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Balance and functional fitness benefits of a Thai boxing dance program among community-dwelling older adults at risk of falling: A randomized controlled study

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ABSTRACT

Objective: The present study aimed at examining the effects of a Thai Boxing dance (TBD) program on balance performances and functional fitness in community-dwelling older adults at risk of falling who have no comorbidities leading to falls.

Methods: Seventy-eight participants were randomly equally assigned either to a 4-week TBD program or to a control group receiving a fall prevention booklet. Static and dynamic balance performances, and functional fitness including lower limb muscle strength, body flexibility, and agility were evaluated before and after the intervention, and at 4-month follow-up.

Results: After receiving 4-week TBD intervention, participants showed significantly greater improvements in static balance with eyes open, dynamic balance and all functional fitness when compared to the control group ($p < 0.05$), and these effects except for body flexibility were still maintained at 4-month follow-up ($p < 0.05$).

Conclusions: This study highlights TBD as an intervention for improving balance and functional fitness of community-dwelling seniors at risk of falling.

1. Introduction

An increase in life expectancy resulting from advances in modern medicine raises the proportion of older people in modern societies (Chen et al., 2016; Kapteyn, 2010). Similar to other developing countries, in 2018, the Thai senior population was reported to be growing rapidly with over 16.10% of the population aged over 60 years (Social & Quality of Life Database System of Thailand, 2019) and it was projected to go up to 19.2% by 2020 (Department of Older Persons, 2017). Falls have been a common threatening problem facing the older adults and they are defined as unexpected events in which the person unintentionally comes to rest on the ground, floor, or lower level (Donath, van Dieën, & Faude, 2016). One-third of older adults fall every year and half of them will report falling again in the subsequent year (Rubenstein, 2006). Fall-related injuries cause hospitalization due to serious injuries and lead to increasing health care costs and the tendency of dependence (Fernández-Argüelles, Rodríguez-Mansilla, Antunez, Garrido-Ardila, & Muñoz, 2015; Jones, Ghosh, Horn, Smith, & Vogt, 2011).

Multifactorial problems with extrinsic and intrinsic risk factors result in falls (Karlsson, Magnusson, von Schewelov, & Rosengren, 2013). Particularly, intrinsic risk factors for falling including decreased postural balance, sensory impairment, muscle weakness, and decreased agility have been identified (Jeoung, 2015; Karlsson et al., 2013). Among the intrinsic factors, Shumway-Cook, Baldwin, Polissar, and Gruber (1997) proposed that decreased postural balance and movement skills in the older adults without comorbidities may be very strong predictors of the likelihood for falls. Numerous aging-induced anatomical and physiological changes in the older persons have been proposed to cause difficulties in information feedback to the afferent and efferent neural pathways, which decreases the performance of postural control centers (Barbieri & VitÓrio, 2017). As a result, physical degeneration of the older people contributes to decreased functional capacity, level of physical activity and poor response of the postural muscles to disturbances, and an increased rate of falls (Donath et al., 2016; Fernández-Argüelles et al., 2015; Barbieri & VitÓrio, 2017). Jeoung (2015) reported a moderate degree of correlation between postural control deficits, and low physical activity as well as fear of falls. In this regard, interventions having the main aim of improving intrinsic factors including balance and functional fitness of older adults

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at risk of falling which are easier to identify and have greater potential for being controlled would be beneficial (Bueno-Cavanillas, Padilla-Ruiz, Jimenez-Moleon, Peinado-Alonso, & Galvez-Vargas, 2000).

An increased knowledge regarding intrinsic factors contributing to falls in older adults has convinced to the development of several fall prevention interventions. Physical exercises have been considered as a preventive method for reducing risk of falling, although standard protocols of training for older adults indicating intensity, duration and frequency of exercises needed to obtain advantages from those, are still lacking (Fernández-Argüelles et al., 2015). Initiation and maintenance of the habit of regular exercise in older people is quite difficult when compared to young people due to lack of interest (Eyigor, Karapolat, Durmaz, Ibisoglu, & Cakir, 2009). It has been suggested that cultural dance-based exercise could make the exercise for the older persons more interesting (Eyigor et al., 2009; Hui, Chui, & Woo, 2009) because it relates to their cultural context, traditions, lifestyles and needs, and because it can be performed individually or in a group (Janyacharoen, Laophosri, Kanpittaya, Auvichayapat, & Sawanyawisuth, 2013). Currently, there are several types of cultural dance exercise for senior adults including Tai Chi Chuan (Rahal et al., 2015), Turkish folkloric dance (Eyigor et al., 2009), Greek dance (Sofianidis, Hatzitaki, Douka, & Grouios, 2009) and samba dance (Serra et al., 2016). A recent systematic review showed that these dances significantly improved balance, gait and dynamic movement, lower limb strength, and physical performance of older adults (Fernández-Argüelles et al., 2015). Thai Boxing or Muay Thai, a martial art of Thai people, has gained international attention in recent years (Vail, 2014). Nowadays it has been applied as a dance exercise with music for older people (Tantiwiboonchai, Kritpet, & Yuktanandana, 2017). It allows the use of punches, kicks, and elbow and knee strikes to create exercise (Vail, 2014). Only one study by Tantiwiboonchai et al. (2017) examined the effects of Thai Boxing aerobic dance in healthy seniors and found that this intervention could reduce the bone absorption process, improve lower muscle strength and endurance, and static and dynamic balance in those participants. As Thai Boxing dance (TBD) provides a multi-directional movement, low impact exercise, and may be a socially engaging mode of physical activity, it may be a choice of exercise for older persons (Keogh, Kilding, Pidgeon, Ashley, & Gillis, 2009; Tantiwiboonchai et al., 2017). However, there is no evidence for therapists who need to prescribe the TBD for the individuals of advanced age at risk of falling. Therefore, the objective of this study was to evaluate the effects of TBD on static and dynamic balance performance, and functional fitness for community-dwelling older adults at risk of falling who have no comorbidities leading to falls.

