



Multifactorial Fall Prevention Intervention with Tai Chi on Physical Function in Urban Community-Dwelling Older Adults with Fall History

Siriwan Khruesanit¹, Lalita Kaewwilai², Kwanjai Amnatsatsue²,
Patcharaporn Kerdmongkol²

¹Master of Nursing Science Program (Community Nurse Practitioner), Department of Public Health Nursing, Faculty of Public Health, Mahidol University, Bangkok, Thailand

²Department of Public Health Nursing, Faculty of Public Health, Mahidol University, Bangkok, Thailand

Correspondence: Lalita Kaewwilai, Faculty of Public Health, Mahidol University, 420/1 Ratchawithi Road, Ratchathewi, Bangkok 10400, Thailand. Email: lalita.kae@mahidol.ac.th

Received: 1 April 2026; Revised: 22 May 2026; Accepted: 4 June 2026

Abstract

Background: Falls among older adults are a significant public health concern associated with reduced lower extremity muscle strength and balance. **Objective:** This study aimed to evaluate the effectiveness of a multifactorial fall prevention intervention with Tai Chi on lower extremity muscle strength and balance among community-dwelling older adults with a fall history in Bangkok, Thailand. **Methods:** A quasi-experimental, two-group pretest–posttest design was employed ($n = 60$; experimental = 30, comparison = 30). The experimental group received an 8-week program incorporating fall prevention education and fall risk assessment, Tai Chi training, scenario-based risk management, home hazard assessment, digital reinforcement via LINE Official Account, and family-engaged home visits. The comparison group received usual care and a fall prevention manual. **Results:** Post-intervention, the experimental group demonstrated a statistically significant improvement in lower extremity muscle strength compared with the comparison group. The mean Five Times Sit-to-Stand Test (FTSST) completion time decreased from 11.64 ± 2.07 seconds to 9.63 ± 1.53 seconds in the experimental group, whereas only a minimal change was observed in the comparison group (15.08 ± 3.40 seconds to 15.74 ± 3.75 seconds). ANCOVA-adjusted means confirmed a significant between-group difference in lower extremity function, with the experimental group demonstrating a shorter FTSST completion time than the comparison group (11.04 vs. 14.20 seconds; $F(1,57) = 36.33$, $p <$

.001, partial $\eta^2 = .389$). Dynamic balance also improved significantly in the experimental group compared with the comparison group. Dynamic balance improved significantly following the intervention. The mean Timed Up and Go (TUG) test time decreased from 10.45 ± 1.86 to 8.75 ± 1.55 seconds in the experimental group, compared with a marginal reduction from 14.13 ± 3.95 to 13.93 ± 4.08 seconds in the comparison group. ANCOVA-adjusted mean TUG times demonstrated a significant between-group difference, favoring the experimental group (10.34 vs. 12.34 seconds; $F(1,57) = 17.53$, $p < .001$, partial $\eta^2 = .235$). Static balance also showed significant improvement. Within the experimental group, Wilcoxon signed-rank test results indicated a significant increase in static balance performance (pre-intervention: median = 40.00 s, IQR = 7.75; post-intervention: median = 40.00 s, IQR = 0.00; $Z = -2.437$, $p = .015$). Furthermore, post-intervention static balance was significantly better in the experimental group than in the comparison group, as demonstrated by the Mann–Whitney U test ($Z = -2.762$, $p = .006$). **Conclusion:** This multifactorial program incorporating Tai Chi significantly improved lower extremity muscle strength and balance, providing a feasible, low-cost model to improve physical function and reduce fall risk among community-dwelling older adults.

Keywords: Older adults, Tai chi, Physical function, Muscle strength, Balance, Fall prevention

What Was Known

- Falls among community-dwelling older adults are strongly associated with lower extremity muscle weakness, impaired balance, and reduced neuromuscular function.
- Tai Chi improves neuromuscular function, proprioception, and postural stability in older adults, yet evidence on its integration within structured multifactorial programs in urban Asian community settings remains limited.
- Multifactorial fall prevention interventions that combined exercise with education, environmental modification, and behavioral support are more effective than single-component exercise programs, yet the specific contribution of digital adherence monitoring to sustaining exercise dose remains understudied.

What's New and Next

- A community-based multifactorial program with Tai Chi as the core exercise component significantly improved lower extremity muscle strength and balance in urban Thai community-dwelling older adults with a fall history.

- Digital follow-up using LINE Official Account for exercise reminders, video guidance, and direct feedback achieved 96.7% home Tai Chi practice adherence, demonstrating a low-cost, scalable model for sustaining exercise dose in community settings.
- Future randomized controlled trials with multiple follow-up time points should examine long-term sustainability of physical function gains and integration of this multifactorial model into primary care fall prevention programs and national aging policy frameworks.

Introduction

Falls are among the most common and serious adverse events in older adults and are leading causes of injury, disability, and loss of independence⁽¹⁾. Approximately one-third of adults aged 65 years and older experience at least one fall each year, with a significant proportion encountering recurrent falls⁽²⁾. These incidents are associated with increased healthcare utilization, restricted mobility, and lower quality of life⁽³⁾. The physical, psychological, and economic consequences of falls emphasize the importance of effective prevention strategies for aging populations⁽²⁻⁴⁾.

The causes of falls in older adults are multifactorial, encompassing intrinsic factors such as declines in lower extremity muscle strength, impaired balance, and reduced mobility and extrinsic factors such as environmental hazards, medication use, and inappropriate footwear⁽³⁻⁵⁾. All these factors impair safe performance of transitional movements such as standing, walking, and turning, directly increase fall risk. Therefore, interventions that improve lower limb strength and balance are important in fall prevention.

