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PREVENTION & REHABILITATION: Randomised Controlled Trial

Walking meditation promotes ankle proprioception and balance performance among elderly women

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ABSTRACT

Background: Age-related change of proprioception affects body balance among the elderly. Walking meditation (WM)—a mindfulness practice—involves focusing on leg movements while walking slowly, possibly improving brain processes for perception and balance adjustments. This study investigates the WM's effects on ankle proprioception and balance among the elderly.

Methods: Fifty-eight women aged 69.25 ± 6.06 were randomized into control ($n = 29$) and WM ($n = 29$) groups. The WM group engaged in 8 weeks of WM practice (30 min/day, 3 days/week). The absolute angular error of the ankle reposition test (AAE) was measured by an electrogoniometer. The balance performance was evaluated using the Berg Balance Scale (BBS), Functional Reach Test (FRT), and Timed Up and Go test (TUG). Data were analyzed using two-way ANOVA and Bonferroni post hoc test and BBS with nonparametric statistics.

Results: At baseline, the WM group's AAE, BBS, FRT, and TUG were $4.2 \pm 1.6°$, 51.3 ± 4.1 points, 21.7 ± 5.7 cm, and 11.1 ± 2.5 s, respectively, whereas those of the control group were $3.6 \pm 2.0°$, 51.0 ± 5.0 points, 21.6 ± 5.2 cm, and 10.2 ± 3.1 s, respectively. Post-training, WM group showed significant decrease in AAE ($2.4 \pm 0.9°$) and displayed improvements in BBS, FRT, and TUG (55.4 ± 0.9 points, 29.1 ± 5.8 cm, and 8.1 ± 1.1 s, respectively) ($p < 0.01$). Conversely, the control group presented no change in AAE, significant decreases in BBS and FRT, and slower TUG ($p < 0.01$). No difference was found between WM and control groups at the baseline. However, post-training, WM group demonstrated significant improvements in AAE, BBS, FRT, and TUG as compared to the control group ($p < 0.001$).

Conclusions: WM practice improved the balance and ankle reposition sense among the elderly. It can be used as an alternative form of training to promote balance and ankle proprioception. The results supported that balance performance worsens among the elders who do not engage in physical training.

1. Introduction

Falling is an incident that occurs commonly among the elderly people, especially women (Gale et al., 2016). With advancing age, balance ability gradually decreases and the fall risk markedly increases (Shumway-Cook et al., 1997; Bramahova and Hlavacka, 2008). Both external and internal factors influence one's balance performance. Besides input from visual and vestibular systems, one important internal factor affecting balance is age-related change in proprioception (Shaffer and Harrison, 2007; Liutsko et al., 2014). Elderly people normally have poor kinesthetic and proprioceptive senses. As a result, they usually respond slowly to postural reaction for balance control when compared to young adults (Goble et al., 2009).

The systematic review and meta-analysis demonstrated that frail elders, who received exercise, showed improvement in their physical function (Gine'-Garriga et al. 2014). The conclusive improvements in physical function included muscle strength, flexibility, and gait speed, but endurance and balance outcomes continued to be inconsistent declarations (Gine'-Garriga et al. 2014). Even though it was still uncertain which exercise characteristics were the most effective, the task-specific and proprioceptive exercises were recommended for balance and functional ability improvements. Also, regular exercise was suggested to maintain the physical performance of the elderly people as opposed to less exercise or low level of physical activity (Kaesler et al., 2007, Gine'-

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Garriga et al. 2014).

Many studies have confirmed that the traditional Chinese form of exercise Tai Chi is effective in maintaining balance among the elderly by way of better proprioception (Xu et al., 2004; Liu et al., 2012; Guo et al., 2014), particularly ankle proprioception (Guo et al., 2014). With its continuous slow movements and conscious awareness of the body moves like body-mindfulness practice, Tai Chi provides proprioceptive and neuromuscular control (Xu et al., 2004; Liu et al., 2012; Guo et al., 2014).

Walking meditation (WM) entails mindfulness practice of the Buddhist style. The practice was performed by concentrating one's attention on leg and foot movements during slow-speed walking. During WM practice, the individual has to be continuously aware and concentrate on his/her body, foot, and leg movements while walking slowly in a peaceful environment. It has some characteristics, such as slow movements with body weight shifting from unilateral to bilateral and body awareness, that are similar to Tai Chi. Thus, WM provides both mental and physical practice, and it may also benefit the balance ability and proprioception of ankle among the elderly.

