Effects of Home-Based Tai Chi and Lower Extremity Training and Self-Practice on Falls and Functional Outcomes in Older Fallers from the Emergency Department—A Randomized Controlled Trial

Hei-Fen Hwang, RN, MS,[*†] *Sy-Jou Chen, MD,*[†‡] *Jane Lee-Hsieh, RN, MSN,*[§] *Ding-Kuo Chien, MD,*[¶] *Chih-Yi Chen, MS,*[†] *and Mau-Roung Lin, PhD†***

OBJECTIVES: To compare the effects of guided home-based tai chi chuan (TCC) and lower extremity training (LET) and of levels of self-practice on falls and functional outcomes in older fallers.

DESIGN: Randomized controlled trial.

SETTING: Taipei, Taiwan.

PARTICIPANTS: Individuals aged 60 and older who had fall-related emergency department visits at least 6 months before participating in the study and ambulated independently at baseline (N = 456).

INTERVENTION: Six months of TCC or LET.

MEASUREMENTS: Four types of fall measures (falls, time to first fall, fallers, recurrent fallers) and six functional measures (handgrip strength, balance, mobility, fear of falling, depression, cognitive function).

RESULTS: The TCC group was significantly less likely than the LET group to experience any falls during the 6-month intervention (incidence rate ratio (IRR) = 0.30, 95% confidence interval (CI) = 0.15–0.60), and the effects remained significant after 12 months of follow-up (IRR = 0.32, 95% CI = 0.14–0.71). These effects remained significant for injurious falls during the 6-month intervention (IRR = 0.33, 95% CI = 0.16–0.68) and the entire 18-month study (IRR = 0.39, 95% CI = 0.18–0.83). Similar results were obtained when another two fall measures (time to first fall, number of fallers) were used. Moreover, participants who independently practiced TCC or LET seven times per week or more were significantly less likely to experience injurious falls during the 6-month intervention (IRR = 0.41, 95% CI = 0.20–0.83) and the 18-month study (IRR = 0.43, 95% CI = 0.21–0.87) than their counterparts, had a significantly longer time to first injurious fall, and were significantly less likely to have an injurious fall during the 6-month intervention. Cognitive function improved to a greater extent in the TCC group than in the LET group over the 18-month study.

CONCLUSION: Home-based TCC may reduce the incidence of falls and injurious falls more than conventional LET in older fallers, and the effects may last for at least 1 year. **J Am Geriatr Soc 64:518–525, 2016.**

Key words: exercise; falls; older people; prevention tai chi

Effective interventions have been developed for lowering the incidence of falls in older people,[1] but practical application of these interventions is challenging because developing cost-effective programs that require broad dissemination, adoption, and implementation is necessary to reduce the burden of falls.[2]

The U.S. Preventive Services Task Force states that the net benefits of exercise or physical activity in preventing falls are moderate and that those of multifactorial interventions are small.[3] Tai chi chuan (TCC) has demonstrated efficacy in reducing falls and associated injuries[4–6] and reducing symptoms of certain chronic illnesses and improving overall health and well-being.[7,8] Nonetheless, whether TCC is a more-effective preventive and therapeutic exercise than conventional exercise practices in reducing falls remains unknown because only a few studies have directly compared the effects of TCC with those of other forms of exercise on

From the *Department of Nursing, National Taipei University of Nursing and Health Science; †Institute of Injury Prevention and Control, College of Public Health and Nutrition, Taipei Medical University; ‡Department of Emergency Medicine, Tri-Service General Hospital, National Defense Medical Center; §Graduate Institute of Allied Health Education, National Taipei University of Nursing and Health Science; ¶Department of Emergency Medicine, Mackay Memorial Hospital; and **Master Program in Long-Term Care, College of Nursing, Taipei Medical University, Taipei, Taiwan.

Address correspondence to Dr. Mau-Roung Lin, Institute of Injury Prevention and Control, Taipei Medical University, 250 Wu-Hsing Street, Taipei 110, Taiwan. E-mail: mrlin@tmu.edu.tw

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fall reduction, and their results are inconsistent.[9–12] Furthermore, qualitative information rather than quantitative aspects of the practice frequency of TCC or other exercise interventions was assessed in the previous studies, and the effect of self-practice on reducing falls has rarely been reported. Therefore, it is essential to have a setting where older people at high risk of falls can be identified and efficient interventions can be delivered. The emergency department (ED) may be an appropriate place for targeting people in high-risk groups who should receive fall interventions because falls are the most common cause of injuries treated in the ED[13] and are the most consistent predictor of subsequent falls in older people.[14] However, older adults who have presented to an ED after a fall have seldom been identified to receive a fall-prevention intervention.