Exercise-based interventions are recommended as effective strategies to enhance physical function and reduce fall risk in older adults⁽⁶⁾. Among exercise intervention, Tai Chi has received particular attention for fall prevention due to its distinctive biomechanical characteristics that controlled knee flexion, gradual weight transfer, slow posture transitions, and whole-body coordination which directly target the neuromuscular mechanisms underlying fall risk⁽⁷⁻⁹⁾. Tai Chi improves lower extremity muscle strength, dynamic and static balance, and neuromuscular efficiency during transitional movements, while its low-impact nature and minimal equipment requirements make it suitable for community delivery across a range of physical abilities⁽¹⁰⁻¹²⁾. However, exercise alone may not sufficiently address the complex, multifaceted nature of fall risk; multifactorial interventions integrating Tai Chi with education, home hazard modification, digital follow-up, and family engagement are increasingly recommended as they can lead to greater improvements in safety and

functional independence compared with single-component approaches^(3,6,13). While community-based fall prevention programs have demonstrated effectiveness in reducing falls among Thai older adults⁽¹⁴⁾, evidence on multifactorial approaches specifically tailored to urban community settings remains limited, as environmental risks and lifestyle factors differ substantially from rural contexts⁽¹⁵⁾.

As of December 2023, the population of people aged 60 years and older in Thailand accounted for 20.17% of the total population, officially describing Thailand as an aged society⁽¹⁶⁾. Falls are the second leading cause of unintentional injury death among Thai older adults, with approximately one-third of older adults falling at least once per year and 40–60% of them experiencing recurrent falls within the same year^(1, 5). In Lat Krabang District, Bangkok, urban older adults face elevated fall risk compounded by daytime social isolation due to family work commitments⁽¹⁷⁾.

Therefore, this study aimed to evaluate the effectiveness of a multifactorial intervention with Tai Chi as its core exercise component on lower extremity muscle strength and balance among community-dwelling older adults with a fall history in Bangkok, contributing evidence to support integrated, community-based fall prevention programs tailored to urban settings.

Materials and Methods

Study Design & Study Population

A quasi-experimental, two-group pretest–posttest design was employed to examine the effects of a multifactorial fall prevention intervention with Tai Chi as the core exercise component on lower extremity muscle strength and balance among community-dwelling older adults in Lat Krabang District, Bangkok. Participants were allocated to experimental and comparison groups based on community subdistricts to minimize contamination. Outcomes were assessed in the baseline and one week after completing the 8-week intervention.

This manuscript is one of two papers arising from the same investigation (n = 60). The present paper reports lower extremity muscle strength and balance as primary outcomes, examined through the physical mechanisms through which Tai Chi involving controlled movements, weight shifting, and whole-body coordination that strengthens leg muscles and improves balance needed for safe daily activities. A companion paper examining fear of falling as the primary outcome, framed through Bandura's Self-Efficacy Theory, has been submitted separately for publication in a peer-reviewed journal.

Inclusion Criteria

Participants were eligible if they were community-dwelling adults aged 60–75 years who had experienced at least one fall in the past year. Additional inclusion criteria were the following:

1. Functional independence was assessed using the Barthel Activities of Daily Living (ADL) Index. Participants with a Barthel ADL score of ≥ 12 , indicating moderate to high functional independence, were eligible for inclusion⁽¹⁸⁾.
2. Normal cognitive function (Mini-Cog score ≥ 4 ⁽¹⁹⁾)
3. Ability to walk independently without assistive devices
4. Ability to use the LINE application, either independently or with family support
5. Effective communication skills in Thai (listening, speaking, reading, and writing)
6. Willingness to provide informed consent and commit to participation for the study duration

Exclusion criteria

Participants were excluded if they had conditions contraindicating exercise participation including severe cardiopulmonary disease, neurological disorders affecting mobility or balance (e.g., stroke, Parkinson's disease), severe osteoarthritis, or any physician-advised restriction against physical exercise as identified through self-reported medical history at screening.

Sample Size

The sample size was calculated using G*Power version 3.1.9.7, based on an independent samples t-test with an effect size (Cohen's d) of 0.72, referencing a prior fall prevention study in Thai older adults⁽²⁰⁾. A one-tailed test was selected because the study hypothesized a directional effect, specifically that the intervention group would show significantly greater improvement in physical function than the comparison group. With $\alpha = 0.05$ and power $(1 - \beta) = 0.80$, the one-tailed calculation yielded a required sample size of 25 participants per group. Allowing for an estimated 15% dropout rate⁽²¹⁾, the target participants were increased to 30 per group, resulting in a total sample of 60 participants.

Measures & Procedures

The study included three main components: (1) screening of participants, (2) data collection using structured instruments and outcome measures, and (3) implementation of the intervention program. Data were collected at two time points, at baseline (before the intervention) and one week

after the completion of the 8-week intervention (post-test, week 9). This one-week washout period was incorporated to reduce the influence of short-term fatigue from the final exercise session on outcome measurement. All assessments were conducted according to standardized protocols by trained assessors who supervised participants closely throughout physical performance testing to ensure safety and prevent falls.

Screening instruments

Two validated instruments were used to assess participant eligibility during the screening process prior to enrollment.

Functional Status: The Thai version of the Barthel Activities of Daily Living (ADL) Index (score range: 0–20) was used to assess functional independence. Participants with a Barthel ADL score of ≥ 12 , indicating moderate to high independence, were eligible⁽¹⁸⁾.