In addition, current medical science findings have revealed that calmness or peaceful conditions can promote neuronal regeneration. A systematic review and meta-analysis study on meditation practice showed an association with altered brain morphology in some regions, including the regions related to exteroceptive and interoceptive body awareness (Fox et al., 2014). Therefore, the concentrated perception of movements during WM might improve the brain processes involved in ankle proprioception. Moreover, a slow gait activity during WM can be classified as gentle exercise for the elderly. A slow gait speed during WM retains the single leg stance for a longer duration, thereby, providing balance training. Consequently, WM might improve ankle proprioception and balance performance of the elderly.

However, most of the previous studies related to meditation usually investigated its effectiveness concerning the cognitive and psychological functions. There is little evidence related to WM's effects on the physical functions, such as proprioception and balance. Therefore, this study hypothesizes that WM can improve ankle proprioception and balance performance among elderly women.

2. Methods

The study was authorized by the Faculty of Health Science, Srinakharinwirot University (permission document code: MOE 0519.18/HS 477). The study protocol followed the ethical guidelines concerning human research.

2.1. Participants

This study estimated a sample size based on data from the previous study related to the effect of Tai Chi exercise on ankle proprioception in elders (Xu et al., 2004). The sample size was calculated by using G*Power 3.1 with F-test: ANOVA; repeated measure, between factors approach (effect size = 0.44, α = 0.05, power = 0.95, 2 groups). Thus, the total sample size including reservation for 25% dropout was 60 persons (n = 30/group).

Sixty elderly women volunteered for this study. They were informed about the aims of the study and signed the consent form before participation. All the participants lived in Ongkharak district, Nakhon Nayok Province, Thailand. Their physical activity levels, which were evaluated in accordance with WHO criteria, were moderate. They were able to engage in daily activities by themselves and walk independently without any gait aids. They were randomly assigned to a control group (n = 30) or the WM group (n = 30) based on the random draw of lot numbers. Two participants discontinued because one of them moved to another province and another fell ill. Finally, there were 29 participants in each group.

The general characteristics of the participants in the WM and control groups, such as age, weight, height, and body mass index, were not statistically different (see Table 1).

2.2. Intervention

The participants in the WM group attended WM practice for 8 weeks (3 days/week), while the control group engaged in their daily activities as usual. The WM training was conducted by a Buddhist monk, who possessed more than 5 years of experience in WM training. The WM practice was performed with the help of a steady thought (or attention) focusing on the leg and foot movements at every left and right step, alternately, while slowly walking back and forth 8–12 paces repeatedly for 30 min daily.

The proprioceptive sense of right ankle joint and balance performance were assessed at baseline (wk0), the 4th week post-training (wk4), and the 8th week post-training (wk8). The assessors were the same people throughout the experiment and blinded from group randomization.

2.3. Outcome measurements

This study concerned two main outcomes that were related to ankle proprioception and balance performance. The ankle proprioceptive sense was assessed by the absolute angular error of ankle reposition test (AAE) using an electrogoniometer, Biometrics (SG110)®. The balance performance was evaluated using Berg Balance Scale (BBS), Functional Reach Test (FRT), and Timed Up and Go test (TUG).

2.3.1. Absolute angular error of ankle reposition test (AAE)

For AAE measurement, an electrode of electrogoniometer, Biometrics (SG110), was attached to the right ankle at the posterior aspect of calcaneus to the Achilles tendon in parallel. The participant sat a foot clear from the floor on the rim of a high bench with her eyes closed to eliminate visual feedback (see Fig. 1). The starting position of ankle was set at 90°. Then, the ankle was passively

Table 1
Age, body weight and height, and body mass index characteristics of the participants in the study.

Characteristics	Mean ± SD		p-value[a]
	Walking Meditation Group (n = 29)	Control Group (n = 29)	
Age (years)	70.21 ± 6.97	68.28 ± 5.15	0.235
Body weight (kg.)	52.19 ± 9.42	55.59 ± 11.72	0.229
Body height (cm.)	151.31 ± 3.55	152.55 ± 6.07	0.347
Body mass index (kg/m^2)	22.74 ± 3.90	23.82 ± 4.36	0.321

[a] p-value by unpaired *t*-test.

