ผลของการเดินจงกรมต่อการทรงท่าในผู้ที่มีภาวะเส้นประสาทส่วนปลาย
เสื่อมจากเบาหวานชนิดที่ 2

EFFECTS OF WALKING MEDITATION ON BALANCE PERFORMANCE
IN INDIVIDUALS WITH PERIPHERAL NEUROPATHY
FROM TYPE 2 DIABETES

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ผลของการเดินจงกรมต่อการทรงท่าในผู้ที่มีภาวะเส้นประสาทส่วนปลายเสื่อมจากเบาหวานชนิดที่ 2

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EFFECTS OF WALKING MEDITATION ON BALANCE PERFORMANCE IN INDIVIDUALS WITH PERIPHERAL NEUROPATHY FROM TYPE 2 DIABETES

SURAPHINIT SAISATHIT

A Thesis Submitted in partial Fulfillment of Requirements

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BY

SURAPHINIT SAISATHIT

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Walking meditation (WM) has been reported to decrease the fasting blood glucose level and HbA1c in type-2 diabetes and to increase muscle strength, flexibility, agility and dynamic balance among depressed elderly subject. However, it is not known whether or not WM has effects on balance performance in people with type-2 diabetic peripheral neuropathy (DPN). This study aimed to investigate the effects of WM on balance performance among individuals with DPN. The twenty-eight participants with DPN were randomly allocated into a walking meditation (WM, n= 14) group and a control (CG, n= 14) group. The WM group that attended WM training while the CG attended preferred speed walking. Both groups completed 30 minutes of their training, which took place 3 times a week for 4 weeks a total of 12 sessions. The Balance abilities of the participants were assessed using the Timed Up and Go test (TUG), Functional Reach test in forward, sideward to the left and to the right (FRT-forward, FRT-Lt and FRT-Rt respectively), and a 30-second standing on firm surface with eye-opened and eye-closed before and after the training. WM group showed statistically significant improvements in TUG after training and also better than the CG (p=0.001). Additionally, after training, the WM group demonstrated significantly farther FRT-Lt than the CG (p=0.017). As FRT-forward, the WM group presented shorter reach than the CG at the baseline (p=0.04).However, after training, there was no differences in term of the FRT-forward between the WM and the CG. Meanwhile, the CG showed no significant improvements in all parameters. In conclusion, WM training for at least 4 weeks (30 minutes/day, 3 days/week) can improve balance during walking and FRT-Lt in participants with DPN. Therefore, walking meditation can be applied as an alternative exercise to promote balance for individuals with DPN in community dwelling.

Keyword : Balance performance, Diabetes mellitus, Peripheral neuropathy, Meditation

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CHAPTER 1
INTRODUCTION

Background

The World Health Organization reported that more than 90% of people with diabetes mellitus were type 2 diabetes.[1]In Southeast Asia, there were around 72 million adults with diabetes mellitus in 2013 and this figure is expected to rise to 123 million by 2035.[2]Therefore, the type 2 diabetes will becomes one of a major health problems. The type 2diabetes mostly occurs in the elderly if they cannot control blood sugar levels for a long period. The prolonged high blood sugar level usually leads to a lot of complications, especially stiffness of the small blood vessels supplying to nerves, eyes, heart, brain and kidneys. These complications usually result in a high risk of peripheral neuropathy, retinopathy, cardiovascular disease, stroke and nephropathy that affecting the quality of life in people with diabetes.

The complication of nerve degeneration or peripheral neuropathy was reported in 70% of people with diabetes.[1]It mostly shows the impairments of lower extremity functions including an impaired sensation, e.g. proprioception, and muscle weakness.[3]The impaired lower extremity functions are the key contributors of physical activity limitation in gait, balance, and sit-to-stand abilities.

Diabetic peripheral neuropathy (DPN), severely decreases patient's quality of life and self-quality management, and is worsening the prognosis of other diabetes conditions.[4]The DPN reduces sensation in the lower extremities, causes impairment in balance and also increases fall risk because the somatosensory feedback is a very important factor for postural and balance adjustment.[5]Therefore, the somatosensory impairment, particularly a proprioception, from DPN will decrease the balance performance and have a fivefold increased risk of falling.[6]The balance impairment in individuals with DPN is mostly in the medial-lateral plane and is the greatest during stair descent. [6]Furthermore, the balance impairment during standing and gait in persons with DPN may be due to a biomechanical constraint from the abnormal foot conditions that usually found in chronic DPN as well. Since the poor sensation of foot in DPN alters the normal biomechanics of foot, including increased plantar pressure, bony deformities, and limited joint mobility. Up to half of all participants with diabetes have a hammer toe or craw toe deformity.[4]In addition, a decreased sensation of the feet in person with DPN is a risk for foot ulcers, which may result in chronic infected wounds and finally leading to amputation. [5], [6]

Type 2 diabetes is an incurable disease. However, it can be controlled with exercise, proper nutrition and body weight management, as well as medications. For the one who got diabetes with complication, several factors need to be considered when developing and implementing of exercise. For example, the person with DPN who has a joint perception loss should be aware of the excessive intensity of training and the high joint loaded / impact activities. [5]

Walking meditation is a mindfulness practice by slowly walking along with paying attention on foot and leg movements. So, it is alike a gentle walking exercise with low joint impact that can improve peripheral blood circulation to the legs. Moreover, the previous studies found that walking meditation practice for eight weeks improved balance and ankle proprioception in elderly women.[(7)]Buddhist walking meditation program based on aerobic exercise for 12 weeks was also able to reduce depression and increase muscle strength, flexibility, agility, dynamic balance, cardiorespiratory endurance and vascular reactivity (flow-mediated dilation) in depressed elderly. [(8, 9)]In addition, the walking meditation was able to decreased fasting blood glucose level, HbA1c in participants with type 2 diabetes. [(10)]Therefore, walking meditation may help to improve balance performance in persons with DPN. [(11)]However, there is no evidence related to the effectiveness of walking meditation on balance performance in DPN. Hence, this research is interested in the walking meditation effects on balance performance in individuals with type 2 diabetic peripheral neuropathy.

Research question

Does walking meditation improve balance performance in persons with type 2 diabetic peripheral neuropathy?

Purpose of the research

To investigate the effects of walking meditation on balance performance in individuals with type 2 diabetic peripheral neuropathy (DPN)

Outcome measures

The outcome measures for balance performances in this research are 1) maximum time hold on in each condition of standing on firm surface with eye-opened and with eye-closed, 2) Timed up and Go test, and 3) maximum reaching distance of Functional reach test in forward and lateral directions.

Research design

The research is a randomized control trial with single blinded. Persons with type 2 DPN in the experimental group will receive the walking meditation training whereas the control group will receive gentle walking exercise with preferred speed.

Benefit and application

1. The walking meditation can be applied in clinical or community as exercise for promoting balance performance in persons with type 2 diabetic peripheral neuropathy

2. Results of the research can provide the basic information for the further related studies.

Keywords

Diabetes mellitus, Peripheral neuropathy, Balance performance, Meditation

Conceptual framework

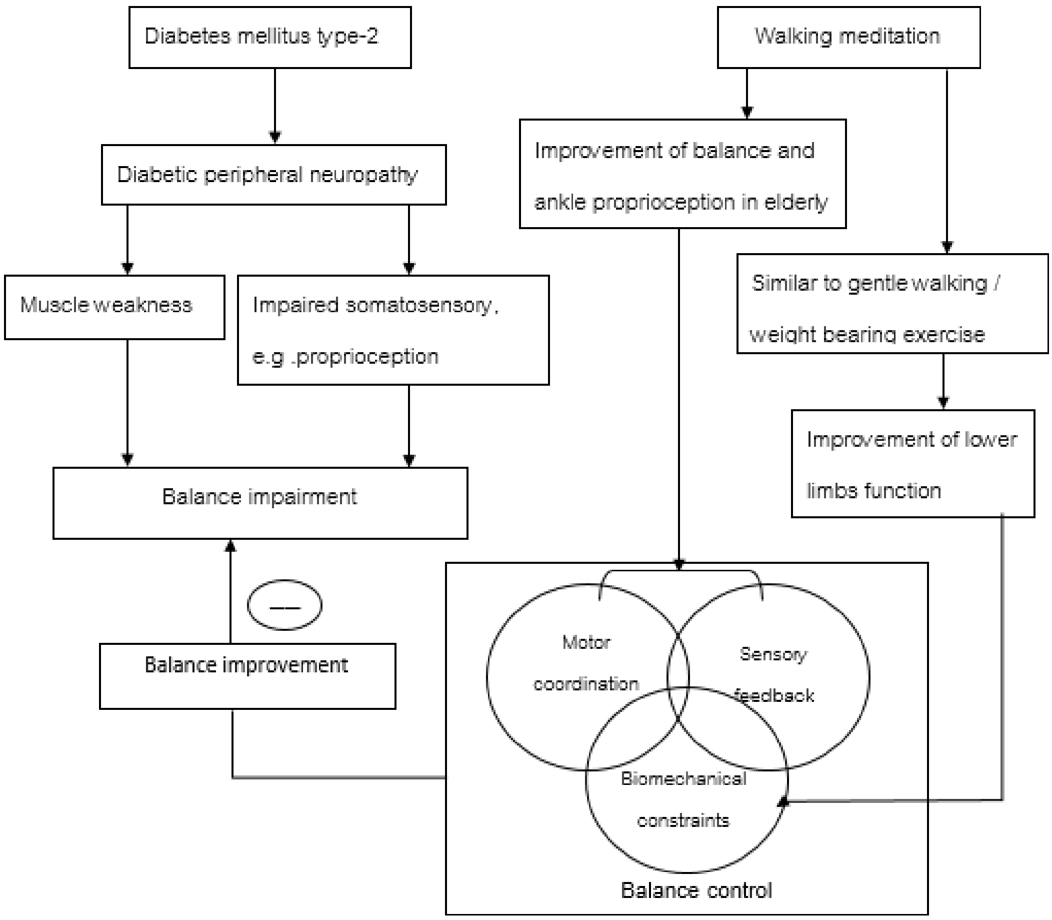

Figure 1 Conceptual framework

CHAPTER 2
THE LITERATURE REVIEW

The information in this chapter was reviewed from the previous documents that important for this research. It includes of the following topics.