Cognitive Status: The Mini-Cog cognitive screening test (score range: 0–5) was used to assess cognitive function. A score of 4 or higher was required for study inclusion indicating intact cognitive function sufficient for safe exercise participation and informed consent⁽¹⁹⁾.

Data collection instruments

A structured interview questionnaire, developed by researchers, was used to gather information on sociodemographic characteristics, health status, and fall-related history at baseline. Data collected included age, sex, height, weight, BMI, blood pressure, marital status, education, monthly income and income source, comorbidities, medication use, exercise habits, and type of residence. Fall history was also recorded, including the number and timing of falls in the past year and any medical treatment received for fall-related injuries.

Outcome measures: Physical function were assessed by using three standardized tools.

1. Five Times Sit-to-Stand Test (FTSST) assesses lower extremity muscle strength. Participants performed five consecutive sit-to-stand cycles from a standard armless chair (43 cm) with arms crossed. Time to complete was recorded (two trials, one-minute rest and average used for analysis). Times over 14 seconds indicated increased fall risk⁽²²⁾.

2. Timed Up and Go Test (TUG) assesses dynamic balance and mobility. During this test, participants stand up from a chair, walk three meters, turn around, return to the chair, and sit down as quickly and safely as possible. A completion time over 12 seconds indicates a higher risk of falling⁽²³⁾.

3. 4-Stage Balance Test for static balance assesses static balance using four positions of increasing difficulty (feet together, semi-tandem, full tandem, single-leg stance). Each position was held for 10 seconds without support. The total time maintained across all four positions (maximum 40 seconds) was recorded⁽²⁴⁾.

Reliability test

Before starting the main study, the outcome measures were tested for reliability with 30 older adults in Bueng Kum District, Bangkok. Test–retest reliability was measured over a one-week interval.

Intraclass Correlation Coefficients (ICC) and Cronbach's alpha were calculated.

- FTSST: $\alpha = .96$; ICC(single) = .85; ICC(average) = .92
- TUG: $\alpha = .98$; ICC(single) = .92; ICC(average) = .96
- 4-Stage Balance Test: $\alpha = .96$; ICC(single) = .90; ICC(average) = .95

These results confirmed excellent test–retest reliability for all physical performance measures used in the study.

Intervention program

The experimental group participated in an 8-week multifactorial fall prevention program with Tai Chi as the core exercise component, addressing both intrinsic and extrinsic risk factors. An overview of the program components is presented in Table 1.

The 8-week multifaceted intervention consisted of:

1. Fall prevention education and Fall risk assessment

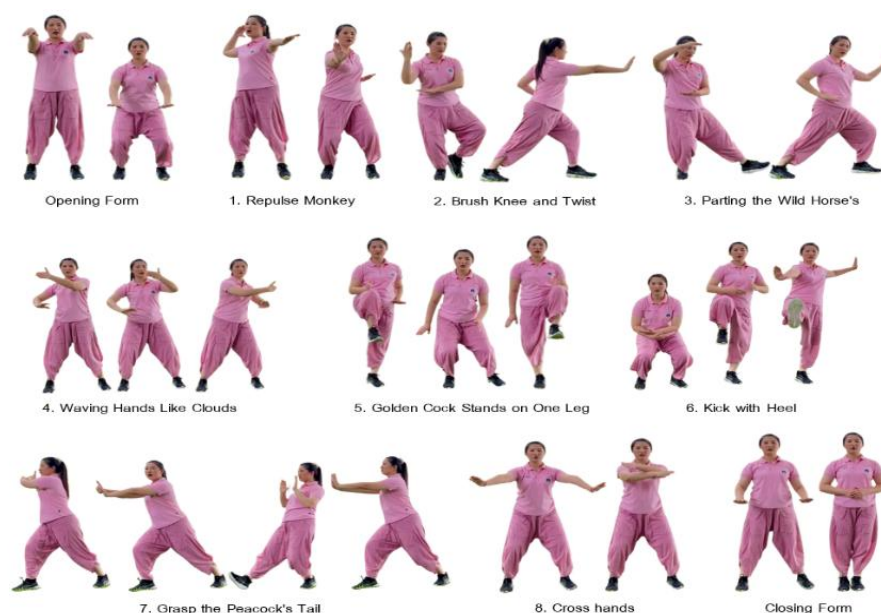
Participants received structured group education on intrinsic and extrinsic fall risk factors using a multidimensional fall risk screening tool to identify individual modifiable risks, supplemented by a fall prevention handbook⁽²⁵⁾.

Table 1. Overview of the 8-Week Multifactorial Fall Prevention Program

Component	Timing	Duration	Delivery
Fall prevention education and fall risk assessment	Week 1	2 hrs/session	Group
Eight-form Tai Chi training (supervised)	Weeks 1–4	2 hrs/session	Group
Scenario-based risk management + first aid	Week 3	2 hrs/session	Group
Home-based Tai Chi practice	Weeks 1–8	35 min×3 times/week	Home
Digital follow-up via LINE Official Account	Weeks 1–8	3 times/week	Individual
Home hazard assessment + family-engaged home visit	Week 8	30 min/participant	Individual

2. Tai Chi training

Participants participated in structured eight-form Tai Chi training based on a standardized protocol ⁽²⁶⁾, as illustrated in Figure 1. delivered through: (2.1) supervised weekly group sessions during Weeks 1–4 (2 hours/session) with certified instructor guidance; and (2.2) independent home practice three times weekly (35 minutes/session) throughout Weeks 1–8, monitored via photographic submissions through LINE Official Account.

