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Immediate effect of self-thai foot massage (STFM) on balance and ankle joint proprioception in patients with type 2 diabetes mellitus and peripheral neuropathy (DPN): A single-blind randomized controlled trial

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Abstract

Standard treatments for patients with type 2 diabetes (T2DM) and peripheral neuropathy (DPN) typically include foot care and exercise programs. Self-Thai Foot Massage has been proposed as an alternative therapy for managing this condition. This study investigated the immediate effects of the single intervention of Self-Thai Foot Massage on balance and proprioception of the ankle joint in T2DM with DPN. Ninety patients were recruited and randomly assigned to either the experimental group (EG), receiving Self-Thai Foot Massage and Standard Foot Care, or the comparable group (CG), receiving only Standard Foot Care. Both groups received a single 50-minute treatment. Balance was assessed using the Mini-Balance Evaluation Systems Test (MBT), ankle joint proprioception was measured using the Ankle Joint Proprioception (JPS) test, foot sensation was evaluated using the Semmes-Weinstein Monofilament Test (SWMT), and the active/passive range of motion of the ankle was measured using the Kinovea program, both before and immediately after a single treatment. The independent t-tests and Two-sample Mann-Whitney tests were used to compare post-treatment data between treatment groups. The EG and CG groups showed significant improvements in all outcome measures from baseline to immediately after the first treatment ($p < 0.05$). The EG group demonstrated greater improvements than the CG group in almost all variables ($p < 0.05$), except for active ankle range of motion in dorsiflexion on the left side. This study highlights the potential benefits of Self-Thai Foot Massage for immediate improvements in balance and proprioception of ankle joint, foot sensation, and ankle range of motion among these patients.

Keywords: Self-Thai foot massage, Standard foot care, Balance, Proprioception

1. Introduction

Diabetic peripheral neuropathy (DPN) is a significant complication of diabetes with the prevalence report about 6-51 % [1], characterized by various forms of nerve damage, affecting joint proprioception and balance functions [2]. In Myanmar, the prevalence of neuropathy is notably high (33.7%), with risk factors including older age, longer duration of diabetes, and a history of smoking [3]. DPN is attributing these to diminished sensory input from the skin, muscles, and joints. Additionally, mobility issues arising from stiffness in joints further contribute to postural instability and fall risks, particularly in older individuals [4, 5].

Various types of balance impairments, including static, dynamic, and functional instability, are observed in DPN patients [6, 7]. Standard treatments for DPN typically involve foot care and exercise [8]. Traditional Thai foot massage has shown promise in improving functional balance and range of motion in ankle and toe joints [9], activating the somatosensory system through stimulation of cutaneous receptors, Golgi tendon organs, muscle spindles, and joint receptors [10]. Self-administered Thai foot massage, being both accessible and effective, holds potential as a treatment modality for DPN patients, with its gentle pressure likely to be safe for diabetic feet. Previous studies have focused primarily on the immediate effects on skin blood flow, skin temperature, and range of motion [11] or on balance performance using tools like the Timed Up and Go test (TUG) [9].

The Mini-Balance Evaluation Systems Test (Mini-BESTest or MBT) is a validated tool for assessing balance and gait, known for its reliability and validity in various populations, including those with neurological conditions [12, 13]. Recent research further supports its utility in evaluating balance changes in type 2 diabetes (T2DM) patients with DPN [14, 15]. This assessment has not been studied as an outcome measurement in studies of massage effectiveness. However, the specific effects of self-Thai foot massage on joint proprioception, which could potentially enhance all dimensions of balance as measured by the MBT, have not been adequately studied. Despite these advancements, there remains a gap in understanding the immediate effects of self-Thai foot massage on balance and proprioception in T2DM patients with peripheral neuropathy. The hypothesis of this study is that self-Thai foot massage may improve balance and proprioception after a single treatment.

Therefore, this study aims to investigate the immediate effects of a single session of self-Thai foot massage combined with standard foot care on balance and joint proprioception in T2DM patients with peripheral neuropathy, compared to standard foot care alone.

2. Materials and methods

2.1 Study design

This study was conducted using an assessor-blinded randomized controlled trial. The study adhered to the CONSORT checklist and was registered with clinical trials in Thailand (registration number: TCTR20200515010; May 15, 2020). It was conducted at the outpatient diabetic clinics of Yangon General Hospital (YGH) and North Okkalapa General Hospital (NOGH) in Yangon, Myanmar, as well as the Department of Physical Medicine and Rehabilitation Unit at North Okkalapa General Hospital (NOGH) from July 2020 to February 2022. Prior to participation, they were required to provide informed consent by signing a consent form.