2.1Diabetic mellitus

2.1.1 Definition of diabetic mellitus

2.1.2 Diabetic mellitus population in Thailand

2.1.3 Complication of diabetes

2.1.4 Diabetic foot

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2.3 Walking meditation

2.3.1 Definition of walking meditation.

2.3.2 Mechanism of brain activity while walking.

2.3.3 How to perform walking meditation

2.1 Diabetic mellitus

2.1.1 Definition of diabetic mellitus (Classification and Diagnosis of Diabetes Mellitus and Other Categories of Glucose Intolerance) [12]

Diabetes mellitus is by far the most common of all endocrine disorders. The main endocrine that involved diabetes is insulin. Without proper insulin action, the sugar does not get into the cells that need it for energy although there is plenty of sugar in the blood. Therefore, the high level of sugar in the blood is a hallmark for diabetes diagnosis. Glucose, the simplest form of sugar, is the primary source of energy for many vital functions. If glucose cannot get into the cells, the cells will be starved and leading to degenerate. Beside that the unused glucose will build up in the bloodstream, which leads to a series of secondary complications.

The most common symptoms of diabetes mellitus are hyperglycemia, glycosuria, and ketoacidosis. The acute symptoms of diabetes mellitus are all attributable to inadequate insulin action. The immediate consequence of an insulin insufficiency is a marked decrease in the ability of muscle, liver, and adipose (fat) tissue to remove glucose from the blood. In the presence of inadequate insulin action, a second problem establishes itself by producing the hormone glucagon more. Like insulin, glucagon is released from the pancreatic islets. Glucagon acts opposite to the insulin, by which raises the level of blood sugar. The release of glucagon is normally inhibited by insulin. Therefore, in the absence of insulin, the glucagon action elevates concentrations of glucose. For this reason, diabetes may be considered as a two-hormone disease. [13]

Diabetes mellitus can be classified into three distinct types.

1. The insulin-dependent diabetes mellitus (IDDM) or type 1, ketosis-prone type of diabetes is associated with increased or decreased frequency of certain histocompatibility antigens (HLA) on chromosome 6 and with islet cell antibodies. This type of diabetes has been inappropriately termed juvenile diabetes. Since it can occur at any ages, it is recommended that diagnosis based on age of onset be eliminated. [12]

2. The noninsulin-dependent diabetes mellitus (NIDDM) or type 2, no ketosis-prone types of diabetes is not secondary to other diseases or conditions. It has been divided-according to whether or not obesity is presented (obese NIDDM and non-obese NIDDM, respectively), and patients in this subclass can be further characterized by the type of treatment that they received (insulin, oral hypoglycemia agents, diet). [12]

3. The types of diabetes caused by other conditions (implying an etiologies relationship) are considered as the third subclass of diabetes mellitus—

diabetes associated with certain conditions and syndromes. This subclass has been divided according to the known or suspected etiologies relationships. [12]

2.1.2 Diabetic mellitus population in Thailand

The prevalence of diabetes is predicted to increase to 300 million people in the world by 2025. Including Thailand, the number of the persons with diabetes mellitus (DM) is also increasing that can be revealed by the 3rd National health Examination survey (NHES) in 2007 and the 4th NHES in 2009 which showed the DM prevalence in Thai adult rising from 6.7 % to 7.5% [14]Moreover, from the 2009 until 2014, Diabetes Association of Thailand under The Patronage of Her Royal Highness Princess Maha Chakri Sirindhorn reported that Thai people who got DM were rising from 6.9% to 8.9%.[15]

2.1.3 Complication of diabetes

Many organs in the body can be affected by diabetes with chronic hyperglycemia and become the serious complications. The complications from diabetes can be classified as microvascular and macrovascular complications which resulting in organ and tissue damage. The microvascular complications involve small blood vessels, while microvascular complications involve large vessels.

2.1.3.1 Microvascular complication of diabetes

Diabetic Retinopathy

Diabetic retinopathy (DR) is a microvascular complication that can affect the retina, the macula, or both and it is a leading cause of visual disability and blindness in people with diabetes. Poor glycemic control appears to be the important factor that results in development and progression of DR in people with diabetes. The hyperglycemic condition will cause impairment of retinal blood flow, increased inflammatory cell adhesion to retina blood vessels and capillary will be block aged. Those will lead to hypoxia and damage of the retina. [14]

Diabetic Neuropathy

People with diabetes frequently have autonomic neuropathy, including cardiovascular autonomic dysfunction, which is manifested as abnormal heart rate (HR) and vascular control. Physical therapists, commonly encounter diabetes associated PN in the evaluation and treatment of balance and movement disorders because these disorders frequently affect lower-extremity sensation and can cause lower-extremity pain in people with diabetes. Loss of lower-extremity sensation coupled with impaired peripheral vascular function can contribute to lower extremity ulcer, commonly in foot. [14]

2.1.3.2 Macrovascular complication of diabetes

Cerebrovascular disease

Diabetes is an independent risk factor across all ages. For stroke; the risk in people with diabetes is up to 2- to 4-folds greater than whom without diabetes. The elevated blood levels of chronic inflammatory markers are associated with an increased risk for stroke in people with diabetes. [14]

Peripheral artery disease

Peripheral artery disease is characterized by occlusion of the lower-extremity arteries, which can cause intermittent claudication and pain, especially upon exercise and activity, and which can result in functional impairments, and disability. Peripheral artery disease, like the aforementioned vascular diseases, is related to the duration and severity of diabetes. [14]

2.1.3.3 Prevalence of diabetic complications

The prevalence of late complications in persons with diabetes is presented in the Table 2-1. Peripheral neuropathy is quite a high rate of complication which occurred around 34% of diabetes. [16]

Table 1 Diabetic complication

complication	Prevalence of late complications
Peripheral neuropathy	34.0%
Proteinuria	17.0%
Retinopathy	13.6%
Healed foot ulcer	6.9%
stroke	1.9%
Acute foot ulcer/gangrene	1.2%
Myocardial infarction	0.7%
End stage renal failure	0.1%

2.1.4 Diabetic Foot

When examining the feet of a person with diabetes, both feet should be inspected for an evidence of the following risk factors: neuropathy (use a 10 g monofilament as part of a foot sensory examination), limb ischemia, ulceration, callus, infection / inflammation, deformity, gangrene, and Charcot arthropathy.

2.1.4.1 Diabetic foot problems

Diabetic foot problems are limb-threatening or life-threatening in persons with diabetes. , Immediate referral of the persons with diabetic foot problems to acute services and inform the multidisciplinary foot care service (according to local protocols and pathways) is recommended [17], so they can be assessed and received an individualized treatment plan. Examples of the limb-threatening and life-threatening diabetic foot problems include the following [17]:

- Ulceration with fever or any signs of sepsis.
- Ulceration with limb ischemia.
- Clinical concern that there is a deep-seated soft tissue or bone infection (with or without ulceration).
- Gangrene (with or without ulceration).

2.1.4.2 Charcot arthropathy or Diabetic neuroarthropathy

Charcot foot often occurs in patients with diabetic peripheral neuropathy resulting from repetitive mechanical trauma and bony destruction to the foot due to an impaired pain and proprioceptive sensation, and also poor autonomically stimulated vascular reflex. Acute Charcot arthropathy is usually shown as redness, warmth, swelling or deformity (inparticular, when the skin intact), joint effusion and bone resorption.[18] The clinical signs and symptom of acute Charcot artropathy are alike cellulitis and gout. The acute Charcot arthropathy should be concerned although the deformity is not present or pain is not reported, particularly after injury. To confirm the diagnosis of acute Charcot arthropathy, promptly refer the person within 1 working day to the multidisciplinary foot care service for evaluation and treatment. Offer non-weight-bearing treatment until definitive treatment can be started by the multidisciplinary foot care service. In more than 75% of cause patient will present with some degree of pain in the otherwise. Early detection of acute Charcot syndrome with the proper management such as immobilization and non-weight bearing can decrease the risk of foot deformity, ulceration and amputation.[(17),(19)]

2.1.5 Diabetic peripheral neuropathy

Diabetic peripheral neuropathy (DPN) is defined as the presence of symptoms and/or signs in the peripheral nerves, predominantly affecting the lower extremities without other causes of neuropathy.It approaches 50% in subjects with long-duration of diabetes. The metabolic effects of chronic hyperglycemia and the consequence of ischemia on the peripheral nerves lead to neuro-axonal dysfunction and damage. The pathophysiology of DPN from hyperglycemic effects are including of an increase in oxidative stress yielding advanced glycosylated end products(AGEs), a polyol accumulation causing impaired (Na+/K+)-ATPase activity, homocysteinemia and decrease in nitric oxide leading to impaired endothelial function. These effects result in sodium accumulation, impaired axonal transport and structural damage to the nerve. [16]

2.1.6 Drug therapy [20]

The physician will give drug therapy to decrease blood sugar to the person with diabetes who can't control blood sugar by nutrition control or exercise. However, before drug instruction, contraindication and investigation should be considered. The contraindication of drug that use for reducing blood sugar are as follows

1. Diabetes mellitus type1 or Diabetes from pancreas
2. Emergency diabetes
3. Stress status
4. Pregnancy
5. Allergic to drug (sulfonylurea)
6. Poor tissue perfusion (non-use biguanide)

Opportunity to decrease blood sugar when using medication is 70% of patient, while the other 30% is primary failure. The medication or drug for reducing blood sugar can be separated into 5 types;

1. Sulfonylurea include glipizide, glibenclamide, glimepiride, gliquidone
2. Biguanide include metformin

3. Glucosidase inhibitor include acarbone, voglibose

4. Thiazolidinedione include rosiglitazone,pioglitazone

5. Non sulfonylurea secretagogue include repaglinide, nateglinide

2.1.7 Mechanism of drug that use for reducing blood sugar

The mechanism of the drug depends on the drug type as the following;

1. Stimulation of pancreas to induce insulin secretion is a mechanism of re sulfonyurea, repaglinide, and nateglinide.

2. Insulin sensitizer to induce insulin working is an action of biguanide, thiazolidinedione, and sulfonyurea

3. Control intestine absorption of carbohydrate is a mechanism of glucosidase inhibitor

4. Decrease in hepatic gluconeogenesis is an effect from all drugs, except glucosidase inhibitor

5. Anaerobic glycolysis induction is a mechanism of biguanide

2.2 The balance ability

The balance ability refers to the ability to maintain the center of mass (Center of Mass; COM) or center of gravity (COG) of the body on the base of supports. [21]Adjust the position or shape of balance refers to the effort to adjust the head and torso in an upright position. When the balance is disturbed from outside force, central nervous system will coordinated control multiple groups of muscles to keep the center of gravity within the boundaries of the base standoff support.