To address the aforementioned concerns, a randomized controlled trial was designed to compare the effects of TCC with those of conventional lower extremity training (LET) on reducing falls and injurious falls in older fallers who presented to an ED. The potential effects of the frequency of TCC or LET self-practice were also investigated.

METHODS

Study Participants

Study participants were recruited from two hospitals affiliated with Taipei Medical University. People aged 60 and older who received fall-related medical attention between January 2011 and December 2012 in the ED of either of the two hospitals at least 6 months before the study (an older person was presumed to have recovered from a fall injury within 6 months[15]) and who could independently ambulate were invited by telephone to enroll in the study and participate in the baseline assessment. Exclusion criteria were major unstable cardiopulmonary disease (ischemic chest pain or shortness of breath on mild exertion), cognitive impairment (Mini-Mental State Examination (MMSE) score <24), and contraindications to physical exercise (e.g., severe arthritis that limits exercise capability). The of Taipei Medical University (Taipei, Taiwan) institutional review board approved the study protocol, and written consent was obtained from each participant.

Of the 735 eligible persons, 456 who participated in the baseline assessment were randomized. After randomization and before starting any intervention program, 88 persons (43 and 45 in the TCC and LET groups, respectively) received no intervention because they died; were hospitalized; moved out of Taipei; or were discouraged by family who were concerned about safety of the exercise programs, allowing a stranger (trainer) to enter their homes, or who would be responsible for their children's care during exercise sessions. The study duration was 18 months and comprised a 6-month intervention and 12-month follow-up. The progression of participants through the trial is illustrated in Figure 1.

Randomization

After completing the baseline assessment, potential participants were block-randomized in groups of eight to one of the two intervention groups: TCC and LET. An independent statistician performed randomization using software without stratification of hospital or other variables, and the allocation was concealed using an automated secure website operated by an off-site independent service.

Interventions

Intervention programs were primarily delivered at the residence of each participant once a week over a 6-month (24-week) period. The programs were also conducted in a park or a community center close to the residence of participants upon their request. All participants were asked to practice TCC or LET every day.

Yang-style TCC with 18 movements was taught individually each week for 24 consecutive weeks. TCC instructors from the Association of Taipei City Yang-style TCC who were invited to participate and each had practiced TCC for more than 10 years. Single movements were practiced each week for the initial 6 weeks and mastered through multiple repetitions, and multiple movements were practiced in the subsequent weeks. Each TCC session lasted 60 minutes and comprised a 10-minute warm-up followed by a review of previous movements, an introduction of new movements, and 5 minutes of relaxation. Deep diaphragmatic breathing, weight shifting, displacement of the center of mass, ankle sways, and leg stepping were integrated into each movement.

The LET intervention comprised stretching, muscle strengthening, and balance training at increasing difficulty levels. The training was individualized for each participant, supervised by a physical therapist, and reviewed every week for 24 weeks. Each session lasted 60 minutes and consisted of a 10-minute warm-up, 45 minutes of exercise, and a 5-minute cool-down. Stretching involved the neck, shoulders, hips, knees, and ankles. A series of exercises was performed to increase the stability of the trunk muscles and strengthen the hip extensors and abductors, knee flexors and extensors, and ankle dorsiflexors and plantar flexors. Balance training included rising from a sitting position to a standing position, standing on one leg, tandem walking, walking backward and sideways, and turning 360°.

At the end of the 6-month intervention, each participant in the two intervention groups was reminded to practice the TCC or LET every day if possible to maximize the benefits of the exercise intervention program.

Intervention Participation and Self-Practice

Participants were asked to complete at least 80% of the intervention sessions (≥20 sessions), because learning TCC movements or LET in fewer intervention sessions would impede the progress of the intervention schedule and the benefits of the intervention. They were also reminded to practice TCC or LET every day during the 6-month intervention and 12-month follow-up. The frequency of self-practice during the previous week was calculated monthly through telephone interviews.

Primary Outcomes

Over the 18-month study period, falls were prospectively monitored and recorded daily using a diary, and these records were mailed monthly to the study coordinator.