2.2 Participants

Out of 120 participants referred by doctors for diabetic peripheral neuropathy, ninety met the specified diagnostic criteria for diabetic peripheral neuropathy and were recruited for the study. Demographic characteristics and the duration of diabetes were recorded based on medical records. Inclusion criteria consisted of patients aged between 50-70 years of both sexes, diagnosed with T2DM with well-controlled blood glucose confirmed through three medical assessments, diabetes duration exceeding 5 years, a Michigan Neuropathy Screening Instrument (MNSI) score of ≥ 2.5 out of 10, and a Mini-Balance Evaluation Systems Test (Mini BESTest) score of ≤ 20.5 [16]. Participants also needed to demonstrate an understanding of instructions through the Mini Mental State Examination (MMSE) [17].

Exclusion criteria included peripheral venous insufficiency, cardiac, renal, or hepatic insufficiency, uncontrolled hypertension or myopathy, central nervous system dysfunction (e.g., hemiparesis, Parkinson's disease, cerebellar ataxia, vertigo), loss of sensation, foot ulcers, contraindications to massage such as fever, recent operations, acute injuries, skin diseases, varicose veins, undiagnosed pain, inflammation, osteoarthritis, fractures of the upper and lower extremities within 6 months prior to the study, partial or complete blindness, and severe auditory problems as determined by physical examinations.

The sample size was determined based on a prior study, which investigated the responsiveness of the Mini-BESTest [18]. Utilizing the standard deviation of Mini-BESTest scores after treatment from this study (6.9), the sample size calculation aimed for a power of 80% at a significance level of 5%, with a provision for a 10% dropout rate in estimating the final sample size. The sample size was estimated using the formula by Borm and colleagues [19].

2.3 Randomization

Each participant was randomly assigned to either the experimental group (EG), receiving self-administered Thai foot massage and Standard Foot Care (STFM and SFC), or the control group (CG), receiving only standard foot care (SFC). Randomization was conducted using a stratified block randomized allocation with a 1:1 ratio and block sizes of 4 and 6. Stratification was based on two age groups (50-60 and 61-70 years) to ensure balance across the age categories. A pre-generated random allocation plan, created using a randomization list tool (https://www.sealedenvelope.com), was enclosed in envelopes. The randomization process was made overseen by the researcher's assistant, who was not involved in outcome assessment or treatment administration.

2.4 Experiment procedure

Figure 1 shows the participant flow following recruitment, after randomization all participants (n=90) underwent treatment training in small groups (3-4 participants per group) for one day at the hospital before entering the main study. Training sessions for both groups were held at different times; the EG received training in the morning (9-12 am), while the CG received training in the afternoon (1-4 pm). Participants in the EG were trained in both the self-Thai foot massage (STFM) and Standard Foot Care (SFC). The STFM training, consisting of three sessions, was conducted by the main investigator (SMS), who was certified in a 50-hour intensive course of The Traditional Thai massage (TTM) and validated by a physical therapist (UC) with 20 years of experience in physical therapy and 10 years of Traditional Thai Massage, accredited by the School of Physical Therapy, Khon Kaen University, Thailand. Information regarding SFC was provided by a physical therapist and research assistant (1st PT-researcher assistant) with 14 years of experience in physical therapy in Myanmar. Before training, all participants underwent baseline evaluations (pre-test) for all outcome measures. Subsequently, each participant was randomized to either the EG or CG.

2.5 Treatments

Following randomization, each participant was assigned to receive their designated treatment (EG or CG). Participants in the EG group received both Self Thai Foot Massage (STFM) and Standard Foot Care (SFC), whereas those in the CG group received only SFC, defined as standard care. Consistency was maintained with the one-day training protocol, where a single session of STFM and/or SFC was administered by the same therapists (SMS vs. the 1st PT-researcher assistant) at the same time of day (morning vs. afternoon).