Balance is divided into two conditions that are while stationary (static balance) and while motion (dynamic balance).The balance mechanism is a complex coordination which requires many systems effectively working together. The systems are included of sensory system, motor system and musculoskeletal system. The sensory inputs are from visual, vestibular and somatosensory systems.[22] The visual system receives and transmits information of the image, as well as moving images both linear and diagonally compared with the horizon, to the brain. The somatosensory system, particularly pressure and proprioception, receives the pressure on the palms and soles and also the leg and spinal positions senses from the skin, muscles and joints to the brain. The function of the vestibular apparatus in the inner ear recognizes and conveys the inputs of the head movements in a straight line, and diagonally to the brain. This is the most important feedback for maintaining stability in upright posture in the case of seeing and feeling in the feet are disturbed, such as standing with closing the eyes or on the uneven ground. Finally, all the received inputs will be analyzed by the processing center in the brain, and then the response commands by the motor system will be sent to the muscles to control the movements for balance.[23]

2.2.1 Mechanism of balance control

The balance control mechanism requires an effectively working together of many systems. The vestibular, visual and somatosensory (especially the proprioception) systems will receive information about the head position and movement of the body and send the data to be processed in the central nervous system. Then, the motor system will response to those information and send the signals to control the muscles for the efficient balance and movement. After the motor response, the sensory inputs from the vestibular, visual and somatosensory systems will provide the feedback information to the motor system again for postural and balance adjustment. The loop of sensory inputs/feedback and motor response is working together all the time, and is essential to the proficient postural control and balance. Therefore, impairment of any systems will affect the balance ability.[22]

2.2.2 Balance and gait disturbance in diabetic peripheral neuropathy (DPN)

The presence of DPN in diabetic patients is associated with balance impairment and consecutively increases the risk of falls.[6] Various factors that affect balance in individuals with diabetic peripheral neuropathy are a result of significantly impaired sensation, particularly proprioception, impaired movement strategy, biomechanical structural disorders, and disorientation. In case the presence of neuropathy, it is usually associated with an increased body sway, faster sway speed, greater sway dispersion during bilateral stance with eyes open, and the sway values are exceed with eyes closed when compared to controls.[6] In addition, the patients with DPN walk slower with shorter stride length and lower cadence when compared with healthy controls during self-paced as well as maximal speed conditions because of prolonged double limb support and widened base of support so as to increase stability during walking.[24] In the stability, the patients with DPN less stable posture with and without vision in anterior, posterior, lateral and medial direction.[24]

2.2.3 Related Research

The previous studies about exercise for balance improvement in people with diabetic peripheral neuropathy are reviewed and summarized as shown in table 2.

Table 2 Review of previous studies related to exercise for balance in diabetes mellitus with peripheral neuropathy

Study	Year	Population	Intervention	Control	Follow-up	Outcome	Result
James K. Richardson et al. [25]	2001	DPN; IG: 64.0±6.3 yrs, CG: 63.3±7.6 yrs.	Bipedal toe raises and heel raises, Bipedal inversion and eversion, Unipedal toe raises and heel raises, Unipedal inversion and eversion, Wall slides, Unipedal balance for time.	Neck flexion and rotation stretching with eyes open and then closed. They then used a resistance band to perform strengthening exercises for the scapular abductors, shoulder external rotators, and elbow flexors	3 weeks	Unipedal stance time, functional reach, tandem stance time, score on the activities-specific balance and the activities-specific balance (ABC) scale.	↑Unipedal stance time ↑functional reach test tandem ↑stance time ↑score on the activities-specific balance(ABC)scale, non-sig between IG and CG.
Rapeepan T. et al. [11]	2013	DPN; IG: 68.38±3.99 yrs, CG: 69.35±3.97 yrs.	Group exs.(n=13): Alternated heel and toe rise in standing, standing on one leg, Tandem standing, Ball passing, Ball game, Progression exs.	Upper limb exercise with resistive band (n=14) performed intensity mild to moderate 40%-70% of MHR, 50 mins/day, 3 days/wk, 4 wks.	4 weeks	balance performance: mCTSIB, BBS, TUG; ankle proprioception, fear of falling	↑mCTSIB in condition 3,4. ↑BBS ↑TUG ↑ankle proprioception fear of ↑falling

DPN; Diabetes with peripheral neuropathy, IG; Interventiona group, CG; Control group, Exs.; Exercise

2.3 Walking meditation

2.3.1 Definition of walking meditation

The walking meditation is a part of spiritual development by practicing mindfulness during slowly walking back and forth. The mindfulness practice is just put your mind to rest, do not concern in the past or future, but being concentrated on the present foot pedal along the slow walking at the current time only. The concentration on the foot pedal at the current time during walking is committed by speech or thought along with the action or movement. The walking meditation path is about 8-12 paces. So it can be practiced anywhere. The walking meditation practice is an activity that looks similar to the practice of Tai Chi, Qigong, and Yoga that it is a slow movement. [26]

2.3.2 How to perform walking meditation

Dr. Sirigrinchai recommended that individuals who intended to start practicing walking meditation, they had to determine the behavior of a body to be ready as well as speech and mind, and then immersion of the body movements during walking with consciously awareness. The walking meditation practice has seven phases defined by the delicate thoughts and speech focusing on the leg and foot actions/movements during slowly walking as the following. [27]

1. Phase 1: Right pedal (nor), Left pedal (nor)
2. Phase 2: Raise (nor) – pedal (nor)
3. Phase 3: Raise (nor) – pedal (nor) –tread (nor)
4. Phase 4: Heel raise (nor) – raise (nor) -pedal (nor) –tread (nor)

5. Phase 5: Heel raise (nor) – raise (nor) -pedal (nor)-place down (nor) – tread (nor)

6. Phase 6: Heel raise (nor) – raise (nor) - pedal (nor)-place down (nor) - floor contact (nor)-tread (nor)

7. Phase 7: Heel raise (nor) – raise (nor) - pedal (nor)-place down (nor) - floor contact (nor)-tread (nor) - thinking or not (nor)

2.3.3 The benefits of walking meditation

Walking meditation is one of the spiritual practices in Buddhism. It provides an advantage in terms of exercise and mental management. The walking meditation helps the mind relax from the tension and change the mood inside the body to cool down. Walking meditation is also like a gentle walking exercise. Therefore, it is useful in health care and mental well. (28)

2.4. Related Research

The previous studies about the effects of walking meditation on physical functions are reviewed and summarized as presented in table 3.

Table 3 Review of previous studies related to the effects of walking meditation on physical functions

Study	Year	Population	Intervention	Control	Follow up	Outcome	Result
Suwannawat P. et al.[9]	2011	Elderly people WM: 71.50± 6.31 yrs, CG: 68.70± 6.58 yrs	WM(walking meditation n=10): Walking meditation on 6 phase, 5 days/wk	(n=10):Activity daily living	8 weeks	Osness Balance Test	↑Osness Balance Test
Chatutain A. et al. [7]	2019	Elderly people WM: 70.2±6.97 yrs, CG: 68.3 ±5.15 yrs	WM(walking meditation n=29): Walking meditation on 6 phase, 3 days/ wk	(n=29):free exercise, 3 days/ wk	8 weeks	balance performance: BBS, TUG , FRT; ankle proprioception	↑BBS ↑TUG ↑FRT ↑Ankle proprioception

WM; Walking meditation, MHR; Maximum heart rate, wk; week

Table 3 (continued)

Study	Year	Population	Intervention	Control	Follow up	Outcome	Result
Gainey A. et al.[10]	2016	People with diabetes TW: 63±2 yrs, WM: 58±3 yrs	Traditional walking exercise training (TW; n = 13): phase 1 (weeks 1–6), mild to moderate intensity (50–60% MHR). phase 2 (weeks 7–12), was increased to moderate intensity (60–70% MHR), Buddhist walking meditation exercise training (WM; n = 14): aerobic walking exercise combined with Buddhist meditation. The subjects performed walking on the treadmill while concentrating on foot stepping, 50 mins/day, 3 days/wk		12 weeks	Flow-mediated dilatation (FMD), Arterial stiffness, Ankle-brachial index (ABI), Blood analyses	↑ HbA1c and both systolic ↑ and diastolic blood pressure in WM, flow-mediated dilatation

WM; Walking meditation, MHR; Maximum heart rate, wk; week

2.5 Clinical assessment of diabetic peripheral neuropathy

2.5.1 The Michigan Neuropathy Screening Instrument (MNSI) is a validated score instrument for diabetic neuropathy (DN) screening, being widely used for the diagnosis and quantification of diabetic distal symmetrical peripheral neuropathy. The MNSI consists of two distinct parts: a 15-item self-administered questionnaire that is scored by summing abnormal answers provided by the patient and a lower extremity examination performed by the healthcare professional, including inspection, evaluation of ankle reflexes and of vibration perception at great toe, in which the abnormal findings are scored. The MNSI has both higher sensitivity and specificity than individual DN tests separately; a self-administered questionnaire scoring 7 or above, or a clinical examination score of 2 or above provided a positive diagnosis of DN, which was considered more severe with the increase of the MNSI score. [29]

2.6 Functional balance assessment

There are many balance assessment tools. However, the tool that easy to use in the community, and take less time are reviewed as follows.