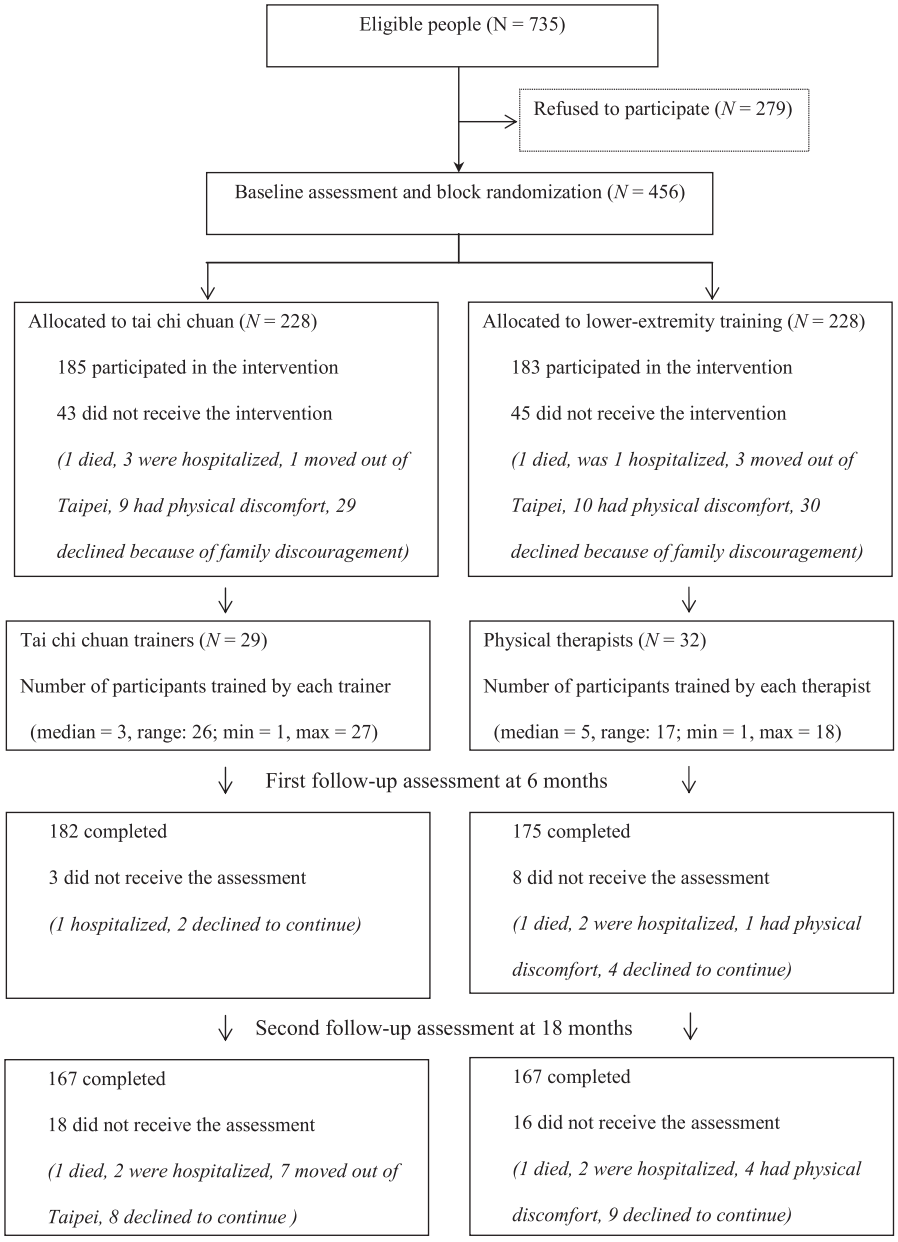

Figure 1. Flow diagram of study participants.

When a participant failed to return the diary or provided incomplete data, two research assistants blinded to the group assignment provided telephone reminders, making a maximum of five calls. Monthly follow-up of fall records was continued in participants who were unavailable for certain periods. Four fall measures (time to first fall, fall count, number of fallers, number of recurrent fallers) were obtained. A fall was defined as the unintentional loss of balance, with the body hitting the floor or ground from a standing height or lower.[16] An injury was assessed using the Abbreviated Injury Scale (AIS) and scored from 0 to 5,[17] and a fall resulting in an AIS score of 1 or greater was defined as an injurious fall.