2. Methods

2.1. Study design

This study was designed as a single-blinded randomized controlled trial with three measurement points: baseline assessment, 4-week intervention, and 4-month follow-up from baseline. It was conducted between October 2016 and May 2017 at two primary health care units of Mae Chan district, Chiang Rai, Thailand.

2.2. Participants

Males or female ($n = 78$) volunteers who were sedentary defined as any waking activity in a sitting or reclining position such as watching TV and other seated or lying activities, non-disabled, community-dwelling adults, aged 60 years and older, and lived in Chiang Rai province, were asked to participate in this study. They were recruited through advertisement via local senior centers and primary health care units. Interested older adults were screened whether they met the criteria of this study by a medical doctor who was not aware of participant recruitment and interventions. Older adults were included in this study if they were able to walk independently without gait-aid devices and participate in a TBD exercise program without any existing symptoms such as angina pectoris or dizziness, and if they had a risk of falling measured by using Berg Balance Scale (BBS) less than 49 score (Santos, Souza, Virtuoso, Tavares, & Mazo, 2011), had clear comprehension and adequate hearing and vision, and were willing to be randomly allocated. Older adults were excluded if they had cognitive impairment defined as having a score of Mini-Mental State Examination (MMSE) less than 25 (Cameron & Monroe, 2011), disorders or diseases including major unstable cardiopulmonary conditions, neurological conditions and neuropathy, cancer, severe orthopedic conditions such as spinal stenosis, arthritis of lower extremities screened by using oral illness history taking and a physical examination, or regular participation in MTD. The eligible participants gave written informed consent before participation. This study was approved by the Human Research Ethics Committee of Mae Fah Luang University (REH-60129), based on the Declaration of Helsinki. This study was also registered at the website of Thai Clinical Trials Registry (TCTR20180208001).

2.3. Sample size calculation

The sample size was estimated using a formula of repeated measures analysis of variance (ANOVA) on the basis of the Timed Up and Go (TUG) test. Regarding our pilot study, an effect size of 0.72 was found for TUG test in community-dwelling older adults at risk of falling and assuming a significance level of 0.05, and power of 0.90. A sample size of 39 was required for each group that allowed for 30% attrition.

2.4. Intervention

Seventy-eight eligible participants were randomly assigned to TBD group ($n = 39$) or fall prevention educational booklet group (control group) ($n = 39$) by a simple randomization method. Randomization results were concealed in a sealed and opaque envelope. A research assistant who was unaware of intervention and evaluation processes administered the randomization. At this time, the participants who participated in the TBD group would be offered a fall prevention educational booklet after the study was terminated. Similarly, those in the fall prevention educational booklet group would be offered a TBD program as well.

2.4.1. Thai boxing dance (TBD) program

The 4-week TBD program was modified from Kantamara (2010) and Tantiwiboonchai et al. (2017). The participants in this group were appointed to familiarize themselves with this program on one day prior to the experiment. The TBD program was conducted as a group dance program with a maximum of 10 participants in each group. Prior to performing dance exercises, the participants warmed up on a stationary bicycle for 5 min with a light load (25 W) at a comfortable speed (40 rotations per minute) and did 5 min of upper and lower limb stretching. This was followed by 30 min TBD with specific patterns including straight punch to the face, hook to the face, uppercut to the chin, long uppercut to the chin, downward elbow to the face, side hook elbow to the chin, uppercut elbow to the chin, upward elbow to the chin, reverse elbow to the chin and low kick to the outside of a thigh (See the supplementary material). While performing each pattern, the participants stepped in a square-like direction following a Muay Thai song. The dance was taught by progressing from the choreography at a slow pace at weeks 1 and 2 to a faster pace at weeks 3 and 4. This allowed a body transition from double standing to step standing or one leg standing and emphasized shifts and changes of base of support. Each pattern of TBD was performed 10 times. This dance continued for over 30 min session, three sessions per week; however, the participant could rest at any time during the dance period if they had any uncomfortable symptoms or felt tired. After the dance intervention, there followed a 10 min cool-down by walking and muscle stretching similar to the warm-up period. Each

TBD group was led by a trained instructor with four assistants, all of whom danced with the participants so that each participant was guided and corrected.