**Figure 1** Eight-form Tai Chi movements used in the intervention program

3. Simulation-based risk management and basic first aid training

Participants practiced identifying high-risk situations, applying safe movement strategies, performing basic fall injury assessment, and exhibiting appropriate help-seeking behaviors.

4. Home hazard assessment with environmental modification guidance

Participants used a structured checklist to identify and reduce fall hazards in home areas, including bathrooms, floor surfaces, lighting, furniture, and stairways.

5. Digital reinforcement via LINE Official Account

Continued support included reminders to complete exercises, instructional videos of Tai Chi, motivational feedback for exercises, and a direct communication to the research team.

6. Home visit and family engagement

At Week 8, a 30-minute individual home visit reinforced Tai Chi progress, reassessed home modifications, provided individualized feedback, and involved family members in ongoing fall prevention planning

Content Validity and Pilot Testing

The intervention content was reviewed by three experts in geriatric medicine, fall-prevention physiotherapy, and Tai Chi/public health. The Scale-Level Content Validity Index (S-CVI) was 1.00, indicating excellent content validity. Before implementation, a pilot test with 10 community-dwelling older adults was conducted to assess the clarity of materials, safety procedures, and session logistics.

Adherence Monitoring and Fidelity

Adherence was monitored through photo or video submissions of home Tai Chi practice via the LINE application and through participants' self-reported practice logs. The research team consistently examined these records and delivered reminders, motivation, and feedback via the LINE application. The Tai Chi sessions were co-facilitated by the primary researcher, a certified community nurse practitioner, and a Traditional Chinese Medicine specialist from Huachiew Chalermprakiet University, who is formally qualified to instruct Tai Chi. Before the study implemented, the primary researcher underwent structured Tai Chi training under the guidance of this specialist to ensure delivery consistency and competency. To ensure fidelity, all sessions adhered to standardized protocols and were conducted by the same trained research team.

Comparison Group

The comparison group received usual care from local health services. Additionally, the fall prevention manual was distributed to participants in the comparison group by the research team at the beginning of the study period⁽²⁵⁾.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 30.0. Descriptive statistics summarized participant characteristics, and baseline comparability was assessed using chi-square, independent-samples t-tests, or Fisher's exact test as appropriate. Normality was assessed using the Shapiro–Wilk test; FTSST and TUG were normally distributed, while the 4-Stage Balance Test was not. Within-group changes were analyzed using paired t-tests or Wilcoxon signed-rank tests, and between-group comparisons using independent t-tests or Mann-Whitney U tests accordingly. Given significant baseline differences in FTSST and TUG, ANCOVA with corresponding pre-test scores as covariates was performed to control for baseline imbalance and provide adjusted between-group estimates.

Results

Participant Characteristics

Sixty community-dwelling older adults aged 60–75 years were allocated to the experimental ($n = 30$) and comparison ($n = 30$) groups, with 100% retention at study completion. No statistically significant between-group differences were observed in any baseline sociodemographic, clinical, or fall-related characteristics ($p > .05$), confirming group comparability prior to the intervention (Table 2).

Fall History

Fall-related characteristics are presented in Table 3. Most participants reported one fall in the past year, with approximately one-third experiencing two or more falls. Falls occurred most frequently in the morning indoors, particularly in the bathroom, with tripping and slipping as the most common mechanisms and bruising as the most frequent injury outcome. Most participants managed injuries through self-care at home (e.g., rest, cold compresses, and over-the-counter pain relief). No statistically significant between-group differences were observed for any fall-related characteristic ($p > .05$).

Table 2 Baseline Personal and clinical characteristics of participants by study group (n=60)

Variable	Experimental (n=30)		Comparison (n=30)		p-value
	n	%	n	%	
Female	26	86.7	22	73.3	.197 ^a
Age (years), mean±SD	66.77±3.58		68.77±4.42		.059 ^b
BMI (kg/m ²), mean±SD	24.06±2.43		25.40±4.34		.146 ^b
Normal BP (90–139/60–89 mmHg)	23	76.7	23	76.7	1.000 ^c
Any chronic disease	17	56.7	18	60.0	.793 ^a
No regular exercise	16	53.3	9	30.0	.067 ^a
Married	16	53.3	18	60.0	.602 ^a

SD, standard deviation; BMI, body mass index; BP, blood pressure.

^aChi-square, ^bIndependent t-test, ^cFisher's exact test**Table 3** Fall-related characteristics (previous 12 months)

Variable	Experimental (n=30)		Comparison (n=30)		p-value
	n	%	n	%	
Number of falls in past year					1.000 ^a
1 fall	20	66.7	20	66.7	
≥2 falls	10	33.3	10	33.3	
Falls in the morning (05:00–11:59)	21	70.0	18	60.0	.236 ^a
Self-treatment at home after injury	22	73.3	17	56.7	.176 ^a
Fall location: bathroom	12	40.0	12	40.0	
Mechanism: tripping	17	56.7	17	56.7	
Mechanism: slipping	17	56.7	18	60.0	
Injury: bruising	24	80.0	21	70.0	

^aChi-square

Baseline Physical Function

Baseline physical function outcomes are presented in Table 4. The experimental group demonstrated significantly shorter FTSST and TUG completion times than the comparison group at baseline ($p < .001$), indicating better initial lower extremity strength and mobility. No significant between-group difference was observed for static balance ($p = .904$). Given these baseline differences, ANCOVA with baseline scores as covariates was used for FTSST and TUG comparisons.