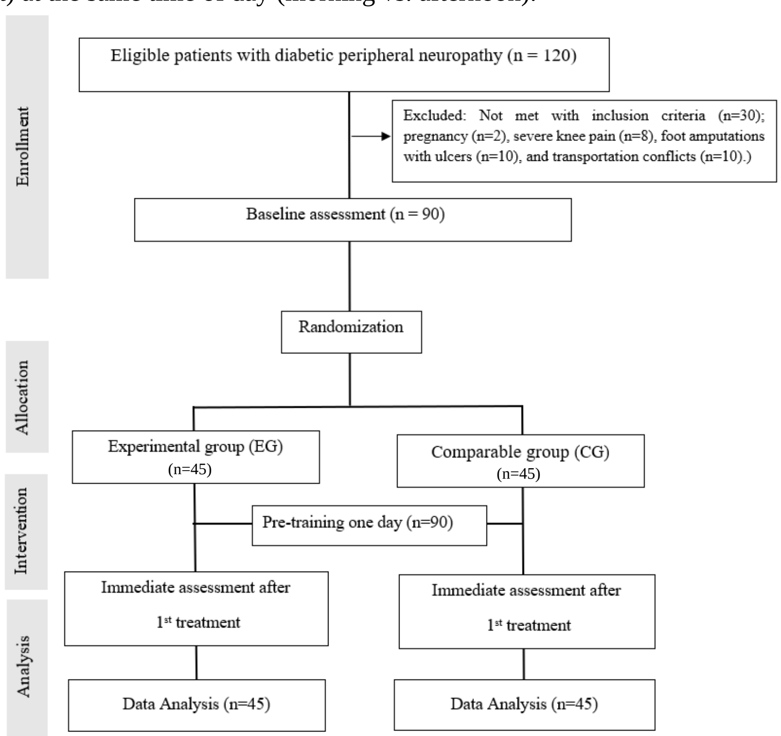

Figure 1 CONSORT flow diagram of the two study groups.

2.5.1 Self-Thai Foot Massage (STFM)

The Self-Thai Foot Massage (STFM) treatment, as modified from prior studies, lasted 25 minutes per leg (totaling 50 minutes), targeting the foot, ankle, and lower leg areas. The participants were positioned in a sitting posture using two chairs: one for sitting and the other for supporting and resting the massage leg [9]. The massage protocol for each leg comprised a 5-minute wrap-up session, incorporating stretches for the lower back and leg muscles, followed by 25 minutes of STFM, which integrated Thai foot massage and leg stretching techniques. The 25 minutes of STFM included: 1) at the heel and along the sole of the foot until the the base of the metatarsophalangeal joint (MTP) for 3 minutes, 2) at the center of the support line at the base of MTP for 1 minute, 3) at the base of the MTP for 3 minutes, 4) from the ankle to the base of the MTP for 3 minutes, 5) at the base of the MTP (dorsum) for 3 minutes 6) apply gentle pulling of all the toes for 3 minutes and 7) at anterior leg (3 minutes), posterior leg (3 minutes) and lateral leg for 3 minutes, respectively. The massage was administered using thumb pressing, with pressure gradually increasing along specific lines. Participants were encouraged to communicate any discomfort, ensuring the pressure remained below the pain threshold. Pressure was maintained for 5-10 seconds at each massage point, and this sequence was repeated 3-5 times for each massage line or point [9, 20, 21]. In the hospital setting, the STFM treatment was administered to groups of 3-4 participants, mirroring the training sessions they underwent.

2.5.2 Standard Foot Care (SFC)

The single-session foot care (SFC) treatment, lasted for 50 minutes and was administered by the first PT-researcher assistant [14]. It comprised two programs: a 10-minute foot care program and a 40-minute balance exercise program. The foot care program included patient advice and education on conducting a daily foot examination, adapted from the guidelines provided by Diabetes UK in 2016. This program consisted of nine items and took approximately 10 minutes to complete [14, 22].

The balance exercise program comprised eight steps, incorporating balance and walking exercises such as standing on heels/toes, tandem stance, one-leg stance, toe walking, heel walking, and tandem walking, along with functional strength and endurance exercises like sitting to standing and step-up. This comprehensive program, which lasted 40 minutes, was developed based on studies [14, 23].

2.6 Outcome measures

Outcome measures were assessed at the pre-test (prior to randomization) and immediately after a single treatment session by a well-trained physical therapist with 3 years of experience in Physical Therapy in Myanmar, acting as the second PT-researcher assistant. This assistant was blinded to the treatment allocation of each participant. To ensure consistency in assessment procedures, the second PT-researcher assistant underwent training to become the assessor, following standardized manual guidelines for the outcome measures.

