of BAE in enhancing ankle perfusion by ABI evaluation have been demonstrated (24). Therefore, STFM has the potential to alleviate pain and improve sensation and blood circulation (23). The concurrent use of BAE and STFM is expected to enhance efficacy, reduce the duration of treatment, and be easily executed, therefore establishing it as a preferred treatment technique for DPN

METHOD

Study Design

Study design is classified as experimental research and utilizes a one-group pre-test and post-test design approach.

Participants

The sample of the study is patients diagnosed with DPN, recruited from a private hospital in Yogyakarta, participated in this study between May and June 2024. A sampling technique was applied with non-probability technique utilizing a purposive method, specifically process that involves

respondents who fulfil the established inclusion and exclusion criteria. Patients diagnose with DPN, aged 21 to 60 years, and have the ability to sit for 15 minutes without pain were considered eligible to participate. The exclusion criteria were participants who had diabetic foot ulcer, peripheral venous insufficiency, cardiac, renal, or hepatic insufficiency, central nervous system dysfunction, or myopathy. Application of the central limit theorem to compute the effect size. For values of *n*=30, the sampling distribution exhibits an approaching normal distribution. The researcher specified an attrition rate of 20% for the entire sample with total 36 participants to eligible.

Intervention

Participants who completed the BAE and SFMT measurements twice every day (13.00 and 19.00 pm) for a duration of seven days. During this phase, individuals engage in BAE and later STFM. The integration process of BAE (24) and STFM (25) involves the following steps: (a) Assuming a supine position for a duration of 2-3 minutes; (b) Raising the legs using pillows or walls at an angle ranging from 45 to 90 degrees for a duration of 2-3 minutes; (c) Sitting with the legs hanging over the edge of the bed; (d) Flexing your ankles vertically for a duration of 3 minutes; (e) Rotating the soles of your feet laterally and inwardly for a duration of 3 minutes; (f) Rotating your toes with your forefinger until you feel discomfort; (g) Then, apply pressure to the meridian lines of the metatarsophalangeal (MTP), starting from the gap between the big toes and the gap between the little toes; (h) Utilize your forefinger to apply pressure to the proximal MTP points on the soles of the feet; (i) Apply pressure to the five distal MTP points on the soles of the feet. Apply pressure to the five massage points on the distal MTP, situated on the back of the sole above the toes, until pressure is felt; (j) Next, apply pressure to the meridian lines from the proximal to the complete MTP, starting with the gap between the big toe and the gap between the little toe on the back of the foot; (k) The ring technique should be employed to massage all joints on the digits, starting from the proximal end and extending to the distal end; (l) Apply pressure to the heel using both thumbs until a sensation is detected, then transfer the pressure downwards to the posterior knee joint. Cross the legs and position them on the opposite leg; (m) Massage the malodorous region (placed posterior to the ankle) with both palms and fingers, extending to the front of the knee joint; (n) Cross the legs and place them on the leg opposite to the one being massaged. Using both thumbs, apply pressure to the malodorous area behind the ankle until a sensation of pressure is felt. Then, proceed to push downwards towards the medial knee joint; and (o) Last, lie in bed silently for 10 minutes with both legs straight to your body and your body covered in a blanket.

Outcomes Instrument

Michigan Screening Instrument (MNSI)

The DPN score is determined using the Michigan Screening Instrument (MNSI) questionnaire, which requires a minimum score of 2 out of 13 points or the presence of at least two DPN symptoms in the past (MNSI subjective). Moreover, in the context of physical examination, a score above 1 out of 10 points on the MNSI physical examination scale (MNSI objective; (26).

Ankle-Brachial Index (ABI)

The researcher conducted the ABI, utilizing a blood pressure cuff to quantify lower extremity perfusion. To compute the ABI, divide each ankle systolic pressure by the brachial systolic pressure. We then divide the greater of the two systolic pressures for each leg by the higher of the two arm pressures to determine the right and left ABI.

Study Fidelity

Patients received educational guidance by distributing videos, leaflets, and monitoring papers. The runtime of both BAE and STFM a video with approximately 15 minutes with Javanese subtitles. This monitoring paper assesses whether participants adhere to the provided intervention during the 7-day.

Subsequently, participants will receive a leaflet that includes the sequential phases and visual representations of diabetic foot circulation exercises that incorporate both BAE and STFM.

Data Analysis

The data was analyzed using the Statistical Package for Social Sciences (SPSS) version 26.0. Descriptive statistics were employed to assess demographics. Statistical measures such as the mean and standard deviation were computed for outcomes. The paired-sample t-test and Cohen's d was chosen to assess the differences and effect size in ABI and MNSI between the pre-test and post-test scores. The threshold for statistical significance was established at $p< 0.05$.