2.6.1 Modified Clinical test of Sensory integration of balance (mCTSIB)

The mCTSIB is an accepted test for balance assessment on static surface, It was supported and accepted by many studies as a valid clinical balance assessment tool. It is also an ideal balance assessment for baseline screening following a mild traumatic brain injury as concussion. [30]The mCTSIB is a comprehensive test to approach each of the systems contributing to balance as visual, vestibular and somatosensory. Additionally, the mCTSIB show a high inter and intra-rater reliability as well.

The mCTSIB consists of 4 conditions providing a generalized assessment of how well a patient can integrate various senses with respect to balance, and compensate when one or more of those senses are compromised. The 4 conditions tested are as follows. [18]

1. Eyes open, firm surface condition: This condition is to provide a baseline. Information. Balance control is available by all three sensory inputs: visual, vestibular and somatosensory.

2. Eyes closed, firm surface condition: The visual is not available in this condition, while the somatosensory and vestibular are available. If the patient performs poorly the vestibular or somatosensory may be compromised, with an increase in visual dependency.

3. Eyes open, unstable surface (foam) condition: The somatosensory is compromised; but visual and vestibular inputs are available. If the patient performs poorly, visual or vestibular system may be compromised, with an increase in somatosensory dependency. Somatosensory input consists of proprioception and touch and allows the muscle to make constant automatic adjustment to maintain balance and avoid falls.

4. Eyes closed, unstable surface (foam) condition: The visual input is not available, and the somatosensory is compromised; while only vestibular is available. If patient's performance is reduced, the vestibular system may be disrupted. The vestibular system is responsible for processing information about movement with respect to gravity; more specifically rotation, acceleration/ deceleration, and head stabilization. The vestibular system also works with the visual system to stabilize the

eyes and maintain posture during exertion. Vestibular disorders cause a feeling of dizziness and unsteadiness. [31]

2.6.2 Timed up and go test (TUG)

Timed up and go test (TUG) has also been used as dynamic balance measure but is more relevant as a mobility and functional task. Correlated with the Berg Balance Scale (r=-.72) and the Barthel Activities of Daily Living Index (r=-.51).Test timed volunteer rise from a chair, walk three meters, turn, walk back, and sit down. During this test, volunteer wear footwear. No orthotic or prosthetic device is allowed during the test. All chairs used have an approximate seat height 45 cm and armrest height 65 cm. Time test used a stopwatch to time each test and recorded the time in second. No score if they were unable to complete the test or required assistance to refrain from falling during test. [6],[32]

2.6.3 Functional reach test (FRT)

Functional reach test is a measure of the distance reaching forward beyond arm's length while maintaining a fixed base of support in standing position. It is excellent predictive validity in subject at risk of falls. To perform the Functional reach test, volunteer stands comfortably parallel to a wall. Then, raise their arms to 90 degree of flexion. A yardstick is place parallel to the subject's raised arms. The researcher measure and records the placement of the end of the subject's third metacarpals head along yardstick this being termed position 1. In position 2, the volunteer reaches as far forward as possible without losing his/her balance and the researcher measures and records the placement of the same landmark along the yardstick. The mean difference between position 1 and position 2 over 3 trials in which each volunteer performed defined as the test result. If the volunteers touch the wall or require any assistance from the assessor, it invalidates the trial. The assessor guards all volunteers at a supervision level of assistance during the maneuver. [(6),(32)]

2.6.4 Timed unilateral stance performance test:

Subject is asked to stand comfortably and fixed his eyes forward to a point. Thereafter the subject was asked to stand on the right and left foot separately as long as possible without losing balance or fall. The time duration that the subject could stand without losing balance is recorded.

CHAPTER 3
METHODOLOGY

The details of methodology including sample size, inclusion and exclusion criteria, and the procedure are described as the following.

3.1 Participants

The participants for the study were invited and enrolled by volunteer. All participants were recruited from Ruamkue village community, Tawee wattana, Bangkok, Thailand. The eligible participants (n=28) were randomly assigned to Walking meditation group (WM, n= 14) and control group (CG) based on drawing lots. The inclusion and exclusion criteria are as follows.

The inclusion criteria:

1. Females or males aged 40-75 years old with type 2 diabetic mellitus diagnosed by the physician.

2. Never practice walking meditation.

3. The evaluated scores by the Michigan Neuropathy Screening Instrument (MNSI) in the section of a self-administered questionnaire have to be ≥7 points, and/or that in the section of clinical examination have to be ≥ 2points.

4. Independent walking and never practice walking meditation

5. Able to understand and follow the instructions.

6. Be informed and signed the informed consent before the enrollment.

The exclusion criteria:

1. The diseases that affect the central nervous system such as Parkinson's disease, hemiparesis, etc.

2. Partial or total amputation of lower extremities.

3. Body mass index (BMI) > 40 kg/m2 (18)

4. Attending another exercise during the study.

5. Got a contraindicated complication for exercise as mentioned in the American Diabetes Association Guidelines such as severe systematic infection, autonomic neuropathy, preproliferative and proliferative retinopathy, uncontrolled hypertension, severe cardiovascular, and severe respiratory conditions. [19]

6. Severe foot problems that affect mobility or walking such as acute foot ulcer or foot condition that need orthotics or special shoes.

7. Back, hip, knee and leg problems causing pain that impediment to walking such as back pain with nerve root irritation, hip or knee arthritis.

3.1.1 Sample size calculation

This study was a clinical trial to investigate the effects of walking meditation on balance ability in the persons with diabetic peripheral neuropathy. Therefore, the sample size of this study was estimated by the previous clinical trial which studied the effects of balance training program on balance performance in individuals with diabetic peripheral neuropathy as well.[11] The sample size of the previous study was totally 18 persons (9 persons/group). However, for 50% of dropout would be concerned, therefore the total sample size of this study was 28 persons (14 persons /group).

The study protocol followed the ethical guidelines concerning human research and was approved by the Medical service department health info the Bangkok (permission document code: U042h/60). The study was authorized by the Clinical Trial Registry (RCT code: TCTR20190210001).

3.2 Research procedure

The study procedure was conducted as the followings steps (Figure 2).

1. All participants were screened by the inclusion and exclusion criteria. The participants who passed the criteria were informed about the objectives, benefits and methodology and signed an informed consent for participation.

2. The participants were simply randomized into two groups, as an experimental group (walking meditation group) and a control group.

3. All participants were evaluated balance ability by standing on a firm surface with eye-opened and wth eye-closed conditions, Time Up and Go test (TUG), and Functional reach test (FRT).

4. Both walking meditation and control groups were received the health education following the 10 guidelines of foot self-care (e.g., washing and checking feet every day, applying skin lotion if skin is too dry, avoid wearing tight shoes, wearing shoes and socks at all times, and refraining from smoking) by a nurse.

5. Before and after every training session, the researcher inspected participants' feet to be aware of foot ulcer and took notes every time. In addition, all participants had to wear socks and shoes during walking meditation practice or gentle walking exercise.

6. Then, the walking meditation group received walking meditation training for 4 weeks (30 minutes/day, 3 days/week.). The protocol of walking meditation were described later.(7),(11)Within a 30 minutes/day of walking meditation, the training was split into 3 intervals for 10 minutes/interval, and rest by sitting on a chair for 2 minutes between the intervals to prevent fatigue.

7. Whereas, the control group received a gentle walking exercise with self-preferred speed for 4 weeks (30 minutes/day, 3 days/week). Within a 30 minutes/day of the gentle walking exercise, it was split into 3 intervals for 10 minutes/interval and rest by sitting on a chair for 2 minutes between the intervals to prevent fatigue.

8. Then, all participants were re-assessed balance ability after 4 weeks of training same as before the training.

9. Every time before and during training, the researcher checked vital signs of the participants and be aware of the hypoglycemia by observation and asking all participants about the hypoglycemic symptoms such as shakiness, pale skin color, dizziness, sweating, clumsy/jerky movements, hunger, or headache. If there are any symptoms, the researcher will let the participant rest and take some carbohydrate as

honey or syrup. Then the symptoms will be monitored until relieving, if not, the participant will be transferred to the nearest hospital.

10. The researchers who conducted the training and the balance assessment were not the same person. The one who was an assessor was blinded from the group randomization of all participants.

Protocol of walking meditation

The walking meditation practice composed of six phases defined by the delicate thoughts (or attention) focusing on the leg and foot movements during slowly walking as the following sequences. [21]

Phase 1: keeping attention to the foot movement during slowly walking (alternate left and right foots) along with speaking "Right pedal (nor), Left pedal (nor)" in every left and right steps alternately.

Phase 2: keeping attention to the more delicate of the foot movement during slowly walking along with speaking "Raise (nor) – pedal (nor)" in every left and right steps alternately.

Phase 3: keeping attention to the more delicate of the foot movement during slowly walking along with speaking "Raise (nor) – pedal (nor) –tread (nor)" in every left and right steps alternately.

<u>Phase 4</u>: keeping attention to the more delicate of the foot movement during slowly walking along with speaking "Heel raise (nor) – raise (nor) -pedal (nor) – tread (nor)" in every left and right steps alternately.

<u>Phase 5</u>: keeping attention to the more delicate of the foot movement during slowly walking along with speaking "Heel raise (nor) – raise (nor) -pedal (nor)-place down (nor) – tread (nor)"in every left and right steps alternately.

<u>Phase 6</u>: keeping attention to the more delicate of the foot movement during slowly walking along with speaking "Heel raise (nor) – raise (nor) - pedal (nor)-place down (nor) - floor contact (nor)-tread (nor)"in every left and right steps alternately.

Each phase was practiced by slowly walking back and forth in the path of 8-12 paces repeatedly for 30 minutes/day, 2 days/phase. Therefore, to complete all of 6 phases of the walking meditation is 12 days. The volunteers attended the walking meditation practice 3 days/week for 4 weeks.