In this study, balance, proprioception of the ankle joint, and foot sensation were defined as the primary outcome measures. Secondary outcome measures included the active/passive range of motion of the ankle, measured. Details of all outcome measures are described as follows:

2.6.1 Balance using Mini BESTest (MBT)

Balance in this study was assessed using the Mini-Balance Evaluation Systems Test (Mini BESTest), which comprises 14 steps: sit-to-stand, rise to toes, stand on one leg, compensatory stepping correction (forward, backward, and lateral), stance with feet together (eyes open) on a firm surface, stance with feet together (eyes closed) on a foam surface, incline with eyes closed, change in gait speed, walk with head turns (horizontal), walk with pivot turns, step over obstacles, and timed up & go with dual task (3-meter walk). The measurement unit is a scoring (the total scores are 28):

Prior to the study, the Mini BESTest demonstrated excellent reliability, with inter-rater reliability in type 2 diabetic peripheral neuropathy patients reported as ICC=0.95 with a 95% CI of 0.91–0.97, and intra-rater reliability reported as ICC=0.93 with a 95% CI of 0.87–0.96 [13]. Furthermore, it exhibited high responsiveness based on distribution-based determinations [14].

2.6.2 Ankle joint proprioception (JPS)

Ankle joint proprioception (JPS) was assessed using a hand-held goniometer for dorsiflexion and plantar flexion, conducted actively. Participants were positioned supine on a treatment table with their hips and knees at 0° and their heels off the edge of the table. To eliminate visual cues, participants were blindfolded during the assessment. The axis of the goniometer was positioned 1.5 cm inferior to the lateral malleolus, with the stationary arm aligned parallel to the longitudinal axis of the fibula and the moveable arm parallel to the longitudinal axis of the 5th metatarsal. Dorsiflexion and plantar flexion were randomly tested [24]. The measurable unit for JPS is degree.

For dorsiflexion assessment, participants were instructed to bring their foot to a target angle of 20° dorsiflexion and hold that position for 3 seconds before returning to the neutral position. Then, they were asked to actively reproduce the target angle they had just achieved. The difference between the perceived angle and the actual angle was recorded as the proprioceptive difference. This process was repeated three times for each movement, and the mean difference was calculated for measurement.

Similarly, for ankle plantar flexion, participants were tested at a target angle of 60° plantar flexion using the same procedure. The total assessment time was approximately 20 minutes. The intra reliability of using a universal goniometer for measuring active ankle range of motion was reported to be high (Intraclass Correlation Coefficient, ICC = 0.91-0.97) [25].

2.6.3 Foot sensation using Semmes-Weinstein Monofilament Test (SWMT)

The Semmes-Weinstein Monofilament Test (SWMT) was utilized to assess foot sensation. This involved applying a 10-g force filament perpendicularly to the skin surface at 10 different sites on the plantar surface of each foot, on both sides. Participants were asked if they felt anything touching their skin. Each examination was repeated three times per site, including at least one sham examination where the filament was not actually placed on the skin. If a patient provided incorrect answers two or more times out of the three examinations per site, the site was considered positive; if an incorrect answer occurred once or less, the site was considered negative. The examinations were conducted at all 10 sites in random order. The measurable unit is the number of positive points. The number of positive points was recorded for each foot side [9, 26]. The sensitivity of SWMF examination ranged from 57% to 93%, and specificity ranged from 75% to 100% [27].

2.6.4 Range of motion of ankle joint

The active and passive range of motion of ankle joint dorsiflexion and plantar flexion were assessed using the Kinovea program (version 0.8.15). Measurements were conducted for 5 minutes following the steps outlined in the program, which can be downloaded from http://www.kinovea.org [28]. The measurable unit of ROM of ankle joint is degree. Intra-rater reliability was assessed with an Intraclass Correlation Coefficient (ICC) of 0.99, and inter-rater reliability was assessed with an ICC of 0.94 [29].

2.7 Statistical analysis

Descriptive statistics were utilized to characterize the demographic features of all participants. The normal distribution of the data was assessed using the Shapiro-Wilk test. Continuous data were presented as mean and standard deviation (SD) and median (interquartile range or IQR), while categorical data were expressed as percentages. To evaluate immediate effects, within-group changes were analyzed using paired t-tests. Prior to this, baseline or pretest comparisons were conducted using independent t-tests. If non-significance was observed, independent t-tests were then used to compare post-treatment data between treatment groups. However, if data from either the EG or CG displayed non-normal distribution, the non-parametric Two-sample Mann-Whitney test was employed. Effect sizes (ES: Cohen's d) for both within-group and between-group analyses were calculated, with ES categorized as trivial (0–0.19), small (0.20–0.49), medium (0.50–0.79), and large (0.80 and greater). The significance level was set at $p < 0.05$ with a 95% confidence interval. All statistical analyses were performed using the STATA version 10 (Texas, USA), licensed for Khon Kaen University.