Ethical Clearance

The study was conducted subsequent to obtaining approval (083/KEP-PKU/III/2024) from the institutional ethics committee of PKU Muhammadiyah Yogyakarta Hospital on 17 June 2017. The patients' consent was acquired in written form and documented.

Table 1. Characteristic of Respondent

Variabel	Mean (SD)/n (%)
Age (years), *mean (SD)*	55.28 (8,95)
20-40	9 (25,0)
40-60	16 (44,0)
>60	11 (30,6)
Gender, *n (%)*	
Male	15 (41,7)
female	21 (58,3)
Education level, *n (%)*	
ISCED <3	23 (63,9)
ISCED ≥3	13 (36,1)
BMI (kg/m^2), *n (%)*	
≥25 dan <18.75	21 (58,3)
≥18.75 dan <25	15 (14,7)
Phyical activity, *n (%)*	
<7.5 MET hours/weeks	29 (80,6)
≥7.5 MET hours/weeks	7 (19,4)
Drugs	
Oral	19 (52,8)
Injection insulin	12 (33,3)
Both	5 (13,9)
Disease duration (years), *mean (SD)*	8.03 (2,63)
1-5	6 (16,7)
6-10	16 (44.4)
>10	14 (38.9)
Blood glucose (mg/dL), *n (%)*	
Uncontrolled	23 (63,9)
Controlled	13 (36,1)

Note. number (n); standard deviation (SD); BMI=Body mass Index; ISCED=The International Standard Classification of Education; MET=Metabolic equivalent of task

RESULTS

Characteristic of Respondents

Table 1 demonstrated that the mean age of the participants was 56.8 (0.6) years, and they had been diagnosed with DM for 8.7 (0.3) years. The majority of participants were male (58.3%), married (69.4%), had BMI ≥25 and <18.75

(58.3%), engaged in physical activity below 7.5 MET (80.6%), used oral medicine (52.8%), had uncontrolled blood glucose (63.9%), and had obtained <3 ISCED (63.9%).

The results of the analysis showed that there was a difference between pre and post-test on all dependent variables with a *p*> 0.001. There was a large influence on decrease MNSI subjective with an effect size of 0.71. Although, the subjective MNSI objective showed the lowest effect size value compared to other outcomes, its value was still in the large effect size category (Table 2).

The results showed that for the average subjective MNSI value mean (SD) in patients before the intervention was 10.47 (2.05), while after treatment the average subjective MNSI value (SD) decreased to 7.69 (2.32) with mean differences (SE) of -2.78 (0.30) with the magnitude of the effect on the intervention being 0.71 and a *p*-value> 0.001. In addition, the average objective MNSI value (SD) in patients before the intervention was 4.21 (1.62), while after treatment the average objective MNSI value (SE) decreased to 2.61 (1.70) with a mean difference (SE) of -1.60 (0.35) with a magnitude of effect on the intervention of 0.38 and a *p*-value >0.001.

Before the intervention, the mean (SD) right ABI value in patients was 0.70 (0.06). After treatment, the mean (SD) right ABI value decreased to 0.80 (0.08) with a mean difference (SD) of 0.01 (0.01). The intervention had a size of impact of 0.59 and a *p*-value> 0.001. Furthermore, the left ABI value of patients has a mean (SE) of 0.71 (0.05) before the intervention. After treatment, the mean (SE) left ABI value increased to 0.78 (0.07) with a mean difference (SE) of 0.07 (0.01). The magnitude of effect on the intervention is 0.51 and the *p*-value is greater than 0.001.

Table 2. The Combination Effect of BAE and STFM on DPN Symptoms and ABI

Variables	Mean (SD)		Mean diff	SE	Effect size	*P value*
	Pre	Post				
MNSI Subjective	10.47 (2,05)	7.69 (2,32)	-2.78	0.30	0.71	>0.001
MNSI Objective	4.21 (1,62)	2.61 (1,70)	-1.60	0.35	0.38	>0.001
ABI Right	0.70 (0,06)	0.80 (0,08)	0.01	0.01	0.59	>0.001
ABI Reft	0.71 (0,05)	0.78 (0,07)	0.07	0.01	0.51	>0.001

Note. Ankle brachial index (ABI); Michigan Screening Instrument (MNSI); Standard deviasi (SD); Standard eror (SE). Cohen's d with 0.50-0.80 values moderate and ≥0.80-1.20 values strong.