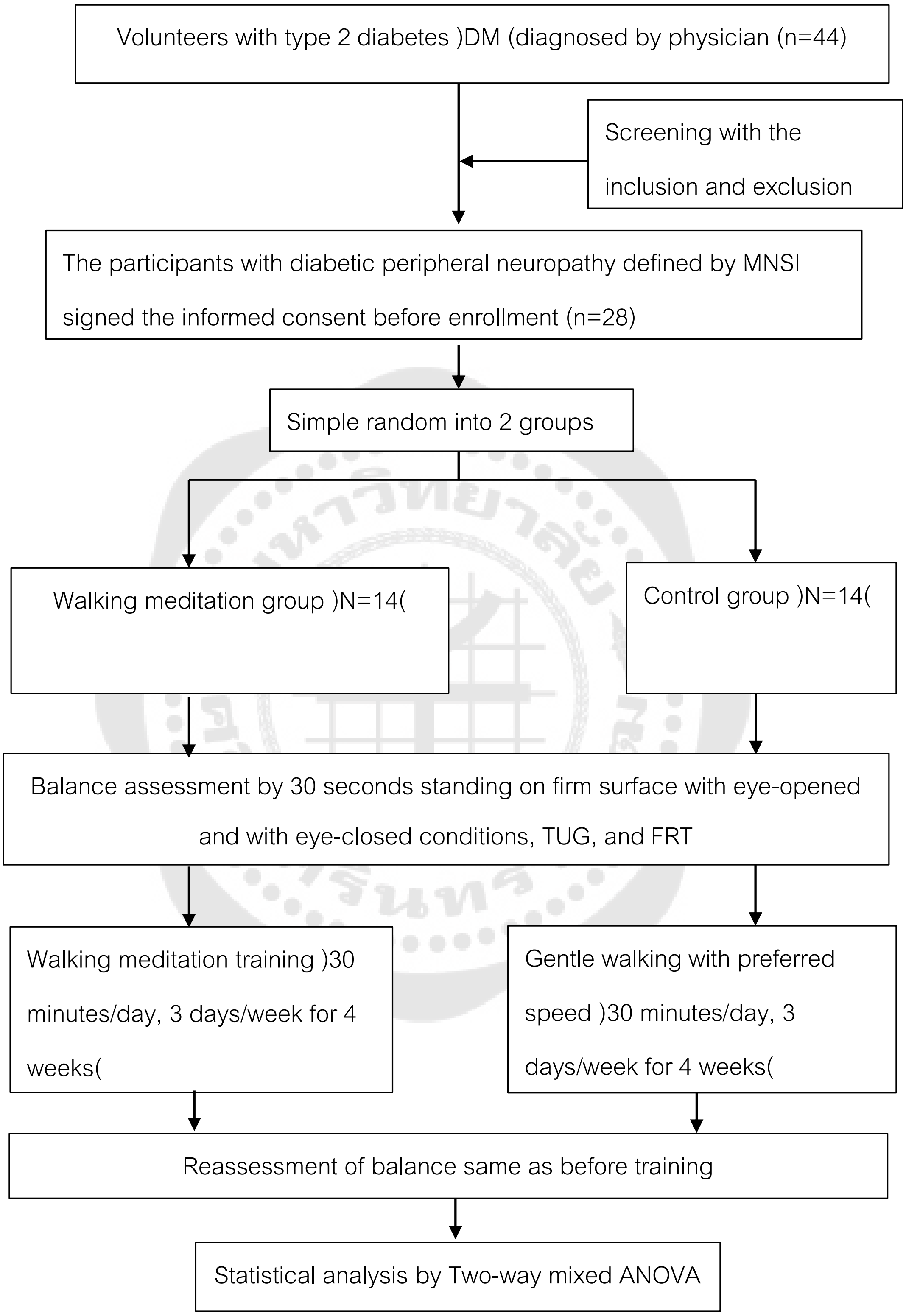

Figure 2 Flow chart of the study procedure

Note :TUG= Timed Up and Go Test, FRT = Functional reach test

3.3. The instruments for peripheral neuropathic screening in the recruitment of participants

The Michigan Neuropathy Screening Instrument (MNSI) was used for peripheral neuropathic screening in the recruitment of participants. It consists of two parts: a 15-item self-administered questionnaire and a clinical examination of lower extremities as shown in the appendix A. The questionnaire contains of 15-item questions related to neuropathic and vascular symptoms and it is scored by summing abnormal answers provided by the patient as the MNSI manual guide. The lower extremity examination part has to perform by the healthcare professional. It includes of a foot inspection, monofilament sensation, the ankle reflex test and the vibration sense test at the great toe, in which the abnormal findings are scored, The volunteers with type 2 DM who got the self-administered questionnaire score $\geq$7 points, and/or a clinical examination score $\geq$ 2 points were determined as positive diagnosis of neuropathy and were recruited to the research. [29]

3.4 Outcome measurement

The outcome measures representing balance performances of this research included of 1) maximum time hold on in each condition of standing on firm surface with eye-opened and with eye-closed, 2) Timed up and Go test, and 3) maximum reaching distance of Functional reach test in forward and lateral directions.

3.4.1 Standing on a firm surface with eye-opened and with eye- closed conditions

This study evaluated of balance control during static standing composes of 2 conditions, as follow 1) stand on a firm surface with eyes open and 2)stand on a firm surface with eyes closed. For each condition, the subject was asked to stand with arms across the chest, once with his/her feet apart as shoulder width and once with their feet closed together (total of 4 test conditions). The time that subject can maintain balance was recorded until a maximum of 30 seconds long or stopped if the subject moved hands off the chest, or moved feet from the starting position, or opened their eyes during an eyes-closed condition. Three trials were performed for each condition. The representative value of a maximum time to maintain balance was averaged from the 3 trials for each condition.[(21),(30)]

3.4.2 Timed up and go test (TUG)

The TUG was applied for assessment of dynamic balance during transition from sit to stand, walking and turning. The test was performed by asking subject to rise from a chair, walk three meters, turn, walk back, and sit down. the subject was allowed to wear shoes during the test. The chair has the armrests and it's approximate seat height is 45 cm.The time was recorded since rising up from the chair until coming back to sit down by using a stopwatch.The representative value of the maximum time for TUG was averaged from the 3 trials. [(32),(33)]

3.4.3 Functional reach test (FRT) in forward and lateral directions

The FRT is a balance assessment of postural stabily limit.The distance that subject can reach as far forward as possible beyond the arm's length while maintaining a fixed base of support in standing position is measured. To perform the Functional reach test, the subject stood comfortably with the right side parallel to a wall. Then, as a starting position, the subject raised the right arm up to 90 degree of flexion with elbow straight. A yardstick was attched to the wall parallel to the subject's raised arms. Then the researcher asked the subject to reach forward as far as possible without loosing balance. The researcher measured the displacement of reaching from the starting position to the maximum reach. The landmark for measuring the reaching on the yardstick is at the tip of the subject's right middle finger, Each subject was tested for 3 trials in each directions as forward, sideward to the left and to the right. The representative value of the distance for FRT in each directions was averaged form the 3 trials.[32]

3.5 The statistical analysis

All outcome data were normal distribution when testing by Kolmogorov – Smirnov test. Therefore, the two-way ANOVA mixed model was used for analysis of the training effect, time effect and training x time interaction. Then, when there was any statistically significant effect found from the two-way ANOVA, comparisons of each time points between groups and that of within each group were analyzed by independent t-test and dependent t-test respectively. The level of statistical significance for all tests was set at $p < 0.05$.

CHAPTER 4
RESULTS

The study investigated the effects of walking meditation on balance performance in individuals with type-2 diabetic peripheral neuropathy (DPN) by a randomized control trial with single blinded of the assessor. Participants with type-2 DPN in the walking meditation group (WM) received walking meditation training whereas the control group (CG) received gentle walking exercise with self-preferred speed. All participants were resident in Ruamkue village community, Tawee Wattana, Bangkok, Thailand. They participated throughout the study and no one dropped out.

The outcome measures of this study to represent the participants' balance performance included of static standing balance on a firm surface with and without visual feedback, dynamic balance during gait, and stability limit in reaching as follows; 1) maximum time hold on in each conditions of standing on firm surface with eye-opened and with eye-closed, 2) Timed up and go test (TUG), and 3) Functional reach test in the directions of forward (FRT-forward), sideward to the left (FRT-Lt), and sideward to the right (FRT-Rt).

The baseline characteristics related to age, genders, body weight, body height, body mass index (BMI), the scores from Michigan neuropathy screening instrument (MNSI) test, 30-second standing with eye-opened and with eye-closed, timed up and go test (TUG), functional reach test forword (FRT-forward), functional reach test sideward to the left (FRT-Lt), and functional reach test sideward to the right (FRT-Rt) of participants in the walking meditation group and those in the control group were presented in Table 5. There was no significant difference of age, body weight, body height, BMI, MNSI score, 30-second standing with eye-opened and with eye-closed, TUG, FRT-Lt, and FRT-Rt between the WM and CG, except the FRT-forward, as shown in Table 5.

Noticeably, for the outcome measure of a maximum time hold on in each conditions of standing on a firm surface with eye-opened and with eye-closed, both walking meditation and control groups either at pre-test or post-test reached the ceiling of the test, 30 seconds. Therefore, by the test of static standing balance on a firm surface in either eye-opened or eye-closed conditions, no significant difference between pre-and post-test within each groups and between groups was found, and no need to be statistically analyzed this outcome further.

Table 4 Baseline characteristics of participants

Characteristics	Mean±SD		P-value#
	Walking meditation group(n=14)	Control group (n=14)	
Age (year)	64.57±7.15	62.86±6.29	0.58
Gender :female/male	10/4	8/6	
Weight (kg)	69.14±4.76	68.64± 5.95	0.07
Height (cm)	163.14±7.56	163.43±6.70	0.61
BMI (kg/m^2)	26.07±2.42	25.75±2.49	0.09
Michigan neuropathy screening instrument score (marks)	3.5±0.34	3.42±0.33	0.73

Table 4 (Continued)

Characteristics	Mean±SD		P-value#
	Walking meditation group(n=14)	Control group (n=14)	
30-second standing with eye-opened (seconds)	30.00±0.00	30.00±0.00	1.00
30-second standing with eye-closed (seconds)	30.00±0.00	30.00±0.00	1.00
Timed up and go test (seconds.)	7.18 ± 0.66	7.20 ± 0.27	0.90
FRT-forward (centimetres)	27.99±6.54	33.41 ±6.74	0.04*
FRT-Lt (centimetres)	21.1±3.42	19.16±3.21	0.15
FRT-Rt (centimetres)	24.66 ± 4.77	25.35±4.36	0.69

p-value from independent t-test comparing between walking meditation and control groups,*Significant difference at p <.05, FRT-forward = functional reach test in forward direction, FRT-Lt =functional reach test sidward to the left, FRT-Rt = functional reach teat sideward to the right

As two-way ANOVA mixed model analysis, the statistically significant effects of time, and time x group interactions on TUG, and also the group effects on FRT-forward and FRT-Lt were found as shown in Table 6. Meanwhile, there was no effect of group, time and time x group interaction on FRT-Rt. The overview of mean ± SD of the studied outcomes at pre- and post-training of the walking meditation and control groups, and also the p-values from the comparison within group and between groups at post-training are presented in Table 6-7.