3. Results

Ninety patients were recruited and met the inclusion criterion. The demographic and clinical characteristics of participants in both the Experimental (EG) and Control (CG) groups post-randomization were documented. Participants in the EG group (n=45), comprising 40 females (88.9%) and 18 subjects (40%) aged 61-70, with a mean age of 56.4 ± 6.44 years, mean weight of 61.50 ± 11.46 kg, mean height of 1.57 ± 0.6 m, mean body mass index (BMI) of 24.97 ± 4.43 kg/m², and mean duration of diabetes mellitus (DM) of 7.44 ± 3.45 years (mean ± SD), or the CG group (n=45), comprising 35 females (77.8%) and 18 subjects (40%) aged 61-70, with a mean age of 59.27 ± 6.57 years, mean weight of 61.42 ± 11.02 kg, mean height of 1.57 ± 0.08 m, mean BMI of 24.78 ± 4.17 kg/m², and mean duration of DM of 8.78 ± 5.25 years (mean ± SD). Most demographic characteristics were similar between the two groups ($p > 0.05$).

Table 1 presents the average values (means ± SD) and median (interquartile range or IQR) of the outcome measures recorded at pre-test and immediately after the first treatment, including comparisons within and between groups. Table 1 depict the results of the primary outcome. Both treatment groups showed a significant improvement in both total balance scores of MBT (increase) and Joint Position Sense (JPS) (decrease in dorsiflexion/plantar flexion in both right/left legs) compared to the pre-test values or baseline ($p < 0.001$), with a large effect size (> 0.80). Similar results were observed when directly comparing the average values of MBT and JPS between the EG) and CG groups (see Table 1), revealing that the EG group exhibited significantly greater increases in MBT and decreases in JPS in all directions as well as foot sensation in both legs compared to the CG group immediately following the first treatment ($p < 0.001$), with a large effect size (> 0.08).

In the secondary outcome analysis, which included the active and passive range of motion of all directions of both right and left ankle joints, both groups exhibited significant improvements in almost all secondary outcome measures ($p < 0.05$) with medium (0.50-0.79) to large (> 0.80) effect sizes (see Table 1). Furthermore, when comparing between groups, the EG group demonstrated significantly greater improvements than the CG group in almost all variables ($p < 0.05$) with medium (0.50-0.79) to large (> 0.80) effect sizes, except for left active ankle dorsiflexion (ADL) where the p-value was 0.0659 (Table 2).

4. Discussion

This study examines the immediate effects of combining STFM with SFC in the EG group versus SFC only in the CG on balance and proprioception after the initial treatment session in patients with T2DM and peripheral neuropathy. The results indicate notable enhancements in balance, joint position sense, ankle joint range of motion, and foot sensation in both treatment groups from the baseline to immediately after the first treatment ($p < 0.001$). Furthermore, the EG group exhibited superior outcomes compared to the CG group across all outcome measures ($p < 0.05$).

In this study, the Mini BESTest scores (MBT) for balance, particularly in the EG (combining STFM and SFC), showed significant increases compared to the CG or SFC only. The percentage improvement of MBT when compared with a pretest data of EG group is 20.19% and that of CG group is 14.93%. Notably, the MBT scores of patients, especially in the EG, approached normal levels after a single immediate treatment. Additionally, one of the studies found that Thai-foot massage significantly improved dynamic balance in patients with diabetic peripheral neuropathy [9]. Similarly, a previous study found significant balance improvement after a 20-minute massage of the foot and ankle joints in elderly adults [31]. This improvement in balance could be attributed to the ability of massage to enhance blood flow, skin sensation, and joint mobility, thereby potentially reducing pain and alleviating foot paresthesia in diabetic neuropathy patients [30]. The other possible mechanism could be pressure and force applied in STFM contribute to rebalancing, that is attributed to the entire fascial system, the plantar surface of the foot, through the ankle, and onwards up the skeleton, being crucial in maintaining the balance and stability of the whole musculoskeletal system [31]. Hence, it is plausible to suggest that the Self-Thai Foot Massage could enhance balance in patients with diabetic peripheral neuropathy.

Table 1 The immediate effects on the primary outcomes (balance and proprioception of ankle joint) and foot sensation, the comparison of the post- after the 1st treatment between the combination of Self-Thai Foot Massage and Standard Foot Care versus the Standard Foot Care only.