Table 4 Baseline physical function outcomes by study group

Outcome	Experimental	Comparison	p-value
FTSST (s), mean±SD	11.64±2.07	15.08±3.40	<.001 ^b
TUG (s), mean±SD	10.45±1.86	14.13±3.95	<.001 ^b
4-Stage Balance Test (s), median (IQR)	40.00 (7.75)	40.00 (8.29)	.904 ^c

FTSST, Five Times Sit-to-Stand Test; TUG, Timed Up and Go; IQR, interquartile range; s, seconds.

^bIndependent t-test, ^cMann–Whitney U test.

Changes in Lower Extremity Muscle Strength and Dynamic Balance

Within-group pre–post changes are presented in Table 5. The experimental group showed significant improvements in FTSST and TUG ($p < .001$), while the comparison group showed no significant TUG improvement ($p = .430$) and a slight decline in FTSST performance ($p = .040$).

Table 5 Within-group pre–post changes in FTSST and TUG (paired t-test)

Outcome	Group	Pre mean ± SD	Post mean ± SD	t	p-value
FTSST (s)	Experimental	11.64±2.07	9.63±1.53	5.564	<.001
	Comparison	15.08±3.40	15.74±3.75	-2.146	.040
TUG (s)	Experimental	10.45±1.86	8.75±1.55	5.079	<.001
	Comparison	14.13±3.95	13.93±4.08	0.800	.430

FTSST, Five Times Sit-to-Stand Test; TUG, Timed Up and Go; SD, standard deviation; s, seconds.

Adjusted Post-Intervention Comparisons

After adjusting for baseline values, ANCOVA analysis showed that the experimental group had significantly better outcomes than the comparison group on both the FTSST and TUG tests ($p < .001$), as shown in Table 6.

Table 6 ANCOVA comparison of post-intervention outcomes (adjusted for baseline)

Outcome	Adjusted post mean (SE) (Experimental)	Adjusted post mean (SE) (Comparison)	F (1,57)	p-value	partial η^2
FTSST (s)	11.04 (0.34)	14.20 (0.34)	36.328	<.001	.389
TUG (s)	10.34 (0.32)	12.34 (0.32)	17.528	<.001	.235

FTSST, Five Times Sit-to-Stand Test; TUG, Timed Up and Go; s, seconds; SE, standard error; ANCOVA, analysis of covariance (adjusted for baseline values of the corresponding outcome); F, F statistic; η^2 , partial eta squared.

Static Balance Outcomes

Static balance outcomes assessed using the 4-Stage Balance Test are presented in Table 7. The experimental group demonstrated significant within-group improvement ($Z = -2.437$, $p = .015$), while the comparison group showed no significant change ($Z = -1.753$, $p = .080$). Between-group comparison confirmed significantly greater improvement in the experimental group (Mann–Whitney $Z = -2.762$, $p = .006$).

Intervention implementation and adherence

High adherence to the intervention among participants in the experimental group. Most participants (93.3%) successfully completed home hazard modifications. Adherence to home-based Tai Chi practice was also high, with 96.7% regularly submitting photos or videos of their practice through the LINE Official Account. One participant needed family assistance to submit digital evidence. Adherence was further verified through follow-up phone calls, home visits, and activity logs recorded in participants' progress booklets.

Table 7 Static Balance Outcomes within and between-group comparisons

Analysis	Group	Pretest, median (IQR)	Posttest, median (IQR)	Z	p-value
Within-group (Pre-Post)	Experimental (n=30)	40.00 (7.75)	40.00 (0.00)	-2.437	.015
	Comparison (n=30)	40.00 (8.29)	40.00 (8.58)	-1.753	.080
Between-group change (Pre-Post)	Experimental and Comparison	-	-	-2.762	.006 ^a

IQR, interquartile range; s, seconds. Within-group comparisons were analyzed using the Wilcoxon signed-rank test. Between-group comparisons were analyzed using the Mann-Whitney U test. ^aMean rank: experimental 35.12, comparison 25.88.

Discussion

This quasi-experimental study evaluated the effectiveness of an 8-week multifactorial fall prevention program with Tai Chi as the core exercise component on lower extremity muscle strength, dynamic balance, and static balance among community-dwelling older adults with a fall history. Significant improvements in all three outcomes support the value of structured, nurse-facilitated community programs for older adults at high risk of fall. The discussion includes the neuromuscular mechanisms underlying these improvements, the supporting role of non-exercise components, study limitations and strengths, and implications for nursing practice.

Improvement in Lower Extremity Muscle Strength

The experimental group had a significantly lower completion time for the FTSST, indicating better lower extremity muscle strength. The FTSST involves coordinated activation of quadriceps, gluteal muscles and trunk stabilizers. Sarcopenia related to aging and decreased neuromuscular coordination limit the ability to safely perform these movements, thus increasing the risk of falls^(4,27). The eight-form sequence of Tai Chi specifically targets these muscle groups by controlled knee flexion, gradual weight transfer and repeated semi-squat postures, which require sustained activation of the lower extremities, contributing to an improved muscular endurance and coordination^(6,7,11). Previous studies consistently support the effectiveness of Tai Chi-based programs for the balance

and functional outcomes in older adults^(6,26,28). In contrast, the comparison group showed a small decline in FTSST performance consistent with the natural trajectory of age-related muscle decline in the absence of targeted exercise^(4,6) and highlighting the value of structured, nurse-facilitated exercise programs for maintaining functional capacity in older adults.