Secondary Outcomes

Two assessors, blinded to the group assignment, evaluated secondary outcomes (handgrip strength, balance, mobility, fear of falling, depression, and cognitive function) at baseline, the 6-month intervention, and 12-month follow-up. Grip strength of the right hand was assessed using a handgrip dynamometer and measured in kilograms of isometric force; the average of two measurements was used. The Tinetti Balance Test involves 13 maneuvers, with a higher score indicating greater balance ability. The Tinetti Gait Test comprises nine components, with a higher score indicating greater mobility.[18] Fear of falling was assessed using the Falls Efficacy Scale International test, which measures self-efficacy in avoiding falls during seven essential nonhazardous activities of daily living, with a higher score indicating greater fear.[19,20] Depression symptoms were assessed using the 15-item Geriatric Depression Scale, with a higher score indicating a higher depression level.[21] Cognitive status was assessed using the MMSE.[22]

Adverse Events

No participant, TCC instructor, or physical therapist reported any adverse events.

Statistical Analysis

A sample size of 364 participants provided 90% power to detect a 50% difference in the incidence of falls between the LET and TCC groups, according to a previous fall-related study on community-dwelling Taiwanese elderly people over an 18-month period.[23] Considering loss to follow-up (20%), 456 participants were recruited.

The distributions of the four fall measures in the TCC and LET intervention groups over the 6-month intervention and 18-month study were calculated, and the intervention groups were compared to ascertain the presence of any difference in attending the two follow-up assessments, and the factors associated with incomplete follow-ups were subsequently controlled for, eliminating a potential response bias in the study results.

A proportional hazards model was used to investigate the relationship between intervention type and time to first fall during the 6-month intervention and 18-month study period. Data on participants who did not experience falls by the end of the study or the time of death were censored, and hazard ratios (HRs) were estimated. To account for overdispersion (standard errors being underestimated) caused by correlations of recurrent falls within participants, correlations between TCC or LET instructors, and a substantial proportion of participants having no falls, a negative binomial regression model[24] was used to investigate the incidence rate ratio (IRR) of falls between the two intervention groups. A logistic regression model was used to compare the effects of TCC and LET on the occurrences of fallers and recurrent fallers; the odds ratio was converted to a relative risk (RR) because falls are a common outcome in older fallers.[25] The effects of the intervention session and the practice frequency of exercise and their interactions with the intervention program on each of the fall measures were analyzed. The two models were also applied to an injurious falls analysis.

A sensitivity analysis was conducted to examine whether distributions of baseline characteristics were comparable between subgroups divided according to the frequency of exercise (≥7 vs <7 times per week) in the TCC and LET groups, because practice frequency could depend on participant characteristics (e.g., healthy participants might practice an intervention exercise program more frequently than other participants). Characteristics that were incomparable between the groups were adjusted for in the multivariable models.

Crude score changes for secondary outcomes (handgrip strength, Tinetti balance and gait, fear of falling, depression, cognition) over the 6-month intervention and 18-month study period in the TCC and LET groups were compared using paired *t*-tests. Because these secondary outcomes were repeated continuous measures, a mixed-effect model for each outcome was used to estimate how it changed before and after the intervention and how the change depended on the intervention type and other variables.[26]

All statistical analyses were based on the intention-to-treat principle and were performed using SAS version. 9.3 (SAS Institute, Inc., Cary, NC).

RESULTS

Of the 735 eligible persons, 456 agreed to participate in the trial. The 279 nonparticipants were older (73.8 vs 72.4), more likely to be male (45% vs 33%), had less education (18% vs 35% ≥college), and less frequently engaged in regular exercise (66% vs 75%). At the two follow-up assessments, the characteristics of the TCC and LET groups remained similar. Results of the logistic regression analysis for incomplete follow-up revealed that participants who were older, consumed alcohol regularly, and used a walking aid were significantly less likely to have completed the two follow-up assessments.

The distributions of the baseline characteristics (Table 1) between the TCC and LET groups were similar. The distributions of intervention participation, self-practice, and the fall measures during the 6-month intervention and 18-month study are summarized in Table 2. During the 6-month intervention, 145 (78%) participants in the TCC group and 132 (72%) in the LET group participated in 20 or more sessions. During the 6-month intervention, 93 (50%) participants in the TCC group and 122 (67%) in the LET group and during the 18-month study, 74 participants (42%) in the TCC group and 81 (44%) in the LET group independently practiced the exercise program seven or more times per week; the difference between the groups during the 6-month intervention was statistically significant.

Significant differences were observed in median time to first fall, rate of falls, and percentage of fallers for all falls in the TCC and LET groups during the 6-month intervention and the entire 18-month study period. Significant differences were also observed in median time to first injurious fall, rate of injurious falls, and percentage of injured fallers between the two intervention groups during the 6-month intervention and the 18-month study for injurious falls alone. A significant difference was observed in the percentage of recurrent injured fallers between the two intervention groups during the 6-month intervention.