It was important to ask the participants to attend the class regularly through the period of the TBD program. To increase rate of adherence, the participant was given a log book for appointment. All participants were called to remind them of the appointment via telephone one day before dance training. Thus, no participant missed this program over the intervention period.

2.4.2. Fall prevention educational booklet group (control group)

Each participant in this group received a fall prevention educational booklet that comprised factors of falling, prevention of falling, modification of environment and home, and exercise intervention modified from Otago exercise program to prevent falls in older adults such as 15-min walking, knee extension and flexion strengthening and sit-to-stand exercises (Campbell & Robertson, 2003). Each exercise was done for 10 times per session and three sessions over 5 min. They were asked to follow this booklet and perform exercises on a daily basis and instructed to complete a daily logbook.

After 4 weeks of intervention period, all participants were asked to stop their intervention in order to evaluate detraining effects at 4-month follow-up from baseline.

2.5. Outcome measures

All outcome measures were assessed by a trained evaluator with 10-year experience in physical therapy who was blinded to the participant randomization. At the end of intervention, the adverse effects of each intervention were asked.

2.5.1. Primary outcome

2.5.1.1. Dynamic balance performance. The Timed Up and Go (TUG) test is commonly used for evaluating dynamic balance performance in the elderly and it shows high sensitivity and specificity for fall prediction in older adults (Shumway-Cook, Brauer, & Woollacott, 2000) with excellent rater-reliability (ICC = 0.94) (Hofheinz & Schusterschitz, 2010). It includes a series of movements of sitting, standing, walking, and postural control. The participants were asked to rise from an armless chair (46 cm height), walk 3 m as quickly and safely as possible, turn around at a cone placement, walk back, and sit down again (Podsiadlo & Richardson, 1991). The test was performed twice consecutively and a maximum score in seconds was recorded using a stopwatch.

2.5.2. Secondary outcomes

Secondary outcomes consisted of static balance performance, lower limb muscle strength, agility, and back and leg flexibility.

2.5.2.1. Static balance performance. This was evaluated using the sharpened (tandem) Romberg test which has high reliability (Hile et al., 2012). The participant was asked to stand with the non-dominant foot directly in front of the dominant foot with the heel of the non-dominant foot touching the toe of the dominant foot. They were told to wear comfortable footwear. They were tested for a maximum of 60 s each with open or closed eyes. The maximum length of time that participants maintained this position under each condition was recorded. The test was terminated if any foot changed from the original position or hopping occurred.

2.5.2.2. Lower limb muscle strength. The hip flexors, hip extensors, hip abductors, hip adductors, knee flexors, knee extensors, ankle dorsiflexors and ankle plantarflexors of both legs were quantified using a push-pull dynamometer (Baseline® Hydrolic Dynamometer 100 lb/45 kg, USA). The measurement procedures were performed as previously described (Mentiplay et al., 2015). The intra-rater reliability of the assessor of the present study showed moderate to high reliability for all muscles (hip flexors; ICC = 0.82, hip extensors; ICC = 0.89, hip abductors; ICC = 0.76, hip adductors; ICC = 0.91, knee flexors; ICC = 0.88, knee extensors; ICC = 0.81, ankle dorsiflexors; ICC = 0.71, and ankle plantarflexors; ICC = 0.94). Each muscle was tested 3 times with 1 min rest and the average value was recorded.

2.5.2.3. Back and leg flexibility. This was assessed using the chair sit and reach test by asking the participants to be seated on the edge of a chair (17 in. height) while keeping a tested leg extended with ankle dorsiflexion. Then, they reached the toes of the tested leg by their hands and the distance between their fingers and the tips of the toes was measured in cm using a ruler by the blinded assessor. The participants then did this test with the opposite leg. This test was repeated 3 times and a maximum distance for each side was noted (Bhattacharya, Deka, & Roy, 2016).

2.5.2.4. Agility. It was assessed using the 8-foot Up and Go test. It was administered by asking the participants to rise from an armless chair and walk 8 feet as quickly and safely as possible, then turn at a cone and return to the chair. The participants were asked to perform twice consecutively and the maximum score in seconds was recorded (Tongterm, Suputtitada, Lawsirirat, & Janwantanakul, 2015).

2.6. Statistical analysis

The comparability between groups on balance and functional fitness variables was computed using the SPSS program version 20.0 (IBM Corporation, Armonk, NY, USA). Means, standard deviations and 95% confidence intervals (CI) were shown for data. The normality of the distribution was considered with the Shapiro-Wilk test and normal distributed of all data was found. Data was analyzed using a 2 (group) × 3 (test time) analysis of variance (ANOVA) with repeated measures to look for significant interaction (group × time) effects between the groups. Significant interaction effects were further compared using post-hoc Bonferroni pairwise comparisons. The significant level was set at $p < 0.05$.

3. Results

Two hundred ninety-seven older adults were assessed for eligibility and 78 eligible participants were randomized to TBD or control group. One hundred fifty-one elderly were excluded with a BBS score of more than 49, and another fifty-one were not included due to a MMSE score of less than 25 (Fig. 1). The baseline characteristics of participants of each group are presented in Table 1. They were similar between the groups. There was no loss to follow-up and compliance rate of participants was high with 100% and 96% for the group attending TBD and the group following the exercises in the fall prevention educational booklet, respectively. No participants reported any adverse effects during the interventions.