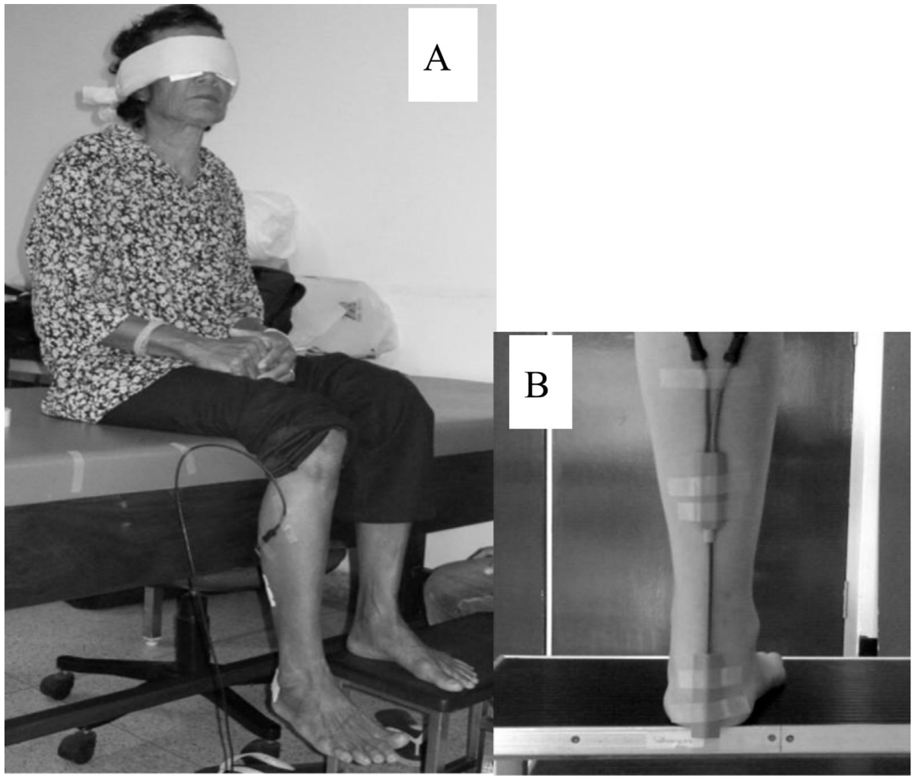

Fig. 1. Absolute angular error of the ankle reposition test. (A) Starting position of a participant. (B) Placement of an electrogoniometer electrode (Biometrics, SG110).

moved to the testing position, as dorsiflexion or plantarflexion, and held at that position for 5 s to let the participant perceive the position. After that, the ankle was relaxed for 5 s, and then the participant was asked to engage in an active reposition of the ankle at each testing position. Six testing positions—three positions for dorsiflexion and the remaining for plantarflexion—were randomly tested with a 30-s rest between each testing position. Signals from the electrogoniometer were recorded. The average AAE of each subject was calculated from the 6 testing positions. All the participants received a practice session for the purpose of understanding and rested for 1 min before testing (Kim et al., 2014).

2.3.2. Balance performance evaluation

The balance performance of each participant was evaluated with the help of the following assessment tools: Berg balance scale (BBS), Functional Reach Test (FRT), and Timed Up and Go test (TUG). For BBS (Berg et al., 1992), each participant performed 14 activities: sitting unsupported, sit-to-stand, standing unsupported, stand-to-sit, transfer from chair to chair, stand with eyes closed, stand with feet together, stand and turn to look behind, reach forward, retrieve object from floor, turn 360°, alternate foot placing on a stool, stand in tandem position, and single leg stance. Each activity was rated on a 5-point rating scale (0–4 points). Thus, the total score of 14 activities was 56 points. A higher score represented a better balance ability.

For FRT (Duncan et al., 1992), the participant stood and flexed her right shoulder at 90°, keeping the elbow straight. Then, the participant was asked to reach forward as far as she could and the reaching distance was measured. The represented reaching distance was the average value of three trials.

For TUG (Podsiadlo and Richardson, 1991), each participant started from sitting on a chair, stood up, walked forward for 3 m, turned, and walked back to sit on the chair. The time from start to finish of the activity was recorded. The test was performed for three trials. The represented TUG for each subject was the average of the three trials.

2.4. Statistical analysis

The main effects of WM and time of training on the studied parameters were analyzed by a two-way ANOVA mixed model and post hoc by Bonferroni, except BBS. The BBS data were analyzed using non-parametric statistics, because the data were not normally distributed. Wilcoxon sign-rank test and Mann-Whitney *U* test were used to compare, both within and between the groups, the BBS parameters. The statistical significance was set at $p < 0.05$.

3. Results

3.1. Absolute angular error of ankle reposition test (AAE)

There was a significant time effect and time × group interaction concerning AAE (see Table 2). AAE in wk8 of the WM group was significantly less than wk4 and wk0 ($p < 0.01$) (see Table 3). The WM group also demonstrated significantly less AAE than the control group in wk8 ($p = 0.001$) but did not show any difference at the baseline and in wk4 (see Table 3). In contrast, the control group did not present any statistical difference with regard to AAE in wk0, wk4, and wk8. However, it was found that the control group revealed a tendency toward a greater increase in AAE in wk8 than in wk4 and wk0 (see Table 3).