Results of the multivariable analysis for each of the four fall measures over the 6-month intervention and 18-month study period are summarized in Table 3. After adjustment for age, regular alcohol consumption, and use of walking aids (to account for follow-up differences), participants who participated in 20 or more sessions did not significantly differ from their counterparts in any of the fall measures. The TCC group was significantly less likely to experience a fall during the 6-month intervention (IRR = 0.30, 95% confidence interval (CI) = 0.15–0.60) and the entire 18-month study period (IRR = 0.32, 95% CI = 0.14–0.71). Similar results were obtained when time to first fall and number of fallers were used. The TCC group was also significantly less likely to experience injurious falls during the 6-month intervention (IRR = 0.33, 95% CI = 0.16–0.68) and the 18-month study period (IRR = 0.39, 95% CI = 0.18–0.83). The difference in effects between TCC and LET on time to first fall and number of fallers remained significant, despite their magni-

Table 1. Baseline Characteristics of Study Participants

Characteristic	Tai Chi Chuan, n = 228	Lower Extremity Training, n = 228
Age, mean ± SD	72.0 ± 8.1	72.7 ± 8.1
Male, n (%)	75 (32.9)	77 (33.8)
Living alone, n (%)	26 (11.4)	26 (11.4)
Marital status, n (%)		
Married	68 (29.8)	70 (30.7)
Single, widowed, divorced	160 (70.2)	158 (69.3)
Education level, n (%)		
≥College	86 (37.7)	76 (33.3)
High school	76 (33.3)	85 (37.3)
≤Elementary school	66 (28.9)	67 (29.4)
Body mass index, kg/m^2, n (%)		
<18.5 (underweight)	9 (4.0)	7 (3.1)
18.5–22.9 (normal weight)	104 (46.4)	97 (42.5)
23.0–24.9 (overweight)	69 (30.8)	79 (34.7)
≥25.0 (obese)	42 (18.8)	45 (19.7)
Current smoker, n (%)	12 (5.3)	8 (3.5)
Regular alcohol use, n (%)	34 (14.9)	23 (10.1)
Regular exercise, n (%)	169 (74.1)	173 (75.9)
Use of walking aids, n (%)	32 (14.0)	42 (18.4)
Visual acuity, n (%)		
Poor	16 (7.0)	11 (4.8)
Moderate	53 (23.3)	62 (27.2)
Good	159 (69.7)	155 (68.0)
Number of falls in past year, n (%)		
0	70 (30.7)	71 (31.2)
1	133 (58.3)	133 (58.3)
≥2	25 (11.0)	24 (10.4)
Number of chronic conditions, mean ± SD	3.4 ± 1.8	3.3 ± 2.0
Number of medications, mean ± SD	1.7 ± 1.2	1.8 ± 1.5
Injury type of index fall, n (%)		
No injury	46 (20.2)	49 (21.5)
Soft tissue injury	110 (48.2)	104 (45.6)
Upper extremity fracture	32 (14.0)	29 (12.7)
Lower extremity fracture	23 (10.1)	18 (7.9)
Spinal fracture	9 (3.9)	13 (5.7)
Traumatic brain injury	6 (2.6)	14 (6.1)
Other	5 (2.2)	1 (0.4)

SD = standard deviation.

tudes being smaller. Moreover, participants who independently practiced the TCC or LET program seven or more times per week were significantly less likely to experience an injurious fall during the 6-month intervention (IRR = 0.41, 95% CI = 0.20–0.83) and the 18-month study period (IRR = 0.43, 95% CI = 0.21–0.87) than those who did not. The effects of self-practice on time to first injurious fall and number of injured fallers during the 6-month intervention were also statistically significant.

Results of the sensitivity analysis revealed that participants who practiced the TCC or LET program seven or more times per week were significantly more likely to be older, be male, and exercise regularly than their counterparts. After age, sex, and regular exercise were included in the final model of the multivariable analysis, similar results were obtained on the effects of self-practice on any injurious fall (IRR = 0.38, 95% CI = 0.19–0.77), first injurious fall (HR = 0.64, 95% CI = 0.40–1.01), and being an injured faller (RR = 0.89, 95% CI = 0.78–1.00) during the 6-month intervention and on any injurious fall alone (IRR = 0.42, 95% CI = 0.20–0.88) during the 18-month period.