Outcomes	Groups	Pre-test		Post-test (Immediate after 1st treatment)		ES within group (95% CI)	Different between groups by comparing the post- test data (95% CI)	p-value	ES between groups (95% CI)
		Median (IQR)	Mean ± SD	Median (IQR)	Mean ± SD				
Primary outcome									
Mini-BESTest (scores): MBT	EG	18 (17:19)	17.89 ± 1.30	22 (21:23) *	21.86 ± 1.38 *	3.22 (2.49 to 3.95)	1.84 (1.28 to 2.41) #	< 0.0001	1.38 (0.91 to 1.83)
	CG	17 (16:18)	17.42 ± 1.29	20 (19:21) *	20.02 ± 1.31 *	2.21 (1.66 to 2.75)			
Joint position sense (JPS): degree (^{0})									
Right ankle dorsiflexion: JDR	EG	3 (1.7:3.3)	2.74 ± 1.04	0 (0:1.7) *	0.75 ± 0.88 *	-2.03 (-2.54 to -1.51)	-1.05 (-1.47 to -0.62) #	< 0.0001 a	-1.03 (-1.46 to -0.58)
	CG	3.3 (1.7:3.3)	2.83 ± 1.11	1.7 (1.3:3) *	1.79 ± 1.15 *	-0.94 (-1.28 to -0.58)			
Left ankle dorsiflexion: JDL	EG	2 (1.7:3.3)	2.5 ± 1.32	0 (0:1.7) *	0.61 ± 1.06 *	-1.49 (-1.91 to -1.06)	-1.06 (-1.55 to -0.57) #	< 0.0001 a	-0.91 (-1.34 to -0.47)
	CG	3.3 (1.7:3.3)	2.76 ± 1.38	1.7 (0.7:2.3) *	1.67 ± 1.27 *	-0.87 (-1.21 to -0.53)			
Right :ankle plantar flexion :JPR	EG	1.7 (1.7:3.3)	2.25 ± 1.03	0 (0:1.3) *	0.57 ± 1.05 *	-1.39 (-1.79 to -0.97)	-0.92 (-1.39 to -0.45) #	< 0.0001 a	-0.82 (-1.25 to -0.39)
	CG	3.3 (1.7:3.3)	2.71 ± 1.23	1.7 (0:1.7) *	1.5 ± 1.20 *	-1.36 (-1.76 to -0.95)			
Left ankle plantar flexion :JPL	EG	1.7 (1.7:3.3)	2.35 ± 1.47	0 (0:0) *	0.28 ± 0.70 *	-1.37 (-1.77 to -0.96)	-1.02 (-1.45 to -0.58) #	< 0.0001 a	-0.99 (-1.42 to -0.54)
	CG	3 (1.7:3.3)	2.66 ± 1.42	1.3 (0:2) *	1.3 ± 1.28 *	-1.15 (-1.52 to -0.77)			
Foot sensation (number of points)									
Right foot: FSR	EG	6 (5:6)	5.91 ± 0.85	7(6:7) *	6.95 ± 0.82 *	1.55 (1.11 to 1.98)	0.82 (0.42 to 1.23) #	0.0001	0.85 (0.41 to 1.28)
	CG	6 (5:6)	5.69 ± 1.00	6(6:7) *	6.13 ± 1.10 *	0.67 (0.35 to 1.00)			
Left foot: FSL	EG	6 (5:6)	5.89 ± 0.75	7 (6:8) *	7.04 ± 0.85 *	1.32 (0.91 to 1.71)	1.09 (0.65 to 1.53) #	< 0.0001	1.04 (0.60 to 1.48)
	CG	6 (5:6)	5.58 ± 1.03	6 (5:7) *	5.96 ± 1.21 *	0.71 (0.38 to 1.03)			

EG, Experimental group using Self-Thai Foot Massage and Standard Foot Care or STFM &SFC); CG, comparable group using Standard Foot Care or SFC); ES = effect size
*Statistically significant difference between pre and post tests (immediate post after treatment) in each treatment group using paired t-tests at p<0.05.
Statistically significant difference of the immediate post after treatment between two treatment groups using independent t-test at p<0.05
a Statistically significant when compare the immediate after treatment between group using non-parametric (Two-sample Mann-Whitney test) due to a non–normal distribution of data at p< 0.001

Table 2 The immediate effects on the secondary outcomes and the comparison of the post- after the 1st treatment between the combination of Self-Thai Foot Massage and Standard Foot Care versus the Standard Foot Care only.