3.1. Dynamic balance performance

A significant group × time interaction effect for the TUG test ($F_{2,74} = 27.13$, $p < 0.001$) was indicated. A post-hoc analysis showed that the TBD group had significantly greater improvement in dynamic balance performance at each follow-up compared to the controls with a mean difference of 1.43 ± 0.27 s (95% CI = 0.90–1.96; $p < 0.001$) at 4-week intervention, and 2.08 ± 0.33 (95% CI = 1.42–2.74; $p < 0.001$) at 4-month follow-up (Fig. 2).

3.2. Static balance performance

Significant interaction effects on the sharpened Romberg test for both open ($F_{2,74} = 62.11$, $p < 0.001$) and closed eyes ($F_{2,74} = 6.81$,

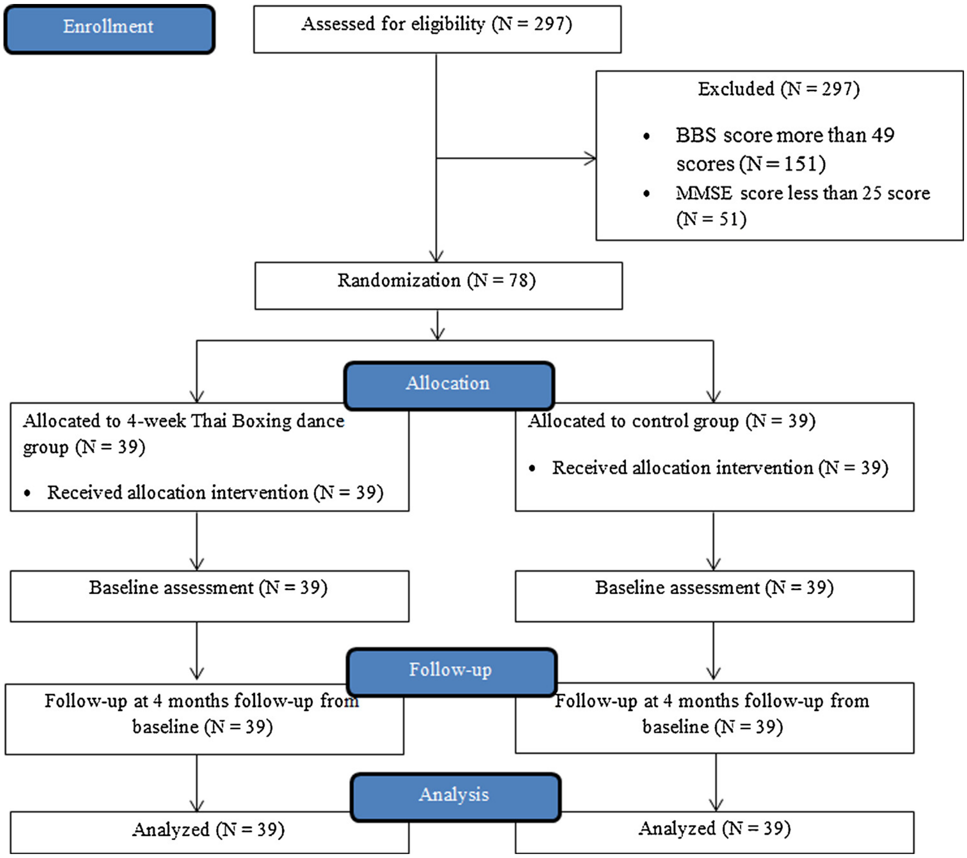

Fig. 1. Flow of the participants.

Table 1
Baseline characteristics of the participants.

Characteristics	Thai Boxing dance group (N = 39)	Control group (N = 39)	*p*-value
Age (year), mean ± SD	66.33 ± 4.33	67.33 ± 4.04	0.88
Gender, n (% female)	33 (84.44)	32 (83.33)	0.91
Height (cm), mean ± SD	154.89 ± 5.71	154.28 ± 6.06	0.98
Weight (kg), mean ± SD	55.83 ± 10.59	56.72 ± 8.07	0.85
MMSE (score), mean ± SD	28.33 ± 1.50	27.78 ± 1.87	0.83
Marital status (%) (single/married)	11.8/88.2	12.4/87.6	0.86
Education (%) (primary school)	74.70	73.80	0.89

Note: MMSE, Mini-Mental State Examination; SD, standard deviation.

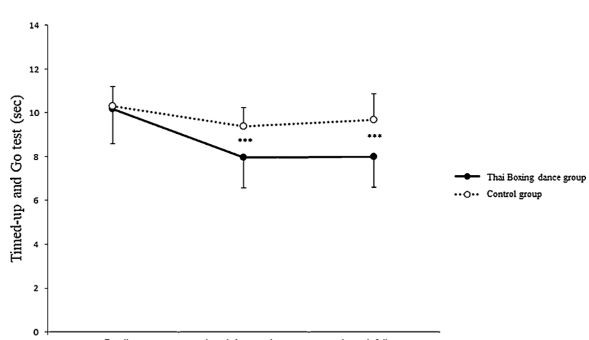

Fig. 2. Dynamic balance performance at baseline, after 4 weeks of intervention, and at 4-month follow-up, in Thai Boxing dance (n = 39) and control (n = 39) groups. ***$p < 0.001$ for the difference between groups at each time point.