Secondary outcomes in the TCC and LET groups at the baseline and two follow-up assessments of the 6-month intervention and 18-month study are summarized in Table 4. For the TCC group, handgrip strength, Tinetti balance and gait, depression, and cognition scores improved significantly during the 6-month intervention, and improvements in handgrip strength, depression, and cognition remained significant during the entire 18-month study period. For the LET group, handgrip strength, Tinetti balance and gait, fear of falling, depression, and cognition scores improved significantly during the 6-month intervention, but only the improvement in handgrip strength remained significant during the 18-month period. Only the change in cognition score at 18 months differed significantly between the two intervention groups. A mixed-effect analysis revealed similar results regarding change in MMSE score during the 18-month period, and TCC scores were 0.49 points (95% CI = 0.01–0.96) higher than LET scores after adjustment for age, alcohol consumption, use of walking aids, number of intervention sessions, and self-practice level.

DISCUSSION

There are several possible reasons for the inconsistent findings of previous studies that compared the effect of TCC with that of other exercise types on fall reduction. First, similar to other exercise types, the effectiveness of TCC might depend on the characteristics of the practitioners. TCC was more effective in healthy and prefrail community-dwelling older people than in frail people or those with serious health conditions.[27,28] Nevertheless, the exercise practice level may have confounded the results; specifically, healthy older people may be more likely to practice an intervention program than frail elderly people. Second, certain TCC intervention programs may not provide a sufficient dose to produce a response, particularly in those with low attendance, adherence, and intensity (<1 session per week) or an insufficient intervention period (<3 months).[11,28,29] Under such circumstances, the role of exercise self-practice must be considered. Third, the estimate of the effectiveness of TCC in fall reduction may vary according to the type of exercise that the control group participated in (e.g., stretching, functional walking, resistance exercise, balance training) because the risk of falls in each exercise control group may differ. Similar to the TCC exercise components, the LET program had multiple components of stretching, strengthening, and balancing. Furthermore, to avoid social support and environmental effects, the TCC and LET intervention programs were home based and individualized. Finally, various fall measures, such as time to first fall; fall counts; and numbers of fallers, recurrent fallers, and injured fallers,

Table 2. Intervention Sessions, Self-Practice, and Fall Measures in the Tai Chi Chuan (TCC) and Lower Extremity Training (LET) Groups During the 6-Month Intervention and 18-Month Study

Outcome	6-Month Intervention			18-Month Study		
	TCC	LET	*P*-Value	TCC	LET	*P*-Value
Number of intervention sessions, n (%)						
≤15	19 (10.3)	28 (15.3)	.30	N/A	N/A	
16–19	21 (11.3)	23 (12.6)		N/A	N/A	
≥20	145 (78.4)	132 (72.1)		N/A	N/A	
Self-practice, times/wk, n (%)						
0–1	11 (5.9)	9 (4.9)	.005	48 (26.0)	41 (24.0)	.71
2–6	81 (43.8)	52 (28.4)		63 (34.0)	58 (31.7)	
≥7	93 (50.3)	122 (66.7)		74 (41.7)	81 (44.3)	
Follow-up, months, median (IQR)	5.4 (0.5)	5.5 (0.4)	.87	17.1 (0.9)	17.1 (0.9)	>.99
All falls data						
Time to first fall, months, median (IQR)	67 (61)	58 (58)	.001	135 (205)	81 (132)	.002
Number of falls, mean ± SD	0.3 ± 0.7	0.6 ± 0.9	.002	0.8 ± 1.1	1.0 ± 1.1	.04
Fallers, n (%)	41 (22.2)	75 (41.0)	.001	72 (41.1)	99 (55.9)	.006
Recurrent fallers, n (%)	14 (7.6)	23 (12.6)	.11	41 (23.4)	54 (31.4)	.10
Falls per person-month	1.01	2.04	.007	1.00	1.87	<.001
Percentage of fallers	0.23	0.43	<.001	0.40	0.57	.004
Percentage of recurrent fallers	0.08	0.13	.09	0.22	0.31	.07
Injurious falls data only						
Time to first injurious fall, months, median (IQR)	67 (66)	61 (44)	.02	147 (201)	101 (206)	.01
Number of injurious falls, mean ± SD	0.2 ± 0.5	0.4 ± 0.7	.01	0.5 ± 0.9	0.7 ± 0.9	.08
Injured fallers, n (%)	31 (16.8)	49 (26.8)	.02	58 (33.1)	80 (45.7)	.02
Recurrent injured fallers, n (%)	5 (2.7)	13 (7.1)	.05	23 (13.1)	26 (15.1)	0.60
Injurious falls per person-month	0.58	1.06	.002	0.50	0.88	<.001
Percentage of injured fallers	0.17	0.28	.02	0.32	0.46	.01
Percentage of recurrent injured fallers	0.02	0.07	.04	0.13	0.15	.54

IQR = interquartile range; N/A = not applicable; SD = standard deviation.