Table 5 The effects of groups as walking meditation and control groups, time as pre-training (at week 0) and post-training (at week 4), and time x group interaction analyzed by a two-way ANOVA mixed model.

Studied parameters	F	p-value
Timed up and go test(TUG)		
Group	2.14	0.155
Time	22.69	0.001**
Time x group	18.33	0.001**
Functional reach test forward (FRT-forward)		
Group	5.01	0.034*
Time	0.13	0.719
Time x group	0.16	0.690
Functional reach test sideward to the left (FRT-Lt)		
Group	6.50	0.011**
Time	3.29	0.081
Time x group	2.54	0.123
Functional reach test sideward to the right (FRT-Rt)		
Group	0.03	0.851
Time	0.75	0.393
Time x group	1.39	0.249

*Significant difference at $p < .05$ by Two Way ANOVA Mixed model

**Significant difference at $p < .01$ by Two Way ANOVA Mixed model

Table 6 The studied outcomes at pre- and post-training of the walking meditation and control groups, and the p-values from the comparison within each group (pre- vs. post-training) and between groups at post-training.

Studied outcomes	group	Mean ± SD		p-value$^{\#}$ (within group)	p-value$^{\$}$ (between groups at post-training)
		Pre-training	Post-training		
Timed up and go test (seconds)	WM	7.18 ± 0.66	6.67 ± 0.66	0.0001**	0.01**
	C	7.20 ± 0.27	7.17 ± 0.22	0.54	
FRT-forward (cm.)	WM	27.99±6.54	28.71±5.76	0.70	0.06
	C	33.41 ±6.74	33.37±6.72	0.54	
FRT-Lt (cm.)	WM	21.1±3.42	24.21±6.38	0.11	0.01**
	C	19.16±3.21	19.36±3.17	0.22	
FRT-Rt (cm.)	WM	24.66 ± 4.77	26.40±6.27	0.32	0.51
	C	25.35±4.36	25.08±4.16	0.19	

WM = walking meditation group, C = control group, FRT-forward = Functional reach test forward

FRT-Lt = Functional reach test sideward to the left, FRT-Rt = Functional reach test sideward to the right

p-value from dependent t-test, $ p-value from independent t-test

Timed up and go test (TUG)

The mean ± SD of TUG for pre-test and post-test in walking meditation group were 7.18 ± 0.66 and 6.67 ± 0.66 seconds respectively, while those in a control group were 7.20 ± 0.27 and 7.17 ± 0.22 seconds orderly. As the time effect, the walking meditation group demonstrated significantly faster of TUG at post-test when compared to pre-test (p=0.001), whereas the control group did not showed significant difference of TUG between pre- and post-test as presented in Figure 3.

As the time x group interaction, after 4-week training, the walking meditation group presented significantly faster of TUG when compared with a control group (p=0.001) as shown in Figure 3.

Figure 3 Comparison of Timed up and go test (TUG) between walking meditation and control groups and pre-training versus post-training within each group. **significant difference at p<0.001

Functional reach test forward (FRT-forward), functional reach test sideward to the left (FRT-Lt) and functional reach test sideward to the right (FRT-Rt)

The mean ± SD of FRT-forward, FRT-Lt and FRT-Rt in walking meditation group for pre-training were 27.99±6.54 cm, 21.1±3.42 cm and 24.66 ± 4.77 cm, and those for post-training were 28.71± 5.76 cm, 24.21± 6.38 cm and 26.40± 6.27 cm respectively. Meanwhile, the mean ± SD of FRT-forward, FRT-Lt and FRT-Rt in a control group for pre-training were 33.41 ±6.74 cm, 19.16±3.21 cm and 25.35±4.36 cm, and those for post-training were 33.37±6.72, 19.36±3.17 and 25.08±4.16 in order.

As a group effect, the walking meditation group showed a significantly farther reaching distance for FRT-Lt after training when compared to a control group (p = 0.017) as presented in Figure 4. In addition, although, the walking meditation group significantly showed less FRT in forward direction when compared to a control group at pre-training (p= 0.04), it was not statistically significant difference in FRT-forward between the two groups at post-training as presented in Figure 5. Also, there was no significant difference in FRT-Rt either within each group or between groups as demonstrated in Figure 6.

Figure 4 Comparison of functional reach test sideward to the left (FRT-Lt)between walking meditation and control groups** .significant difference at p<0.05

Figure 5 Comparison of functional reach test forward (FRT-forward) between walking meditation and control groups. *significant difference at $p<0.05$

Figure 6 Comparison of functional reach test sideward to the right (FRT-Rt) between walking meditation and control groups.

CHAPTER 5
DISCUSSION

This study was conducted to evaluate the effect of walking meditation (WM) training on balance improvement compared to the control with preferred speed walking in individuals with type-2 diabetic peripheral neuropathy (DPN). The results showed that, after 4 weeks training, the walking meditation group had a faster timed up and go test (TUG) than before training (p=0.001) and also than the control group (p=0.001). Also, after training, the walking meditation group was able to reach sideward in functional reach test to the left (FRT-Lt) farther than a control group significantly (p=0.017). Meanwhile, before training, the walking meditation group demonstrated a shorter functional reach test in forward direction (FRT-forward) when compared to the control group (p=0.04), but, after 4-week training, there was no significant difference of the FRT-forward between the walking meditation and the control groups. These findings may demonstrate that walking meditation training for 4 weeks in this study can improve dynamic balance during walking and limit of stability during reaching of persons with type-2 diabetic peripheral neuropathy better than preferred speed walking.

Eventhough, there was a statistically significant improvement of the TUG after training of the WM group and also faster than the control group, the changed value of the TUG improvement of the WM group after training in the study was not larger than the minimum clinical detectable change of TUG of the previous study[34]. Due to, at baseline, TUG of the WM and control groups in this study were within the normative range of persons with the same age [34] and also faster than the cut-off score of the falling risk [35]. Thus, it may still have only small gap for the improvement of TUG. However, WM training still helped persons with type-2 diabetic peripheral neuropathy improve their balance during walking and make them able to walk faster than the control group which received training with preferred speed walking.

WM is a slow walking combined with mindfulness practice by paying the attention to movements of the lower limbs during walking. The biomechanics of a slow walking showed longer single support time of the gait cycle than walking with normal or preferred speed. [36, 37] Additionally, Bráulio N. et al. reported that during single leg standing showed increase in muscle activities.[38]So, the slow walking in WM practice will challenge the participants of the WM group to maintaining their balance and neuromuscular control on a single leg support more than the control group that received walking training with preferred speed. In addition, the prior study in elderly persons reported that WM training improved ankle proprioception which is a somatosensory feedback that necessary for balance and postural control. [7]Furthermore, it was supported that the persons who had practiced meditation showed brain morphological change associated with sensory cortice and insula area that function related to exteroceptive and interoceptive body awareness.[39]Therefore, the improvement of balance performance of the WM group in this study may be due to the neuromuscular control exercise during slow walking, especially during a longer single support time, and the improvement of the ankle proprioception, as well as promoting the exteroceptive and interoceptive body awareness from meditation.

This study found that, at baseline, the WM group had FRT-forward less than normative data of people in the same averaged age [36], whereas the control group had FRT-forward in the normative range. [34], [40] However, after training, the averaged value of a FRT-forward of the WM group tended to increase and was not significantly different from the control group as at the baseline. These may imply that the WM group tended to improve limit of stability during forward reaching after 4-week WM training. Moreover, there were other biomechanical factors affecting limit of stability in forward reaching, for example the strength of gastrocnemius muscle for maintaining posture, and also ankle range of motion and flexibility of calf muscle for providing the excursion of forward leaning. [36] In addition, the previous study supported that flexibility decrease in aging, such as ankle, shoulder, or hip joint, was related to a limitation of the FRT in elderly females. [41], [42] Also, the gastrocnemius is an important muscle to keep balance in FRT. [43] these may be some reasons of difficulty in improving of FRT in forward direction of the WM group.

From the previous studies, the exercises to increase muscle strength, and joint flexibility needed at least 16 weeks [39]and 12 Months respectively.[37]So, the WM training for only 4 weeks in this study may not be sufficient to improve strength and flexibility. In addition, the characteristic of WM practice is likewise a neuromuscular training rather than muscle strength or flexibility training. Therefore, the exercise program for individuals with type-2 diabetic peripheral neuropathy to improve balance performance should include muscle strengthening and flexibility as well.

As FRT-Lt and FRT-Rt, both groups, did not differ at baseline, but, after training, the WM group showed only FRT-Lt more than the control group significantly. On the other hand, no difference in FRT-Rt was found. This may due to all participants were right handed and get used to reaching on the right side in daily activities. The significant improvement of FRT-Lt after training on the WM group when compared to the control group may because, as reaching to the left, the body weight will shift to the left leg as much as reaching farther and the muscles of the left leg has to control to maintain posture on the left leg. WM training, as a slow walking, will provide a chance for participant to learn how to control muscles during maintaining posture in the single support on the left and the right legs more than a preferred speed walking. Therefore, a longer single support time during WM training may also enhance neuromuscular control during weight shifting to the left leg when doing FRT-Lt.