3.2. Balance performance

WM and control groups did not show any significant difference in BBS at the baseline (wk0). Post-training, the WM group

Table 2
The effects of groups (walking meditation and control groups), time (week 0, week 4, and week 8), and time × group interaction analyzed by a two-way ANOVA mixed model.

Studied Parameters	F	p-value
Absolute angular error of ankle reposition test (AAE)		
groups	1.91	0.173
time	6.04	0.003[a]
time x group	13.11	0.001[a]
Functional Reach Test (FRT)		
groups	17.21	0.001[a]
time	12.13	0.001[a]
time x group	78.98	0.001[a]
Timed Up and Go (TUG)		
groups	9.13	0.004[a]
time	3.13	0.048[b]
time x group	57.07	0.001[a]

[a] Significant difference at $p < 0.01$.
[b] Significant difference at $p < 0.05$.

presented a significantly higher BBS score than the control group in wk4 and wk8 ($p = 0.001$) (see Table 3). When considering the time of training within groups, the WM group showed a significant increase in BBS at wk8 as compared to wk4 and wk0 ($p < 0.001$) (see Table 3). Conversely, the control group demonstrated lower BBS scores in wk8 and wk4 when compared to wk0, i.e., at $p < 0.01$ and $p < 0.05$, respectively (see Table 3).

There were statistically significant effects of group, time, and time × group interactions on FRT and TUG (see Table 2). As a group effect, WM group showed a significantly farther-reaching distance for FRT and faster time used for TUG in wk4 and wk8 as compared to the control group ($p < 0.01$) (see Table 3). As a time effect, the WM group demonstrated a farther FRT and a faster TUG since wk4 after training when compared to wk0, which improved further in wk8 ($p < 0.01$) (see Table 3). On the other hand, the control group had shorter FRT distance and slower TUG in wk8 when compared to wk4 and wk0 ($p < 0.01$), respectively (see Table 3). When considering a time × group interaction, WM group demonstrated FRT and TUG improvements along the training time, whereas the control group showed deteriorations with respect to training time.

4. Discussion

This study's results presented that WM practice not only improved balance ability but also enhanced ankle proprioception among the elderly women. WM training can enhance BBS, TUG, and FRT from wk4 after training and can later improve AAE in wk8 when compared to the control group. Therefore, the underlying mechanism of balance improvement with the help of WM might not only be the improvement in ankle proprioception but also an improvement in the muscle control and postural adjustment, which might be a training effect resulting from slow-speed walking.

Since WM practice is a slow walking-like gentle exercise, it will be an added physical activity for the elderly women besides their daily activities. It was found that elders who are engaged in physical activities showed better ankle proprioception than the ones who did not do any kind of physical activity (Petrella et al., 1997). Therefore, the walking activity in WM practice is like a physical activity that can promote ankle proprioception among the elders.

In addition, several studies found that, besides the physical movement, the conscious awareness component of Tai chi was also an underlying mechanism of balance and proprioceptive improvement among the elderly (Xu et al., 2004; Liu et al., 2012; Guo et al., 2014). Long-term Tai chi practitioners also showed better ankle proprioception than swimmers/runners or those with sedentary controls (Xu et al., 2004). Similar to Tai chi, WM involves slow and smooth movements coupled with conscious awareness or meditation. It can also provide effective training factors for proprioception and neuromuscular control to improve ankle proprioception and functional balance (Xu et al., 2003).

Moreover, the previous research showed that the body-scan meditation practice promoted the perceptual decision-making to distinguish a main somatosensory signal from other interfering sensations. Thus, meditation practice in the WM group might help in reducing the misperception of AAE or improving the ankle proprioception (Mirams et al., 2013). Furthermore, the systematic review and meta-analysis study found that the meditation practice was consistently associated with brain morphology alteration in some areas (Fox et al., 2014). The most responsible brain morphological changes included the regions related to exteroceptive and interoceptive body awareness (sensory cortices and insula) (Fox et al., 2014). So, the mindfulness practice in WM, which focuses on the movements of ankles and feet during walking, might encourage the brain processes for an improved perception of ankle positions.

Table 3
The absolute angular error of ankle reposition test (AAE), Berg Balance Scale (BBS), Functional Reach Test (FRT), and Timed Up and Go (TUG) of the walking meditation and control groups at baseline (wk0), week4 (wk4), and week8 (wk8) post-training.