Table 3. Results of Multivariable Analysis for Each Fall Measure (Time to First Fall, Number of Falls, Number of Fallers, Number of Recurrent Fallers) According to All Falls and Injurious Falls During the 6-Month Intervention and the 18-Month Study

Characteristic	All Falls		Injurious Falls Only	
	6-Month Intervention	18-Month Study	6-Month Intervention	18-Month Study
Time to first fall, hazard ratio (95% CI)				
Tai chi chuan/lower-extremity training	0.49 (0.33–0.73)[a]	0.66 (0.49–0.91)[a]	0.56 (0.35–0.89)[a]	0.69 (0.48–0.97)[a]
Intervention session (≥20 vs <20)	0.83 (0.53–1.31)	0.91 (0.63–1.32)	1.00 (0.57–1.75)	0.97 (0.64–1.46)
Self-practice (≥7 vs <7 times/wk)	0.77 (0.53–1.13)	0.88 (0.64–1.19)	0.62 (0.39–0.99)[a]	0.95 (0.68–1.34)
Number of falls, incidence rate ratio (95% CI)				
Tai chi chuan/lower-extremity training	0.30 (0.15–0.60)[a]	0.32 (0.14–0.71)[a]	0.33 (0.16–0.68)[a]	0.39 (0.18–0.83)[a]
Intervention session (≥20 vs <20)	1.25 (0.57–2.75)	1.50 (0.68–3.32)	0.95 (0.38–2.38)	1.12 (0.49–2.54)
Self-practice (≥7 vs <7 times/wk)	0.52 (0.27–1.04)	0.54 (0.30–1.09)	0.41 (0.20–0.83)[a]	0.43 (0.21–0.87)[a]
Number of fallers, RR (95% CI)				
Tai chi chuan/lower-extremity training	0.76 (0.66–0.87)[a]	0.76 (0.62–0.92)[a]	0.86 (0.77–0.96)[a]	0.81 (0.68–0.96)[a]
Intervention session (≥20 vs <20)	1.02 (0.88–1.18)	0.99 (0.77–1.28)	1.06 (0.93–1.21)	1.01 (0.81–1.24)
Self-practice (≥7 vs <7 times/wk)	0.89 (0.78–1.01)	0.92 (0.76–1.11)	0.88 (0.78 0.99)[a]	0.96 (0.81–1.14)
Number of recurrent fallers, RR (95% CI)				
Tai chi chuan/lower-extremity training	0.93 (0.87–1.01)	0.88 (0.77–1.00)	0.96 (0.89–1.03)	0.96 (0.88–1.05)
Intervention session (≥20 vs <20)	1.02 (0.93–1.12)	0.96 (0.81–1.14)	1.00 (0.90–1.10)	1.02 (0.92–1.13)
Self-practice (≥7 vs <7 times/wk)	0.96 (0.88–1.04)	0.95 (0.84–1.08)	0.98 (0.91–1.05)	0.99 (0.90–1.08)

[a]$P < .05$.

CI = confidence interval; RR = relative risk.

have been used in studies, but some subtle differences exist between these fall measures that affect evaluations of the efficacy of TCC or other exercise types. For instance, the number of falls rather than the number of recurrent falls was reduced, implying that the natures of the first fall and subsequent falls may have differed. Therefore, self-practice

Table 4. Scores for Each Secondary Outcome for the Tai Chi Chuan (TCC) and Lower Extremity Training (LET) Groups at Baseline and 6- and 18-Month Follow-Up

Outcome	Mean ± Standard Deviation					
	TCC			LET		
	Baseline	6 Months	18 Months	Baseline	6 Months	18 Months
Handgrip strength, kg	22.6 ± 9.3	23.9 ± 9.1[a]	23.4 ± 9.6[a]	21.3 ± 8.2	22.5 ± 8.3[a]	22.0 ± 8.0[a]
Tinetti balance (range 0–26)	24.1 ± 3.5	24.4 ± 3.5[a]	23.8 ± 4.8	23.8 ± 3.4	24.2 ± 3.4[a]	23.4 ± 4.7
Tinetti gait (range 0–9)	7.6 ± 1.8	8.0 ± 1.8[a]	7.6 ± 2.1	7.3 ± 2.1	7.6 ± 2.1[a]	7.4 ± 2.3
Falls Efficacy Scale International (range 7–28)	11.8 ± 5.1	11.7 ± 4.7	11.8 ± 4.8	11.8 ± 4.7	11.1 ± 3.9[a]	11.4 ± 4.4
Geriatric Depression Scale score (range 0–15)	3.9 ± 3.5	3.1 ± 3.4[a]	3.0 ± 3.1[a]	3.0 ± 3.0	2.5 ± 3.3[a]	2.7 ± 3.2
Mini-Mental State Examination score (range 0–30)	28.4 ± 2.2	29.3 ± 1.6[a]	28.9 ± 3.0[a]	28.0 ± 3.1	28.8 ± 2.5[a]	28.2 ± 3.5[b]