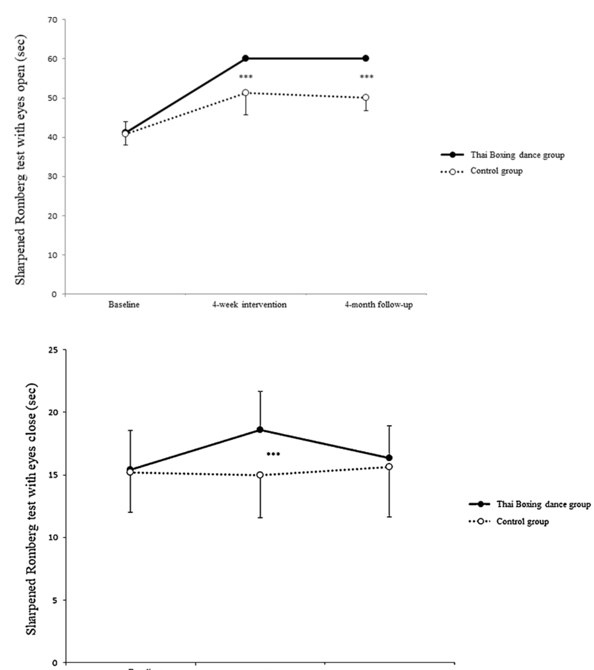

Fig. 3. (A) Static balance performance with eyes open at baseline, after 4 weeks of intervention, and at 4-months follow-up, in Thai Boxing dance (n = 39) and control (n = 39) groups. ***$p < 0.001$ for the difference between groups at each time point. (B) Static balance performance with eyes closed at baseline, after 4 weeks of intervention, and at 4-months follow-up, in Thai Boxing dance (n = 39) and control (n = 39) groups. ***$p < 0.001$ for the difference between groups at each time point.

Table 2
Between group comparisons for muscle strength of lower limb.

Variables	Thai Boxing dance group (n = 39), mean ± SD	Control group (n = 39), mean ± SD	Thai Boxing dance group vs control group, mean ± SD (95% CI)
Left hip flexors (kg)			
Baseline	5.79 ± 0.85	5.79 ± 0.73	0.001 ± 0.18 (−0.36 to 0.36)
4-week intervention	6.22 ± 0.83	5.74 ± 0.82	0.48 ± 0.19 (0.10 to 0.85)*
4-month follow-up	6.07 ± 0.81	5.60 ± 0.79	0.46 ± 0.18 (0.10 to 0.83) *
Right hip flexors (kg)			
Baseline	5.75 ± 1.41	5.86 ± 0.91	−0.10 ± 0.27 (−0.65 to 0.44)
4-week intervention	6.42 ± 1.96	5.54 ± 1.40	0.87 ± 0.39 (0.09 to 1.65)*
4-month follow-up	6.37 ± 1.94	5.47 ± 1.47	0.91 ± 0.40 (0.12 to 1.69)*
Left hip extensors (kg)			
Baseline	5.61 ± 0.75	5.77 ± 0.91	−0.16 ± 0.19 (−0.53 to 0.22)
4-week intervention	6.04 ± 0.91	5.68 ± 0.92	0.34 ± 0.21 (−0.06 to 0.78)
4-month follow-up	5.95 ± 0.86	5.46 ± 0.84	0.49 ± 0.20 (0.10 to 0.88)*
Right hip extensors (kg)			
Baseline	5.77 ± 0.54	5.76 ± 1.26	0.01 ± 0.22 (−0.43 to 0.45)
4-week intervention	6.09 ± 0.71	5.73 ± 1.37	0.36 ± 0.25 (−0.14 to 0.86)
4-month follow-up	6.09 ± 0.74	5.62 ± 1.16	0.46 ± 0.22 (0.01 to 0.90)*
Left knee flexors (kg)			
Baseline	5.27 ± 1.62	5.07 ± 1.11	0.20 ± 0.32 (−0.44 to 0.83)
4-week intervention	5.82 ± 1.46	4.93 ± 0.84	0.89 ± 0.27 (0.34 to 1.44)**
4-month follow-up	5.62 ± 1.45	4.77 ± 0.85	0.85 ± 0.27 (0.31 to 1.40)**
Right knee flexors (kg)			
Baseline	5.29 ± 1.59	5.04 ± 1.00	0.26 ± 0.30 (−0.35 to 0.86)
4-week intervention	5.80 ± 1.62	5.00 ± 1.06	0.80 ± 0.31 (0.17 to 1.42)*
4-month follow-up	5.56 ± 1.58	4.67 ± 1.05	0.89 ± 0.31 (0.28 to 1.50)**
Left knee extensors (kg)			
Baseline	4.83 ± 1.14	4.68 ± 1.00	0.15 ± 0.25 (−0.34 to 0.64)
4-week intervention	5.41 ± 1.13	4.78 ± 0.99	0.63 ± 0.24 (0.15 to 1.12)*
4-month follow-up	5.24 ± 1.11	4.62 ± 0.98	0.62 ± 0.24 (0.13 to 1.09)*
Right knee extensors (kg)			
Baseline	4.97 ± 1.22	4.58 ± 1.14	0.39 ± 0.27 (−0.15 to 0.93)
4-week intervention	5.54 ± 1.21	4.74 ± 1.05	0.80 ± 0.26 (0.28 to 1.32)**
4-month follow-up	5.37 ± 1.20	4.56 ± 1.07	0.81 ± 0.26 (0.30 to 1.34)**
Left ankle dorsiflexors (kg)			
Baseline	3.87 ± 0.61	3.66 ± 0.34	0.22 ± 0.11 (−0.01 to 0.44)
4-week intervention	4.13 ± 0.94	3.67 ± 0.35	0.46 ± 0.16 (0.13 to 0.78)**
4-month follow-up	4.10 ± 0.66	3.64 ± 0.34	0.46 ± 0.12 (0.22 to 0.70***
Right ankle dorsiflexors (kg)			
Baseline	3.83 ± 0.54	3.77 ± 0.33	0.05 ± 0.10 (−0.15 to 0.26)
4-week intervention	4.04 ± 0.89	3.72 ± 0.32	0.32 ± 0.15 (0.02 to 0.63)*
4-month follow-up	4.01 ± 0.58	3.71 ± 0.31	0.30 ± 0.11 (0.09 to 0.51)**
Left ankle plantarflexors (kg)			
Baseline	3.87 ± 0.58	3.73 ± 0.31	0.14 ± 0.11 (−0.07 to 0.35)
4-week intervention	4.23 ± 0.59	3.73 ± 0.34	0.51 ± 0.11 (0.29 to 0.73)***
4-month follow-up	4.07 ± 0.59	3.71 ± 0.38	0.36 ± 0.11 (0.13 to 0.59)**
Right ankle plantarflexors (kg)			
Baseline	3.85 ± 0.62	3.68 ± 0.30	0.17 ± 0.11 (−0.06 to 0.39)
4-week intervention	4.21 ± 0.61	3.70 ± 0.36	0.51 ± 0.12 (0.28 to 0.74)***
4-month follow-up	4.06 ± 0.61	3.65 ± 0.34	0.41 ± 0.11 (0.18 to 0.63)**