For the 30-second standing on firm surface with eye-opened and closed, all participants were able to successfully perform in the maximum 30 seconds either before or after training. These demonstrated that standing on the firm surface with eye closed and eye opened conditions did not challenge enough for the participants with type-2 diabetic peripheral neuropathy of this study. Thus, the static standing balance test for persons with type-2 diabetic peripheral neuropathy should apply standing on a foam surface as well to test the highest performance and the more need of somatosensory feedback involving balance of the patients.

Furthermore, WM, which is a mind-body practice, can be an alternative exercise for balance promotion in people with DPN. The WM can improve TUG of individuals with DPN similar to the previouse study.[11] However, the WM can not improve FRT-forward of the persons with DPN as good as the previous studies. This may because the exercise programs for balance of the previouse studies composed of lower limb strengthening such as heel raise, single leg stance and mini-squating, and also mobility of ankle joint like toe raise, inversion and eversion in standing, [11], [25] Both strength and flexibility of lower limbs' muscles and joints are nescessary biomechanical components needed for postural control. Therefore, the exercise program to improve limit of stability for individuals with DPN should also concern on increase in muscle strength and flexibility.

Study limitations

The study did not assess flexibility of lower extremity muscle and range of motion of ankle joint. These factors may affect or limit the change of FRT, especially in forward direction. This study also determined inclusion/ exclusion criteria of the participants, such as be able to walk independently without gait aid. So, the results of the study cannot be generalized to the severe cases that are unable to walk independently.

Suggestion for further studies

The further study related to training effects on balance, particularly in term of FRT, should concern on flexibility of lower extremity muscle and range of motion of ankle joint. In addition, the effect of walking meditation on ankle proprioception in persons with DPN is interesting to investigate. Also, the more challenged static standing balance assessment by varying the standing surface should be applied to evaluate the effect of somatosensory feedback on balance control in patients with DPN in addition to standing on a firm surface with eye-closed and with eye-opened conditions for the further studies. Moreover, the effects of walking meditation training longer than 4 weeks on balance and lower limbs' muscle strength as well as ankle proprioception in individuals with type-2 DPN are interesting to investigate further.

Conclusion

The study found that walking meditation practice at least 30 minutes a day, 3 days a week, for 4 weeks statistically significant improved TUG ($p=0.001$) and FRT-Lt ($p=0.017$) of individuals with type-2 diabetic peripheral neuropathy better than walking training with preferred speed. Therefore, walking meditation can be applied as an alternative exercise to promote balance for people with type-2 diabetic peripheral neuropathy who able to walk independently in community dwelling.

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APPENDIX

APPENDIX A

Recording Form

แบบบันทึกข้อมูล

ส่วนที่ 1 ข้อมูลทั่วไปของผู้ป่วยโรคเบาหวาน

1. ชื่อ……………………………นามสกุล………………………………………………..

2. ที่อยู่ที่สามารถติดต่อได้

....

....โทร..

3. เพศ ( ) หญิง ( ) ชาย

4. อายุ..................ปี

5. สถานภาพสมรส ( ) โสด ( ) คู่ ( ) หม้าย/หย่าร้าง

6. สถานภาพการอยู่อาศัย (ตอบได้มากกว่า 1 ข้อ)

( ) อยู่คนเดียว ( ) อยู่กับคู่สมรส ( ) อยู่กับบุตรหลาน ( ) อื่นๆ ระบุ

....

7. ระดับการศึกษา

( ) ไม่ได้เรียน (อ่าน-เขียนไม่ได้) ( ) ระดับประถมศึกษา ( ) ระดับมัธยมศึกษา ( ) ระดับปริญญาหรือสูงกว่า ( ) อื่นๆ ระบุ.....................

8. อาชีพ

( ) ข้าราชการ/พนักงานของรัฐ/พนักงานรัฐวิสาหกิจ ( ) ค้าขาย/ธุรกิจส่วนตัว

( ) พนักงานเอกชน/ลูกจ้างเอกชน ( ) รับจ้างทั่วไป

( ) เกษตรกร ( ) อื่นๆ ระบุ.....................................

9. น้ำหนัก………กิโลกรัม ส่วนสูง..............เซนติเมตร ดัชนีมวลกาย................กก./ม2

10. ความดันโลหิต…………………………มม./ปรอท

11. ผลตรวจค่า ABI (ankle brachial index)

ก่อนเข้าร่วม……………………………….หลังเข้าร่วม..

12. น้ำตาลในเลือดหลังงดอาหาร 8-12 ชั่วโมง.................มิลลิกรัม % (ว/ด/ป..............)

13. ระดับ HbA1C……………………%(ระยะเวลา 3 เดือนที่ผ่านมา)

14. ระยะเวลาเป็นเบาหวาน........................ปี

ส่วนที่ 2 ข้อมูลภาวะสุขภาพ

1.	โรคความดันโลหิตสูง	( ) มี	( )ไม่มี
2.	โรคไขมันในเลือดสูง	( ) มี	( )ไม่มี
3.	โรคหัวใจ	( ) มี	( )ไม่มี
4.	โรคไต	( ) มี	( )ไม่มี
5.	โรคโลหิตจาง	( ) มี	( )ไม่มี
6.	โรคมะเร็ง	( ) มี	( )ไม่มี
7.	โรคหลอดเลือดสมอง	( ) มี	( )ไม่มี
8.	โรคพาร์กินสัน	( ) มี	( )ไม่มี
9.	ปัญหาที่หลัง	( ) มี	( )ไม่มี
10.	ปัญหาที่เข่า	( ) มี	( )ไม่มี
11.	การสูบบุหรี่	( ) ไม่สูบ	( ) สูบ ปริมาณ..................มวน/วัน
12.	การดื่มแอลกอฮอล์	( ) ไม่ดื่ม	( ) ดื่ม จำนวน................ครั้ง/สัปดาห์
13.	การผ่าตัดเมื่อเร็วๆนี้	( )ไม่มี	( )มี โปรดระบุ

....

14. ประวัติการรักษาพยาบาลอื่นๆ...

15. ยาที่ได้รับปัจจุบัน...

ส่วนที่ 3 ข้อมูลเกี่ยวกับการออกกำลังกาย

1. การออกกำลังกาย ใน 6 เดือนที่ผ่านมา ( ) ไม่ออกกำลังกาย

( ) ออกกำลังกาย โปรดระบุชนิด................................

2. จำนวนครั้งที่ออกกำลังกาย...........................ครั้ง/สัปดาห์

3. ระยะเวลาที่ออกกำลังกาย.............................นาที/ครั้ง

ส่วนที่ 4 ข้อมูลเกี่ยวกับผลการประเมินด้วย MNSI

แบบสอบถาม สำหรับผู้ป่วย

เครื่องมือวัดอาการปลายประสาทของมิชิแกน

ก. ประวัติผู้ป่วย (สำหรับผู้ป่วยโรคเบาหวาน)

กรุณาสละเวลาประมาณ 2-3 นาที เพื่อให้ข้อมูลเกี่ยวกับความรู้สึกที่ขาและเท้าของคุณ โดยเลือกคำตอบ "ใช่" หรือ "ไม่ใช่" ตามอาการและความรู้สึกของคุณ ขอขอบพระคุณมา ณ ที่นี้

1. คุณรู้สึกชาที่ขา และ/หรือ เท้า หรือไม่?	☐ ใช่	☐ ไม่ใช่
2. คุณเคยรู้สึกปวดและแสบปวดร้อนที่ขา และ/หรือเท้า หรือไม่?	☐ ใช่	☐ ไม่ใช่
3. เวลาถูกสัมผัสบริเวณเท้าคุณรู้สึกไวเป็นพิเศษหรือไม่?	☐ ใช่	☐ ไม่ใช่
4. คุณเป็นตะคริวบริเวณขา และ/หรือเท้า หรือไม่?	☐ ใช่	☐ ไม่ใช่
5. คุณเคยรู้สึกเหมือนเข็มทิ่มแทงที่บริเวณ ขา และ/หรือเท้า หรือไม่?	☐ ใช่	☐ ไม่ใช่
6. คุณรู้สึกเจ็บที่ผิวหนังเวลาโดนกับผ้าปูที่นอนหรือไม่?	☐ ใช่	☐ ไม่ใช่
7. เวลาคุณอาบน้ำ คุณบอกได้หรือไม่ว่าเป็นน้ำร้อน หรือน้ำเย็น?	☐ ใช่	☐ ไม่ใช่
8. คุณเคยมีแผลเปิดที่เท้าหรือไม่?	☐ ใช่	☐ ไม่ใช่
9. แพทย์เคยบอกหรือไม่ว่าคุณมีอาการปลายประสาทเสื่อมจากเบาหวาน?	☐ ใช่	☐ ไม่ใช่
10. คุณรู้สึกอ่อนแรงเกือบตลอดเวลาหรือไม่?	☐ ใช่	☐ ไม่ใช่
11. อาการไม่ปกติของคุณจะหนักขึ้นช่วงกลางคืนหรือไม่?	☐ ใช่	☐ ไม่ใช่
12. คุณเจ็บเท้าเวลาเดินหรือไม่?	☐ ใช่	☐ ไม่ใช่
13. คุณรับรู้ความรู้สึกที่เท้าเวลาเดินหรือไม่?	☐ ใช่	☐ ไม่ใช่
14. ผิวหนังที่เท้าของคุณแตกหรือไม่?	☐ ใช่	☐ ไม่ใช่
15. คุณเคยถูกตัดเท้าหรือนิ้วเท้าหรือไม่?	☐ ใช่	☐ ไม่ใช่

คะแนนรวม____________________

รับรองการแปลจากต้นฉบับจริง

(ผู้ช่วยศาสตราจารย์วรลาภ แสงวัฒนะชัย)

ผู้อำนวยการสถาบันภาษา มหาวิทยาลัยขอนแก่น

MICHIGAN NEUROPATHY SCREENING INSTRUMENT

B. Physical Assessment (To be completed by health professional)

1. Appearance of Feet

	Right		**Left**	
a. Normal	☐ 0 Yes	☐ 1 No	☐ 0 Yes	☐ 1 No
b. If no, check all that apply:				
Deformities	☐		☐	
Dry skin, callus	☐		☐	
Infection	☐		☐	
Fissure	☐		☐	
Other	☐		☐	
specify:	________________		____________________	