[a]$P < .05$ in paired t-test for within-group comparisons.
[b]$P < .05$ in t-test for between-group comparisons.

exercise levels, an exercise control group, and different fall measures were used in this study to produce robust results.

Because self-practice level could depend on participant characteristics, and certain intrinsic factors directly related to poor physical health could influence whether falls result in injury,[30] whether participants in better health and who had a lower risk of injurious falls were more likely to practice the exercise intervention program at a high frequency was examined. Despite the results of additional analyses disproving this conjecture, reverse causality between the self-practice level and injurious falls that prevailed in unmeasured or unknown situational and dispositional factors could have confounded the observational results. A high frequency of exercise practice was significantly associated with fewer injurious falls and injured fallers but not of all falls and fallers. Regular practice of an exercise program reduces the risk of falling,[31] but frequent physical activity could increase the opportunity for falls.[32] Perhaps the two forces pulling in different directions account for the null effect of exercise practice levels on reducing the number of all falls and fallers, whereas TCC may have improved upper extremity strength, reaction times, and cognitive executive function, affecting the probability of injury during a fall.[33] Finally, practice frequency of exercise intervention was seldom assessed in previous intervention trials, but if frequency had not been assessed, then the effectiveness of TCC in reducing injurious falls would have been underestimated because practice levels were lower in the TCC group than in the LET group.

Both interventions improved balance and motor control, muscular strength, depressive symptoms, and cognitive function, although the TCC group did not exhibit greater improvements in the aforementioned functional outcomes than the LET group except in cognition. Previous studies have reported no differences in physical function between people practicing TCC and other active exercise groups.[9–12] One possible explanation is that most of the selected functional measures do not capture specific aspects of the functions that TCC improved, and TCC may have benefited older people by improving cognitive function, particularly in the executive functioning domain, which mitigates the risk of falls. TCC practitioners may have improved hand–eye coordination during tasks involving cognitive processing,[34] and they have better neuromuscular control for postural recovery from a potential fall than age-matched controls.[35] Conversely, a healthy-volunteer effect or a ceiling or floor effect of functional measures for the secondary outcomes probably caused the small difference in the cognitive outcome between the two intervention groups and improvements in the secondary outcomes in the TCC or LET groups. Nonetheless, because the significant results might be attributable to the large sample size, and their small difference is not likely to be clinically meaningful, confirmatory evidence of the difference in cognitive improvement between TCC and LET is required.

Several limitations of this study were observed. First, the presence of a volunteer effect and loss to follow-up may restrict the generalization of results to frail elderly people. Older participants, men, those with low educational levels, those who smoked, and those who seldom performed regular exercise refrained from participating in the trial, and those who were older, consumed alcohol regularly, and used a walking aid were less likely to complete the study. Second, differences between exercise instructors could have resulted in a performance bias. Because the number of participants with a particular instructor differed markedly, differences in characteristics between the TCC and LET instructors were not considered in the analysis, although correlations between exercise instructors were adjusted for. Third, fall measures and the frequency of exercise practice were self-reported and not validated using other sources. Nevertheless, data on all falls and injurious falls were consistent, and the monthly exercise practice level consistently declined after the 6-month intervention, indicating that the results are reliable. Fourth, more-severe injurious falls, such as fractures and brain injuries, were not analyzed because of their rare occurrence (11 TCC, 12 LET); therefore, inferences regarding severe injurious falls should be made with caution. Finally, the costs of the TCC and LET interventions were not estimated or compared, although payments lower than the market rates to were made to the tai chi instructors and physical therapists. The National Health Insurance Administration does not cover payments for home-based physical therapy in Taiwan.

CONCLUSIONS

Home-based TCC may reduce falls and injurious falls in older people who present to the ED more than conventional LET, and the reduction can be maintained for at least 1 year. Further research is required to confirm whether actively practicing an exercise intervention program can reduce injurious falls to a greater extent and lead to differences in cognitive functioning between individuals who practice TCC and LET.

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