Improvement in Dynamic Balance and Mobility

The Timed Up and Go (TUG) Test was used to measure the dynamic balance and significant improvement was found in the experimental group. The TUG assesses multiple components of functional mobility including the sit to stand initiation, forward gait, turning and return, which require integrated neuromuscular coordination across the joint systems of the lower extremity⁽²³⁾. Poor performance on the TUG is associated with a higher risk of falling and loss of independence in daily activities. Tai Chi deals with these components with slow, continuous postural transitions that require participants to maintain control of their center of mass as they move their weight. This practice improves proprioceptive feedback, anticipatory postural adjustments, and dynamic gait stabilization^(29,30). The 8-week duration and three-times weekly practice schedule used in this study is consistent with a recent meta-analysis that confirmed 8-16 week Tai Chi interventions have the most consistent improvements in dynamic balance outcomes among older adults⁽¹²⁾.

The small, non-significant decrease in TUG time in the comparison group may be due to measurement familiarity, practice effects of repeated assessment or small behavioral changes due to the fall prevention handbook and should be considered when interpreting differences between the groups. Baseline differences in FTSST and TUG scores were adjusted using ANCOVA adjusting for baseline scores as covariates. Adjusted analyses showed significantly better outcomes in the experimental group, suggesting the robustness of findings.

Improvement in Static Balance

The experimental group showed a significant improvement in the static balance measured by 4-Stage Balance Test. Static balance requires the precise integration of vestibular, visual and somatosensory inputs. These processes tend to deteriorate with age due to a decline in proprioception, slower neuromuscular response times, and reduced sensorimotor processing^(24,27). These age-related changes are relevant to static balance deficits that increase fall risk during activities of daily living such as standing in confined spaces, reaching overhead and weight-shifting during personal care tasks⁽³⁾. Tai Chi specifically targets these mechanisms by progressively narrowing the base of

support, transitioning from feet together to a single-leg stance. This approach trains the proprioceptive and vestibular systems to integrate sensory input more effectively^(12,29). The 4-Stage Balance Test presents a challenge to participants by progressing from simple standing to a single-leg stance. This progression is closely similar to the balance practiced during the eight-form Tai Chi sequence, allowing individuals to build confidence in similar real-life balance situations. The improvement in static balance is still clinically significant, even though it is smaller than the improvement of dynamic balance. Little improvements in a person's ability to stand stable can reduce fall risk and enhance independence in daily activities such as bathing, dressing and reaching overhead.

Role of Multifactorial Intervention Structure

The main exercise component was Tai Chi, while other elements contributed to the enhancement of physical functions through complementary mechanisms. Fall prevention education and fall risk assessment increased awareness of intrinsic and extrinsic fall risk factors among participants, promoting safer movement behaviors in daily activities. Home hazard assessment and environmental modification directly reduced extrinsic fall risk by extending the protective effect of physical training into the home environment where most falls occur. This is particularly relevant in urban housing contexts where bathroom surfaces, narrow walkways, and stairs present common hazards^(13,17). Scenario-based risk management training enhanced participants' emergency response skills, which in turn reduced potential injury from a fall. Home Tai Chi practice was maintained (96.7% adherence) via digital follow-up (LINE Official Account) with exercise reminders, review of the instructional video, and individualized feedback. The week 8 home visit engagement with the family reinforced safe movement practices within the home environment and established a family support structure for sustained fall prevention behaviors beyond the program period. These components combined addressed both physical and environmental determinants of fall risk, thus creating conditions in which improvements in muscle strength and balance resulting from Tai Chi could be effectively translated into fall prevention in the community^(3,13).

Program Sustainability

The program included several features to support continued fall prevention beyond the 8-week period. Participants received a fall prevention handbook for home safety reference, access to LINE Official Account for digital reinforcement, and family support established through Week 8 home visit. The eight-form Tai Chi sequence is simple to be practiced independently at home, without requiring any equipment. The high adherence rates for home Tai Chi practice (96.7%) and home

hazard modification (93.3%) provide indirect evidence that participants were actively engaged in all components of the program, although the individual contribution of each component cannot be isolated due to the integrated multifactorial design.

Implications for Practice

These findings have implications for the community nurse practitioner who works in a primary care setting. This program, implemented in the context of existing community infrastructure, organized over eight weeks, with minimal equipment, and facilitated by nurses, offers a practical model for improving physical function and reducing fall risk in older adults at high risk of fall. This program can be integrated into community nurses' activities of older adult clubs, geriatric clinics and community health promotion services without specialist referral. The program aligns with the WHO Integrated Care for Older People (ICOPE) framework through structured screening for fall risk, individualized home modifications, and multicomponent exercise delivery, and supports its implementation as a person-centered primary care intervention consistent with international guideline recommendations for fall prevention^(3,31).

Study Limitations and Future Research

There are a few limitations to consider. First, the quasi-experimental design may be prone to selection bias, despite baseline characteristics being similar between groups. Second, the relatively small sample size limits generalizability to larger populations. Third, the 8-week intervention period may not capture long-term sustainability of physical function improvements. Fourth, outcomes were assessed at only two time points, limiting the ability to assess whether improvements were maintained over time.

Despite these limitations, several strengths should be noted. Validated performance-based outcome measures were used, with excellent reliability (ICC = 0.85-0.96) and reduced measurement error. Participant retention was 100% and adherence rates were high, 96.7% for home Tai Chi practice and 93.3% for home hazard modification, suggesting the feasibility and acceptability of this program in community settings.

Future research should include randomized controlled trials with larger and more diverse samples and multiple follow-up evaluations at 1, 3, and 6 months post-intervention, to evaluate the long-term sustainability of enhancements in physical function and to validate the generalizability of these initial findings.