Outcomes	Groups	Pre-test		Post-test (Immediate after 1st treatment)		ES within group (95% CI)	Different between groups by comparing the post-test data (95% CI)	p-value	ES between groups (95% CI)
		Median (IQR)	Mean ± SD	Median (IQR)	Mean ± SD				
Active ankle joint range of motion: degree (^{0})									
Right ankle dorsiflexion	EG	31 (30:32)	31.33 ± 1.67	33 (32:35) *	33.78 ± 2.49 *	1.33 (0.92 to 1.73)	1.49 (0.40 to 2.58) #	0.0044 a	0.57 (1.48 to 0.99)
	CG	31 (30:32)	31.24 ± 2.01	32 (31:33) *	32.29 ± 2.71 *	0.83 (0.49 to 1.16)			
Left ankle dorsiflexion	EG	30 (30:32)	31.00 ± 1.71	33 (32:35) *	33.16 ± 1.91 *	1.53 (1.09 to 1.95)	0.67 (-0.42 to 1.75)	0.0659 a	0.26 (- 0.16 to 0.67)
	CG	31 (30:32)	31.31 ± 2.4	32 (31:33) *	32.49 ± 3.14 *	0.75 (0.42 to 1.08)			
Right ankle plantarflexion	EG	40 (36:41)	38.89 ± 4.35	37 (35:41)	41.16 ± 4.97 *	1.21 (0.81 to 1.58)	3.07 (1.17 to 4.97) #	0.0015 a	0.68 (0.25 to 1.10)
	CG	36 (35:40)	37.18 ± 3.94	42 (37:45)	38.09 ± 4.06 *	0.71 (0.38 to 1.04)			
Left ankle plantar flexion	EG	39 (36:40)	38.69 ± 4.06	41 (38:43)	41.18 ± 4.74 *	1.14 (0.76 to 1.51)	3.36 (1.39 to 5.32) #	0.0024 a	0.72 (0.29 to 1.14)
	CG	37 (34:40)	37.04 ± 4.38	38 (35:41)	37.82 ± 4.6 *	0.67 (0.34 to 0.99)			
Passive ankle joint range of motion: degree (^{0})									
Right ankle dorsiflexion	EG	34 (33:35)	34.42 ± 2.07	36 (34:39) *	36.64 ± 2.76 *	1.38 (0.97 to 1.79)	1.64 (0.46 to 2.83) #	0.0065 a	0.58 (0.16 to 1.00)
	CG	34 (33:35)	33.98 ± 2.27	35 (34:36) *	35.00 ± 2.88 *	0.88 (0.53 to 1.23)			
Left ankle dorsiflexion	EG	33 (32:35)	33.77 ± 2.13	35 (34:37) *	36.04 ± 2.33 *	1.39 (0.98 to 1.80)	1.11 (0.13 to 2.35) #	0.0113 a	0.59 (0.17 to 1.01)
	CG	34 (32:35)	33.88 ± 2.77	34 (33:36) *	34.93 ± 3.48 *	0.77 (0.43 to 1.10)			
Right ankle plantar flexion	EG	42 (40:45)	41.93 ± 4.23	45 (41:47) *	44.13 ± 5.15 *	1.13 (0.75 to 1.50)	2.91 (0.98 to 4.84) #	0.0029 a	0.63 (0.21 to 1.05)
	CG	39 (38:43)	40.24 ± 3.75	41 (38:44) *	41.22 ± 4.00 *	0.99 (0.63 to 1.34)			
Left ankle plantar flexion	EG	41 (40:45)	41.90 ± 4.25	45 (42:47) *	44.15 ± 4.79 *	1.44 (1.02 to 1.86)	3.04 (1.14 to 4.95) #	0.0018 a	0.67 (0.24 to 1.09)
	CG	40 (37:43)	40.38 ± 4.15	42 (38:44) *	41.11 ± 4.29 *	0.74 (0.41 to 1.07)			

EG, Experimental group using Self-Thai Foot Massage and Standard Foot Care or STFM &SFC); CG, comparable group using Standard Foot Care or SFC); ES = effect size
* Statistically significant difference between pre and post-tests (immediate post after treatment) in each treatment group using paired t-tests at $p<0.05$.
# Statistically significant difference of the immediate post after treatment between two treatment groups using independent t-test at $p<0.05$
a Statistically significant when compare the immediate after treatment between group using non-parametric (Two-sample Mann-Whitney test) due to a non–normal distribution of data at $p<0.001$

Similar findings observed significant increases in JPS of ankle joints in both the EG and CG groups from the baseline to immediately post-treatment. The percentage improvement in EG group of JDR, JDL, JPR, and JPL in EG group were 72.63, 75.6, 33.33, and 88.09 %, respectively. While in the CG group were 36.75, 39.49, 37.27, and 51.13 %, respectively. One potential mechanism could be that massage activates the somatosensory system of the feet and ankles, which receives input from various receptors including cutaneous receptors, Golgi tendon organs, muscle spindles, and joint receptors [10]. This activation facilitates precise joint position and movement [32]. The report of a previous study concluded that massages improved proprioception in females with diabetic neuropathy of the lower limbs [33]. This finding is consistent with the present study, suggesting that Self-Thai Foot Massage can enhance joint position sense in patients with diabetic peripheral neuropathy.