Note: SD, standard deviation; CI, confidence interval; kg, kilogram.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$ for the difference between groups at each time point.

$p < 0.001$) were observed. Compared to the control group, the improvements of this outcome with eyes open in each follow-up period were significantly greater in the TBD group with a mean difference of 8.51 ± 0.91 (95% CI = 6.70–10.32; $p < 0.001$) at 4-week intervention, and 9.26 ± 0.61 (95% CI = 8.05–10.48; $p < 0.001$) at 4-month follow-up (Fig. 3a). The TBD group also showed significantly greater improvement in the sharpened Romberg test with eyes closed at 4-week intervention compared with the control group with a mean difference of 3.63 ± 0.74 (95% CI = 2.16–5.11; $p < 0.001$) while it did not demonstrate a significant difference between groups of this outcome for closed eyes at 4-month follow-up (Fig. 3b).

3.3. Lower limb muscle strength

Table 2 indicates the significant group × time interaction effects of the strength of all lower limb muscles ($p < 0.05$). Post-hoc analysis revealed that the TBD provided significantly greater muscle strength of hip flexors, knee flexors and extensors, and ankle dorsiflexors and plantarflexors of both legs after the 4-week intervention ($p < 0.05$), but not for hip extensors when compared to the controls. At long-term follow-up after 4 months, the TBD group also had significantly increased strength of all muscles compared to the control group ($p < 0.05$) (Table 2).

3.4. Back and leg flexibility

Significant group × time interaction was found for the chair sit and reach test of right ($F_{2,74} = 15.26$; $p < 0.001$) and left legs ($F_{2,74} = 17.72$; $p < 0.001$). In particular, post-hoc analysis confirmed that the TBD group had significantly greater lower body flexibility after 4-week

Table 3
Between group comparisons for back and leg flexibility.

Variables	Thai Boxing dance group (n = 39), mean ± SD	Control group (n = 39), mean ± SD	Thai Boxing dance group vs control group, mean ± SD (95% CI)
Left leg (cm)			
Baseline	2.77 ± 3.22	2.62 ± 2.93	0.16 ± 0.71 (−1.25 to 1.56)
4-week intervention	4.87 ± 2.18	3.02 ± 2.60	1.85 ± 0.55 (0.76 to 2.95)**
4-month follow-up	3.58 ± 1.97	2.55 ± 2.71	1.03 ± 0.54 (−0.05 to 2.11)
Right leg (cm)			
Baseline	2.74 ± 3.28	2.75 ± 3.05	−0.003 ± 0.73 (−1.45 to 1.45)
4-week intervention	4.95 ± 2.38	3.15 ± 2.71	1.80 ± 0.59 (0.63 to 2.97)**
4-month follow-up	3.66 ± 2.25	2.68 ± 2.85	0.98 ± 0.59 (−0.19 to 2.15)

Note: SD, standard deviation; CI, confidence interval; cm, centimeter.
** $p < 0.01$ for the difference between groups at each time point.

intervention than did the control group ($p < 0.001$). However, no significant differences between groups were noted for this outcome at 4-month follow-up (Table 3).