Conclusion

This study provides preliminary evidence that an 8-week multifactorial fall prevention program with Tai Chi as the core exercise component was associated with significant improvements in lower extremity muscle strength, dynamic balance, and static balance among community-dwelling older adults with a fall history. Community nurse practitioners can deliver this program within existing primary care infrastructure without specialized equipment, extending nursing care into the home environment where most falls occur. Embedding this approach into national fall prevention pathways is consistent with WHO ICOPE recommendations for person-centered primary care. Future randomized controlled trials with larger samples and long-term follow-up are needed to confirm these findings across diverse populations.

Ethical Approval Statement

This study was approved by the Ethical Review Committee for Human Research, Faculty of Public Health, Mahidol University, Thailand, on 13 August 2025 (Approval No. MUPH 2025-116).

Author Contributions

S.K. and L.K. conceptualized and designed the study and developed the intervention program and study materials. S.K. was responsible for participant recruitment, data collection, and statistical analysis. L.K., K.A., and P.K. provided supervision and methodological oversight throughout the study and contributed academic guidance. S.K. prepared the initial draft of the manuscript. L.K., K.A., and P.K. critically reviewed and revised the manuscript for important intellectual content. All authors read and approved the final manuscript and agreed to be accountable for all aspects of the work.

Acknowledgements

We would like to thank all older adults who participated in this study for their valuable time and cooperation. We also extend our sincere gratitude to the community leaders of Lat Krabang Subdistrict and Khlong Song Ton Nun Subdistrict for their support in facilitating community coordination, participant recruitment, and data collection throughout the study. We further thank the local health personnel and all individuals involved for their assistance with study implementation and follow-up during the research period.

Source of Funding

This study was conducted as part of the first author's Master's degree in Nursing Science (Community Nurse Practitioner). The first author received a graduate scholarship from the Bangkok Metropolitan Administration (BMA) to support tuition and academic training. No specific funding was provided for the research activities reported in this study.

Conflicts of Interest

The authors declare that there is no conflict of interest.

References

1. Department of Disease Control. Fall data: information on falls among older adults aged 60 years and over [Internet]. Bangkok: Department of Disease Control; 2024 [cited 2024 May 13]. Available from: <https://ddc.moph.go.th/dip/news.php?news=23567>. (In Thai)
2. Centers for Disease Control and Prevention. Facts about falls [Internet]. Atlanta: CDC; 2026. Available from: <https://www.cdc.gov/falls/data-research/facts-stats/index.html>, accessed 1 March, 2024.
3. Montero-Odasso M, van der Velde N, Martin FC, Petrovic M, Tan MP, Ryg J, et al. World guidelines for falls prevention and management for older adults: a global initiative. *Age Ageing*. 2022; 51(9): afac205. DOI: 10.1093/ageing/afac205
4. Rubenstein LZ. Falls in older people: epidemiology, risk factors and strategies for prevention. *Age Ageing*. 2006; 35(Suppl 2): ii37-ii41. DOI:10.1093/ageing/afl084
5. World Health Organization. Falls [Internet]. Geneva: WHO; 2024. Available from: <https://www.who.int/news-room/fact-sheets/detail/falls>, accessed 13 May, 2024.
6. Sherrington C, Fairhall NJ, Wallbank GK, Tiedemann A, Michaleff ZA, Howard K, et al. Exercise for preventing falls in older people living in the community. *Cochrane Database Syst Rev*. 2019; (1): CD012424. DOI: 10.1002/14651858.CD012424.pub2
7. Lin J, Ning S, Lyu S, Gao H, Shao X, Tan Z, et al. The effects of different types of Tai Chi exercises on preventing falls in older adults: a systematic review and network meta-analysis. *Aging Clin Exp Res*. 2024; 36(1): 65. DOI: 10.1007/s40520-023-02674-7
8. Dong R, Hamzah MSGB, Awang MMB, Qiu J, Chen S. Effects of Tai Chi on balance and fall prevention in healthy older adults: a randomized controlled meta-analysis. *Front Public Health*. 2026; 13: 1638006. DOI: 10.3389/fpubh.2025.1638006