DISCUSSION

This finding demonstrated that a novel therapy involving the combination of BAE and STFM decreased MNSI score and improved ABI score in patients with DPN after seven-day intervention. At this point, no study has been conducted combining BAE and STFM in relation to DPN symptoms. Therefore, this discussion will present the research independently and analyze both as a whole entity. A previous study revealed that foot massage is a promising method to improve MNSI (27). According to research conducted in Bali, Indonesia, a negative rank score of 72 was achieved using the Wilcoxon Sign Rank Test statistical test. This indicates

that 72 patients experienced a reduction in peripheral DPN complaints as a result of the foot massage intervention, as determined by the MNSI assessment. Although the positive rank results were zero, this indicates that none of the respondents experienced an increase in DPN-MNSI complaints following the foot massage intervention, as indicated by a *p*-value 0.001. This demonstrates that foot massage has a substantial impact on the reduction of symptoms DPN (28). The pain-relieving effect of massage is likely due to the stimulation it produces at the level of the posterior horn of the spinal cord, which activates the superficial ganglion (SG), inhibits T cells, and closes the lymph nodes. Function as gates, and impede the propagation of pain signals (29). The study's findings demonstrated that massage can impede the transmission of the TLR4 signal pathway and decrease the production of inflammatory components, a phenomenon that has been extensively supported by prior research (30).

Thus, combining BAE and STFM might effectiveness to improve ABI and reduce the symptoms of DPN score. Considering the provided data, the combination of BAE and STFM shows a strong likelihood of decreasing DPN symptoms in MNSI and DN4 measures. Although they generally serve the same purpose of enhancing leg circulation to improve blood flow, the reasons behind this effect vary. The BAE approach focuses on physical activity or movement, whereas the STFM approach emphasizes calming blood flow through massage or pressure. Ensuring adequate blood flow is crucial for delivering oxygen and nutrients to nerve cells, hence promoting optimal nerve function and minimizing complaints related to DPN. The gate control theory, which involves inhibiting the transmission of the TLR4 signal pathway and reducing the release of inflammatory factors, can achieve this. As a result, administering both BAE and STFM is a viable supplementary nursing intervention for mitigating DPN symptoms.

Notably, previous research results showed that there was a significant effect of BAE with left and right ABI at the level of *p* <0.01 and *p* <0. 05 (18). In addition, after receiving foot massage, subjects in the experimental group increased ABI values in the right and left legs (t = -8.475, *p* <0.001, SD = 0.044 and t = -10.249, *p* <0.001, SD = 0.060 respectively). Consequently, it is indicated that foot massage can increase ABI in elderly people with diabetes (31). Conducting massage therapy on acupressure points situated on the foot helps enhance blood circulation in the feet. The presence of nerve endings and blood vessels near the acupuncture points would enhance mast cell activation. Histamine and heparin, released by mast cells, induce vasodilation. Also, mast cells release platelet-activating factor (PAF), which makes platelets release serotonin. This may improve ABI (32). Diabetic foot exercises are effective for enhancing circulation, particularly in the foot region. These exercises, which require oxygen, can promote blood circulation, fortify low-lying muscles in the feet, prevent foot abnormalities that may increase the risk of diabetic foot injuries, and stimulate insulin synthesis for glucose transport to cells, thereby reducing blood glucose levels (33).

Essentially the provided data, the combination of BAE and STFM refers to a sequence of leg movements performed during DM leg exercises. These movements are similar to foot massage, which entails applying pressure and movement to ankle or foot. These movements are impacted by hormones, specifically increasing the release of endorphins. These endorphins function as vasodilators of blood vessels, resulting in a decrease in blood pressure, especially in the brachial systolic measure, which has a direct correlation with the ABI value.

LIMITATIONS

An underlying limitation of this study is its single intervention group lacks a control group, thereby prohibiting a more comprehensive assessment of the intervention's efficacy. To address DPN symptoms, it is necessary to implement more extensive time intervention and assessment to achieve a more substantial reduction in

signs and symptoms as well as the ABI. Furthermore, lack of investigation of smoking habits, alcohol status and use of drugs affecting peripheral neuropathy and determination of causality of neuropathy due to B12 and folate deficiency are other limiting factors that may lead to overestimation of DPN.

CONCLUSIONS

The present study employed that ankle exercise and foot massage such as the combination of BAE and STFM is a feasible alternative therapy for ABI and MNSI in patients with DPN. Importantly, to prevent further issues such as peripheral vascular disease and diabetic foot ulcers, the nurse should possess the ability to evaluate the ABI and MNSI in patients with DPN. Also, the community nurses to educate DPN patients in the home care setting about combination of BAE and STFM. Given its safety and user-friendly nature, we recommend that the combination of BAE and STFM be considered as a suitable home therapy option for DPN patients.

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