3.5. Agility

A significant group × time interaction for the 8-foot Up and Go test ($F_{2,74} = 14.71$; $p < 0.001$) confirmed the effect of TBD practice for the older adults at risk of falling. The MTD group needed significantly less time to complete the 8-foot up-and-go test than the controls at 4-week intervention (mean difference = 1.19 ± 0.29; 95% CI = 0.60–1.78; $p < 0.001$) and at 4-month follow-up (mean difference = 1.09 ± 0.30; 95% CI = 0.50–1.68; $p < 0.001$) (Fig. 4).

4. Discussion

In this study, we investigated the effects of a 4-week TBD program in improving balance and functional fitness of community-dwelling older adults at risk of falling. After practicing TBD for 4 weeks, it provided positive therapeutic effects not only in increasing static and dynamic balance, but also in improving lower limb muscle strength, back and leg flexibility, and agility. This program also maintained long-term positive effects on those outcomes, except for back and leg flexibility after 4-month detraining. This is despite previous research exposing balance and functional fitness declines in the detraining period (Carvalho, Marques, & Mota, 2009). To our knowledge, this is the first randomized controlled study to reveal the beneficial influence of the TBD program on indices of static and dynamic balance and functional fitness in a group of community-dwelling older persons at risk of falling.

Seniors at risk of falling show impaired static and dynamic balance performances as well as functional fitness that may cause serious injuries and mortality (Jeoung, 2015; Karlsson et al., 2013). Previous studies reported significant physical advantages of many types of exercise intervention for the elderly such as aerobic exercise (Fleg, 2012;

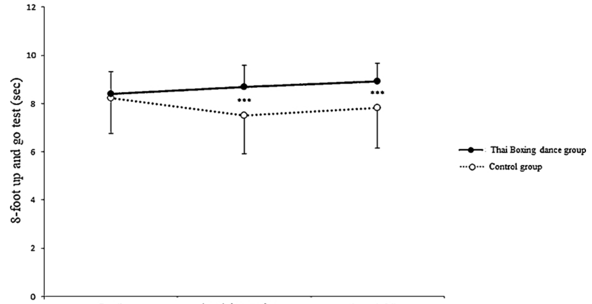

Fig. 4. Agility test at baseline, after 4 weeks of intervention, and at 4-months follow-up, in Thai Boxing dance (n = 39) and control (n = 39) groups. ***$p < 0.001$ for the difference between groups at each time point.

Roma et al., 2013) or balance training (Cho, Hwangbo, & Shin, 2014) but each of these exercise modes may encounter a low rate of compliance due to lack of interest and difficulty commencing (Eyigor et al., 2009; Keogh et al., 2009). The present study chose TBD as a program for seniors at risk of falling and found that 100% of participants who attended the TBD program completed this intervention. All participants in the TBD group reported that it was set as a group-based exercise under supervision resulting in fun. It was also attractive and related to their cultural context which may have been the cause of high compliance rate.

As a result of practicing the TBD, participants in this group had significantly greater improvements in static balance variable with eyes open and closed at 4-week intervention but the detraining effect at 4 months was observed only for eyes open when compared to the controls. The better static performance with eyes open in the TBD group possibly resulted from the significantly improved strength of all lower limb muscles, except for the hip extensors, induced by our dance practice. The program involved stationary bicycling with a light load during the warm-up period, and steps that require several periods while performing the majority of dance positions, and of single-limb standing while performing low kicks to the outside a thigh. Hence, it seems reasonable to state that this dance practice could yield greater muscle strength in lower limb muscles, particularly in the ankle musculature recognized to play a major role in static balance control (Blenkinsop, Pain, & Hiley, 2017; Cattagni et al., 2014; Shumway-Cook & Woollacot, 2016; Tantiwiboonchai et al., 2017). This thought is further supported by researches demonstrating that improving the strength of ankle muscles has been effective in decreasing static postural sway with eyes open in seniors (Cattagni et al., 2014; Shumway-Cook & Woollacot, 2016). Moreover, the participants in the TBD group may use ankle rather than hip mechanisms to maintain their balance, as we have seen improvements during static balance testing. Additionally, a previous study reported an increase in lower limb muscle strength and balance in healthy elderly after training TBD for 16 weeks (Tantiwiboonchai et al., 2017). As mentioned above, it is possible that training TBD also enhances the contribution of the ankle strategy in controlling static balance, possibly by improving active control of ankle stiffness (Winter, Patla, Rietdyk, & Ishac, 2001; Winter, Patla, Ishac, & Gage, 2003).