	Right		**Left**	
	Absent	Present	Absent	Present
2. Ulceration	☐ 0	☐ 1	☐ 0	☐ 1

	Right			**Left**		
	Present	Present/ Reinforcement	Absent	Present	Present/ Reinforcement	Absent
3. Ankle Reflexes	☐ 0	☐ 0.5	☐ 1	☐ 0	☐ 0.5	☐ 1
	Present	Decreased	Absent	Present	Decreased	Absent
4. Vibration perception at great toe	☐ 0	☐ 0.5	☐ 1	☐ 0	☐ 0.5	☐ 1
5. Monofilament	Normal	Reduced	Absent	Normal	Reduced	Absent
	☐ 0	☐ 0.5	☐ 1	☐ 0	☐ 0.5	☐ 1

Signature:______________________________ Total Score __________ /10 Points

ส่วนที่ 5 ประเมินสมรรถภาพการทรงตัว

5.1 การทรงท่าแบบยืนนิ่งบนพื้นราบ (30 วินาที)

	สถานการณ์	ระยะเวลาที่สามารถยืนทรงตัวได้นิ่งไม่เซ (วินาที)			
		ทดสอบครั้งที่ 1	ทดสอบครั้งที่ 2	ทดสอบครั้งที่ 3	เฉลี่ย
ก่อนเข้าร่วมวิจัย	ลืมตา				
	หลับตา				
หลังเข้าร่วมวิจัย	ลืมตา				
	หลับตา				

5.2 Timed up and go test (ระยะทาง 3 เมตร)

	Timed up and go test (วินาที)			
	ทดสอบครั้งที่ 1	ทดสอบครั้งที่ 2	ทดสอบครั้งที่ 3	เฉลี่ย
ก่อนเข้าร่วมวิจัย				
หลังเข้าร่วมวิจัย				

5.3 ผลประเมิน Functional reach test

	ทิศทางที่เอื้อม	Functional reach test (เซนติเมตร)			
		ทดสอบครั้งที่ 1	ทดสอบครั้งที่ 2	ทดสอบครั้งที่ 3	เฉลี่ย
ก่อนเข้าร่วมวิจัย	ด้านหน้า				
	ด้านข้างซ้าย				
	ด้านข้างขวา				
หลังเข้าร่วมวิจัย	ด้านหน้า				
	ด้านข้างซ้าย				
	ด้านข้างขวา				

APPENDIX B

Raw Data

Raw Data

Table 1 Raw data of Michigan neuropathy screening instrument assessment in individual participants of the walking meditation group.

ลำดับ	อายุ	การประเมิน MNSI (physical assessment)												all
		ข้างขวา						ข้างซ้าย						
		Ulceration	Foot inspection		Vibration	Ankle reflex	monofilament	Ulceration	Foot inspection		Vibration	Ankle reflex	monofilament	
				Note.						Note.				
1	53	0	1	fissure	0.5	0	0.5	0	1	fissure	0.5	0	0.5	4
2	75	0	1	fissure	0.5	0	0.5	0	1	fissure	0.5	0	0.5	4
3	62	0	1	fissure	0	0	0.5	0	1	fissure	0	0	0.5	3
4	66	0	1	fissure	0	0	0.5	0	1	fissure	0.5	0	0.5	3.5
5	71	0	1	fissure	0	0	0.5	0	1	fissure	0	0	0.5	3
6	59	0	1	fissure	0	0	0.5	0	1	fissure	0.5	0	0.5	3.5
7	60	0	1	fissure	0.5	0	0.5	0	1	fissure	0	0	0.5	3.5
8	72	0	1	fissure	0	0	0.5	0	1	fissure	0	0	0.5	3
9	62	0	1	fissure	0	0	0.5	0	1	fissure	0.5	0	0.5	3.5
10	73	0	1	fissure	0	0	0.5	0	1	fissure	0.5	0	0.5	3.5
11	64	0	1	fissure	0	0	0.5	0	1	fissure	0.5	0	0.5	3.5
12	70	0	1	fissure	0.5	0	0.5	0	1	fissure	0.5	0	0.5	4
13	65	0	1	fissure	0	0	0.5	0	1	fissure	0	0	0.5	3.5
14	52	0	1	fissure	0	0	0.5	0	1	fissure	0	0	0.5	3.5

Table 2 Raw data of Michigan neuropathy screening instrument assessment in

ลำดับ	อายุ	การประเมิน MNSI (physical assessment)												all
		ข้างขวา						ข้างซ้าย						
		Ulceration	Foot inspection		Vibration	Ankle reflex	monofilament	Ulceration	Foot inspection		Vibration	Ankle reflex	monofilament	
				Note.						Note.				
1	65	0	1	fissure	0	0	0.5	0	1	fissure	0	0	0.5	3
2	58	0	1	fissure	0.5	0	0.5	0	1	fissure	0.5	0	0.5	4
3	67	0	1	fissure	0	0	0.5	0	1	fissure	0.5	0	0.5	3.5
4	66	0	1	fissure	0.5	0	0.5	0	1	fissure	0	0	0.5	3.5
5	70	0	1	fissure	0.5	0	0.5	0	1	fissure	0.5	0	0.5	4
6	60	0	1	fissure	0	0	0.5	0	1	fissure	0.5	0	0.5	3.5
7	60	0	1	fissure	0	0	0.5	0	1	fissure	0	0	0.5	3
8	73	0	1	fissure	0	0	0.5	0	1	fissure	0.5	0	0.5	3.5
9	61	0	1	fissure	0.5	0	0.5	0	1	fissure	0	0	0.5	3.5
10	62	0	1	fissure	0	0	0.5	0	1	fissure	0	0	0.5	3
11	50	0	1	fissure	0	0	0.5	0	1	fissure	0.5	0	0.5	3.5
12	69	0	1	fissure	0	0	0.5	0	1	fissure	0	0	0.5	3
13	65	0	1	fissure	0.5	0	0.5	0	1	fissure	0	0	0.5	3.5
14	54	0	1	fissure	0	0	0.5	0	1	fissure	0.5	0	0.5	3.5

Table 3 Raw data of timed up and go test at pre- and post-training of the walking meditation and control groups.

No.	Timed up and go test (TUG)			
	Walking meditation group		Control group	
	Pre- training	Post-training	Pre- training	Post-training
1	7.49	7.38	6.97	6.88
2	8.74	8.24	7.41	7.12
3	6.98	6.08	7.56	7.19
4	6.90	5.86	7.03	7.13
5	7.17	6.96	7.73	7.70
6	6.13	6.00	6.75	7.08
7	6.09	6.04	6.97	7.02
8	7.29	7.13	6.95	6.93
9	7.57	6.62	7.12	7.10
10	6.98	7.00	7.50	7.53
11	7.61	6.67	7.32	7.33
12	6.99	6.27	7.34	7.27
13	6.95	6.19	7.14	7.14
14	7.67	7.00	7.10	7.09

Table 4 Raw data of functional reach test)forward, sideward to the left and to the right directions(at pre -and post-training of the walking meditation and control groups.

No.	Functional reach test (FRT)											
	Walking meditation group						Control group					
	Pre- training			Post-training			Pre- training			Post-training		
	FRT-forward	FRT-Lt	FRT-Rt	FRT-forward	FRT-Lt	FRT-Rt	FRT-forward	FRT-Lt	FRT-Rt	FRT-forward	FRT-Lt	FRT-Rt
1	37.47	15.07	25.33	33.17	21.67	29.17	41.00	14.60	25.73	36.67	14.90	25.73
2	24.33	23.00	24.97	25.33	23.03	25.17	24.33	23.00	24.40	23.67	22.87	24.13
3	29.73	19.37	29.20	18.83	32.43	33.93	29.73	19.37	29.20	28.47	20.03	29.27
4	31.33	21.33	21.90	25.87	19.23	31.37	24.80	21.33	22.43	26.93	23.13	23.87
5	29.30	28.17	25.47	21.90	32.63	34.40	32.57	18.67	21.43	32.50	18.90	21.57
6	29.10	24.80	34.63	33.23	16.53	20.37	42.10	19.77	32.13	41.93	19.83	30.50
7	23.07	18.87	18.20	35.93	25.13	17.07	27.57	16.50	17.50	27.40	16.70	16.93
8	20.77	22.77	22.43	29.53	20.40	24.67	28.23	19.83	25.73	27.87	19.57	25.20
9	38.70	18.40	19.77	37.03	37.93	30.33	38.77	12.03	19.77	39.60	12.00	20.20
10	17.00	21.37	18.17	28.73	28.20	13.30	28.43	21.13	27.70	28.37	21.17	27.13
11	21.93	19.7	24.73	22.83	20.00	25.27	28.83	18.77	23.03	29.53	19.23	22.17
12	23.40	21.5	23.57	23.97	21.83	25.10	39.57	20.70	27.60	40.60	20.73	26.90
13	29.80	23.5	31.93	30.10	23.20	32.77	41.67	24.40	32.60	42.70	23.43	32.63
14	35.97	16.3	25.07	35.57	16.73	26.73	40.23	18.13	25.67	41.17	18.63	25.00

Table 5 Raw data of standing on a firm surface with eye-opened and with eye -closed conditions at pre -and post-training of the walking meditation and control groups.

No.	Standing on a firm surface							
	Walking meditation group				Control group			
	Pre-training		Prost-training		Pre-training		Prost-training	
	eye-opened	eye-closed	eye-opened	eye-closed	eye-opened	eye-closed	eye-opened	eye-closed
1	30	30	30	30	30	30	30	30
2	30	30	30	30	30	30	30	30
3	30	30	30	30	30	30	30	30
4	30	30	30	30	30	30	30	30
5	30	30	30	30	30	30	30	30
6	30	30	30	30	30	30	30	30
7	30	30	30	30	30	30	30	30
8	30	30	30	30	30	30	30	30
9	30	30	30	30	30	30	30	30
10	30	30	30	30	30	30	30	30
11	30	30	30	30	30	30	30	30
12	30	30	30	30	30	30	30	30
13	30	30	30	30	30	30	30	30
14	30	30	30	30	30	30	30	30

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