The notable improvements observed in the EG concerning both balance and JPS may be attributed to increases in foot sensation and the range of motion (both active and passive) of the ankle joint. The better improvement in foot sensation (reduction of the number of positive points) of the EG than the CG group, with the percentage difference of the right foot sensation (FSR) of the EG and CG group were -0.71% (lower is better) and 2.17%, while the left foot sensation (FSL) of both groups showed the opposite results; the EG and CG group were 19.52% and 6.81 % respectively. The enhancement of foot sensation only in the right foot could stem from the utilization of STFM, stimulating the nervous system. This stimulation may promote the creation of myelin sheath around nerves, facilitating more effective signal transmission to organs and nerves. This stimulation occurs through direct stimulation of sensory receptors in the skin and tissues via the autonomic parasympathetic system, leading to decreased sympathetic tone and increased parasympathetic tone. Consequently, this leads to vasodilation of blood vessels beneath the skin and muscle relaxation [34]. The other possible mechanism could be explained similarly to the effect of "Reflexology" wherein pressure and force applied in STFM contribute to rebalancing [35]. The effects of rebalancing are attributed to the entire fascial system, from the plantar surface of the foot, through the ankle, and onwards up the skeleton, being crucial in maintaining the balance and stability of the whole musculoskeletal system. Additionally, the mechanisms involved in pressure touch have identified two ion channels that are directly activated by the exertion of pressure on cell membranes. These ion channels have been shown to play a key role in proprioception [35]. However, Chatchawan and colleagues reported no significant difference between the two treatment groups immediately after treatment in patients with diabetic peripheral neuropathy, which contrasts with our findings [9]. These inconsistencies may arise from variations in assessment methods, as well as the stage and condition of T2DM with peripheral neuropathy.

The improvement in joint range of motion were found in both groups with the range of percentage improvement of 1.81 to 7.82 % while the EG group showed a better result in all directions and both active and passive movements, except for only the left active ankle dorsiflexion (ADL). A previous study that investigated the immediate effects of STFM and TFM on ankle joint range of motion in T2DM patients with peripheral neuropathy, revealed significant improvements in both groups [11]. This finding aligns with the results of the present study. Additionally, another study showed that improvements in range of motion and foot skin sensation were associated with enhanced dynamic balance performance [9]. The improvement of joint range of motion following STFM could be attributed to the deep pressure techniques employed, resembling joint mobilizations, which are believed to enhance flexibility and range of motion in the lower leg and foot [36].

The participants in the present study exhibited a very high level of JPS accuracy, with minimal baseline JPS errors. However, only the active ankle joint position sense error was examined in this study, limiting the generalizability of the findings to other joints. Follow-up assessments were not included, which could have provided valuable insights into the stability of the observed effects over time. In addition, non-blinded participants were unavoidable in this study due to the nature of the study design, which may lead to potential expectancy bias.

According to the present study, STFM can improve balance, as measured by the MBT scores, and enhance ankle joint proprioception, as measured by a hand-held goniometer, in T2DM patients with peripheral neuropathy. Both the treatment (STFM) and the outcome assessments are easy to administer, low-cost, and practical for use as an alternative protocol in hospital settings and potentially in the community. Future trials should confirm these findings and consider assessing the potential retention effects to further elucidate their implications.

5. Conclusions

A single treatment combining self-Thai foot massage with standard foot care may improve balance, ankle joint proprioception, foot sensation, and the ankle range of motion (except for the active ankle range of motion in dorsiflexion on the left side) in diabetic patients with peripheral neuropathy compared to standard foot care alone.

6. Ethical approval

The study was approved by the Research Ethics Committee of the Center for Ethics in Human Research, Khon Kaen University Thailand (HE 632108) as well as by the Universities of Mandalay Medical Technology and University of Medicine Mandalay in Myanmar for Human Research.

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8. Conflicts of interest

The authors have no conflicts of interest relevant to this article**.**

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