The TBD practice group also significantly improved its dynamic balance performance compared to the controls. Age-related decline in strength of lower limb muscles and age-related increases in active trunk postural stiffness may be associated with a reduced dynamic balance performance (Sofianidis et al., 2009; Zarzeczny et al., 2017). The possible mechanisms of this improvement could be 1) the TBD group significantly gained lower limb muscle strength (Table 2) that could increase their ability to perform TUG or dynamic balance tests, 2) the TBD practice requires a body transition from double standing to alternate feet standing or one leg standing and emphasizes shifts and changes of base of support that challenge the postural-control system to maintain equilibrium when the center of gravity is shifted to the limits of stability. And 3) the dance practice may increase self-confidence of movements, and reduce age-related anxiety and fear of falling (Sofianidis et al., 2009). The improvements observed in static and dynamic balance performance of this study are consistent with the findings of Tantiwiboonchai et al. (2017) that TBD aerobic dance enhanced the ability to control balance in both static and dynamic conditions in elderly women.

Older adults often show flexibility loss that may be related to muscle disuse, and restraints of soft tissues such as collagen changes and mechanical stress and these are associated with a decreased ability to perform activities of daily living of the elderly (American College of Sports Medicine, 2009). Back and leg flexibility of the TMD group improved more than in the control group at 4 weeks of intervention, even though our participants had few problems of flexibility. This is supported by the results of previous findings of studies that applied traditional Thai art as dance programs (Janyacharoen et al., 2013; Tantiwiboonchai et al., 2017). It is possible because upper and lower limb muscle stretching as one element of the TBD program may be enough to significantly improve flexibility of senior adults. On the contrary, the body flexibility parameter was not different between groups after 4 months of detraining. This could be explained by the notion that aging results in a reduction in the elasticity of muscles, tendons, ligaments and joint capsules because of cross-linking between adjacent fibrils of the collagen after detraining (Park & Lee, 2015).

Agility, one component of functional fitness, was obviously improved in the TBD group after 4 weeks of training and at detraining period, as compared to the control group. It may be due to the improvements in balance performance and lower limb muscle strength after practicing the TBD. The participants practiced TBD stepping in a square-like pattern by progressing from the choreography at a slow pace in the first two weeks to a faster pace in the latter two weeks. This conjecture is supported by the finding of Hallage et al. (2010) which proposed that progressive step aerobics training could significantly improve agility in sedentary elderly women. Improvement in agility in the elderly may reduce rate of falling and serious injury-related falls (Donath et al., 2016). However, agility comprises other aspects including the cardiovascular, perception and cognition systems in addition to the neuromuscular system (Donath et al., 2016). Thus future studies should examine the effect of TBD intervention on those systems.

Generally, detraining occurs in individuals who perform exercise for numerous weeks or months and then ceased (Dudley & Snyder, 1998). Although previous studies of detraining in older adults reported significant decreased physical fitness achieved during training (Carvalho et al., 2009; Teixeira-Salmela et al., 2005), the present findings showed that the positive effects of TBD on the majority of outcome measures in older adults at risk of falls (mean aged 66–67) were maintained over 4-month follow-up. Toraman and Ayceman (2005) reported that dynamic balance, lower body strength and flexibility, and agility remained significantly above post-training levels in young older participants (aged 60–73) after 2 weeks of detraining. Ivey et al. (2000) investigated the effects of age on muscle strength loss during 31- week detraining and found that muscle strength remained significantly above baseline levels in older men (aged 65–75). These studies are in accordance with the present study observing positive persistent effects on balance and physical fitness in the elderly at risk of falls even though methodologies of those studies were different from that of our work.

The strengths of this study are that it was conducted in an assessor-blind randomized controlled design that can minimize measurement bias, and that it extended the knowledge derived from a previous quasi-experimental study (Tantiwiboonchai et al., 2017) for applying TBD to senior adults at risk of falling. Further, all participants attended over the whole of study period, thus the results were not compromised by the effects of participant attrition. Additionally, this study also provided evidence of the long lasting effects of TBD practice on static and dynamic balance performance, lower limb muscle strength, and agility at 4 months after intervention ceased.

Some limitations of this study need to be stated. Firstly, the participants were relatively young older adults aged ranging 60–70 years and the findings cannot be transferred to older age groups or to seniors with other underlying diseases. Secondly, it only considered the efficacy of the TBD program on clinical balance outcomes such as TUG test and sharpened Romberg test. Future studies should include analysis of postural sway measurements using a force platform which may provide in-depth information of balance ability. Thirdly, a fall prevention educational booklet was employed as a control intervention in this study. Other exercise interventions such as other dance practices or balance training should be compared to TBD in order to provide better insight into the effects of TBD. Finally, this study only investigated the effects on the lower limb muscles. Further studies should consider trunk muscles, which are associated with balance and physical activity of the elderly (Suri, Kiely, Leveille, Frontera, & Bean, 2009), to determine whether their strength and endurance are improved after the TBD program.

5. Conclusions

In conclusion, the present study revealed improvements in static and dynamic balance and functional fitness in senior adults with a risk of falling after participating for 4 weeks in a TBD program. These beneficial effects were maintained for 4 months. Since TBD is a cheap and safe exercise intervention it may be implemented as an alternative intervention by health care providers or communities for promoting physical function and well-being of the elderly at risk of falling.

Conflicts of interest

The authors declare there are no conflicts of interest.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.archger.2019.04.010.

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