9. Lomas-Vega R, Obrero-Gaitan E, Molina-Ortega FJ, Del-Pino-Casado R. Tai Chi for risk of falls: a meta-analysis. *J Am Geriatr Soc.* 2017; 65(9): 2037-43. DOI: 10.1111/jgs.15008
10. Chen W, Li M, Li H, Lin Y, Feng Z. Tai Chi for fall prevention and balance improvement in older adults: a systematic review and meta-analysis of randomized controlled trials. *Front Public Health.* 2023; 11: 1236050. DOI: 10.3389/fpubh.2023.1236050
11. Li L, Guo S, Ding B, Zhang J. Effectiveness of Tai Chi exercise on balance, falls, and motor function in older adults: a meta-analysis. *Front Med (Lausanne).* 2024; 11: 1486746. DOI: 10.3389/fmed.2024.1486746
12. Cui Z, Xiong J, Li Z, Yang C. Tai chi improves balance performance in healthy older adults: a systematic review and meta-analysis. *Front Public Health.* 2024; 12:1443168. DOI: 10.3389/fpubh.2024.1443168
13. Hopewell S, Adedire O, Copsey BJ, Boniface GJ, Sherrington C, Clemson L, et al. Multifactorial and multiple component interventions for preventing falls in older people living in the community. *Cochrane Database Syst Rev.* 2018; (7): CD012221. DOI: 10.1002/14651858.CD012221.pub2
14. Wandee P, Jirapongsuwan A, Powwattana A, Chansatitporn N. Implementation of community-based fall prevention program for Thai older persons: a cluster randomized controlled trial. *Sci Rep.* 2026; 16(1): 4464. DOI: 10.1038/s41598-025-34663-3
15. Thiamwong L, Xie R, Tongsiri S, Ng BP, Park JH, Rodniam J, et al. Urbanization, falls, and fear of falling in community-dwelling older adults in Thailand. *Innov Aging.* 2023; 7(Suppl 1): 239. DOI: 10.1093/geroni/igad104.0785
16. Department of Older Persons. Situation of the Thai older persons 2023 [Internet]. Bangkok: Ministry of Social Development and Human Security; 2023. Available from: https://www.dop.go.th/th/statistics_page?cat=12&id=2563, accessed 13 May, 2024. (In Thai)
17. Somsopon W, Kim SM, Nitivattananon V, Kusakabe K, Nguyen TPL. Issues and needs of elderly in community facilities and services: a case study of urban housing projects in Bangkok, Thailand. *Sustainability.* 2022; 14 (14): 8388. DOI: 10.3390/su14148388
18. Collin C, Wade D, Davies S, Horne V. The Barthel ADL Index: a reliability study. *Int Disabil Stud.* 1988; 10(2): 61-3. DOI: 10.3109/09638288809164103

19. Borson S, Scanlan J, Brush M, Vitaliano P, Dokmak A. The mini-cog: a cognitive vital signs measure for dementia screening in multi-lingual elderly. *Int J Geriatr Psychiatry*. 2000; 15(11): 1021-7. DOI: 10.1002/1099-1166(200011)15:11<1021::AID-GPS234>3.0.CO;2-6
20. Wangpayom S, Incharoen S, Ponpetch K, Sirijoti K, Kaewchusen N. Effects of fall prevention program with multifactorial intervention on fall prevention behavior and balance among community-dwelling older adults in Trang Province [Internet]. 2023. Available from: <https://he02.tcithaijo.org/index.php/apnj/article/view/263261>, accessed 10 May, 2025. (In Thai)
21. Piboon K, Methaphat C, Jaidee W, Oppawongsapat D, Tabootwong W, Inchai P, et al. The effects of multifactorial fall prevention program on balance, physical fitness, and fear of falling among community-dwelling older adults [Internet]. 2022. Available from: <https://he02.tci-thaijo.org/index.php/jcra/article/view/253352>, accessed 13 May, 2025. (In Thai)
22. Buatois S, Miljkovic D, Manckoundia P, Gueguen R, Miget P, Vancon G, et al. Five times sit to stand test is a predictor of recurrent falls in healthy community-living subjects aged 65 and older. *J Am Geriatr Soc*. 2008; 56(8): 1575-7. DOI: 10.1111/j.1532-5415.2008.01777.x
23. Tiedemann A, Shimada H, Sherrington C, Murray S, Lord S. The comparative ability of eight functional mobility tests for predicting falls in community-dwelling older people. *Age Ageing*. 2008; 37(4): 430-5. DOI: 10.1093/ageing/afn100
24. Rossiter-Fornoff JE, Wolf SL, Wolfson LI, Buchner DM. A cross-sectional validation study of the FICSIT common data base static balance measures. *J Gerontol A Biol Sci Med Sci*. 1995; 50(6): M291-7. DOI: 10.1093/gerona/50A.6.M291
25. Bangkok Metropolitan Administration, Health Department, Office of Public Health System Development. Health literacy promotion booklet: older adults — no falls, no forgetfulness. Bangkok: Bangkok Metropolitan Administration; 2024. (In Thai)
26. Moonong R, Lagampan S, Rawiworakul T. Effects of a self-efficacy program using Tai Chi to prevent elderly fall in flat communities [Internet]. 2022 [cited 2025 Dec 5]. Available from: <https://he01.tci-thaijo.org/index.php/JRTAN/article/view/256190>, accessed 5 December, 2025. (In Thai)

27. Cruz-Jentoft AJ, Bahat G, Bauer J, Boirie Y, Bruyere O, Cederholm T, et al. Sarcopenia: revised European consensus on definition and diagnosis. *Age Ageing*. 2019; 48(1): 16-31. DOI: 10.1093/ageing/afy169
28. Mahaprom T, Mahawong S, Watunyu S. Effects of Tai Chi exercise on posture and balance among older adults [Internet]. 2017. Available from: <https://he02.tci-thaijo.org/index.php/TJONC/article/view/95858>, accessed 10 November, 2025. (In Thai)
29. Tsang WW, Hui-Chan CW. Comparison of muscle torque, balance, and confidence in older Tai Chi and healthy adults. *Med Sci Sports Exerc*. 2005; 37(2): 280-9. DOI: 10.1249/01.mss.0000152735.06282.58
30. Nan L, Grunberg D, De Silva S, Sivaramakrishnan D. Evaluating the effectiveness of Tai Chi in short-term, medium-term, and long-term on balance and strength among the elderly: a systematic review and meta-analysis. *Arch Gerontol Geriatr Plus*. 2024; 1(4): 100080. DOI: 10.1016/j.aggp.2024.100080
31. Colon-Emeric CS, Whitson HE, Pavon J, Hoenig H. Risk assessment and prevention of falls in older community-dwelling adults: a review. *JAMA*. 2024; 331(16): 1397-406. DOI: 10.1001/jama.2024.1416