Parameters	Mean ± SD		p-value compared between groups
	Control group (n = 29)	Walking meditation group (n = 29)	
AAE (degrees)			
wk0	3.6 ± 2.0	4.2 ± 1.6	0.176
wk4	3.2 ± 1.5	$3.0 \pm 0.8^{**}$	0.597
wk8	4.2 ± 2.2	$2.4 \pm 0.9^{**,\#\#}$	0.001^{++}
BBS (points)			
wk0	51.0 ± 5.0	51.3 ± 4.1	0.969
wk4	$49.3 \pm 4.7^{*}$	$54.3 \pm 2.0^{**}$	0.001^{++}
wk8	$48.7 \pm 5.0^{**}$	$55.4 \pm 0.9^{**,\#\#}$	0.001^{++}
FRT (centimeters)			
wk0	21.6 ± 5.2	21.7 ± 5.7	0.954
wk4	20.3 ± 4.4	$25.5 \pm 5.7^{**}$	0.001^{++}
wk8	$18.4 \pm 4.2^{**,\#\#}$	$29.1 \pm 5.8^{**,\#\#}$	0.001^{++}
TUG (seconds)			
wk0	10.2 ± 3.1	11.1 ± 2.5	0.220
wk4	11.2 ± 2.7	$9.2 \pm 1.6^{**}$	0.002^{++}
wk8	$12.1 \pm 2.6^{**,\#\#}$	$8.1 \pm 1.1^{**,\#\#}$	0.001^{++}

Significant difference within the group; compared to wk0 $^{*}p < 0.05$, $^{**}p < 0.01$, compared to wk4 $^{\#\#}p < 0.01$, and significant difference between groups $^{++}p < 0.01$.

Although the balance performance of the elders in the WM group showed statistically significant and improved scores related to BBS, FRT, or TUG from wk4 after training, the mean scores of these parameters improved and reached the normative data of the community-dwelling elders later at wk8, especially the scores concerning BBS and TUG (Steffen et al., 2002). Also, the change of BBS in the WM group after 8 weeks of practice was greater than that of the minimal detectable change in BBS among the elderly (Donoghue et al. 2009). Therefore, this confirmed that WM can remarkably improve the elderly women's balance performance when practiced at least 8 weeks (30 min a day, 3 days/week).

The improvement of FRT in WM can be explained by the biomechanics of slow-speed walking. Since WM practice involves slow walking, the participants had to maintain the eccentric control of gastrosoleus in a single leg support during a transitional period from mid-stance to heel-off, which was longer than their daily or fast speed walking (Van Hedel et al., 2006). Thus, WM practice challenges the eccentric control of gastrosoleus, which is an important function of the calf muscles to maintain balance while reaching forward (Maranesi et al., 2016).

In contrast, the control group presented deteriorations in AAE, BBS, TUG, and FRT, particularly in wk8, as compared to the baseline. These deteriorations can support the previous studies that suggested balance ability and proprioception of the elderly are associated with age-related decline (Bramahova and Hlavacka, 2008; Granacher et al., 2008). Moreover, especially in wk8, the control group showed a tendency to decrease the FRT distance, which was less than the cut-off score for fall risk (<18.5 cm) that was found in fallers aged 79.7 ± 6.7 (Thomas and Lane, 2005). This might suggest that elders with moderate physical activity level should receive additional physical exercise to maintain or promote their balance. Additionally, WM practice, at least 30 min a day and thrice a week, can be one of the recommended additional exercises to maintain or promote balance ability for the elderly women.

4.1. Limitations of the study

This study included only the elders with moderate physical activity level. Thus, this study's results cannot refer to the elders with high or low physical activity levels. Also, this study did not examine the functional changes of the brain during WM practice. Therefore, the improvement of ankle proprioception in this study might not be clearly linked to the improvement of brain processes from meditation or mindfulness mechanisms.

4.2. Future research directions

The effects of WM on ankle proprioception and balance in elders with different physical activity levels and among people with impaired ankle proprioception or balance require further investigation. Future research related to brain activities and biomechanics of WM would be exciting. Furthermore, the comparative effects on the balance and proprioception due to meditation, both with and without walking, would be interesting to know.

5. Conclusions

WM improved ankle proprioception and balance performance of the elderly women. The characteristics of WM, as a slow walking form along with the mindfulness of foot and leg movements, provided a longer period of single leg stance and increased the neuromuscular control. Therefore, WM is a gentle exercise and balance training form with body-mind practice that promotes proprioception and balance performance among the elders. Additionally, the results also supported that balance performance and ankle proprioception are related to the age-related decline among elders, who do not engage in any kind of physical training.

Declarations of interest

None.

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