Effects of Sun-style Tai Chi exercise on physical fitness and fall prevention in fall-prone older adults

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Aim. This paper reports a study to determine changes in the physical fitness (knee and ankle muscle strength, balance, flexibility, and mobility), fall avoidance efficacy, and fall episodes of institutionalized older adults after participating in a 12-week Sun-style Tai Chi exercise programme.

Background. Fall prevention has a high priority in health promotion for older people because a fall is associated with serious morbidity in this population. Regular exercise is effective in fall prevention for older adults because of improvements in strength and balance. Tai Chi exercise is considered to offer great potential for health promotion and rehabilitation, particularly in the maintenance of good mental and physical condition in older people.

Methods. A quasi-experimental design with a non-equivalent control group was used. Data were collected from September 2001 to January 2002. A total of 68 fall-prone older adults with a mean age of 77·8 years participated in the study, and 29 people in the Tai Chi group and 30 controls completed the post-test measures. The Tai Chi exercise programme was provided three times a week for 12 weeks in the experimental group. Data were analysed for group differences using *t*-tests.

Results. At post-test, the experimental group showed significantly improved muscle strength in knee and ankle flexors ($P < 0{\cdot}001$) and extensors ($P < 0{\cdot}01$), and improved flexibility ($P < 0{\cdot}01$) and mobility ($P < 0{\cdot}001$) compared with the control group. There was no significant group difference in fall episodes, but the relative risk ratio for the Tai Chi exercise group compared with the control group was 0·62. The experimental group reported significantly more confidence in fall avoidance than did the control group.

Conclusion. The findings reveal that Tai Chi exercise programmes can safely improve physical strength and reduce fall risk for fall-prone older adults in residential care facilities.

Keywords: fall avoidance efficacy, falls, nursing, older adults, physical fitness, Tai Chi exercise

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Introduction

Fall prevention has a higher priority in health promotion with older populations since approximately 30% of people over 65 years of age who live in the community fall each year (Tinetti *et al.* 1994). The percentage of those falling is even higher within long-term care facilities: 40–50% of these residents will fall during any given year (Sauvage *et al.* 1992). Falling is associated with serious morbidity: 20% of those who fall will require medical attention and 10% will sustain a fracture, half of whom require hospitalization to manage this (Gillespie *et al.* 2003). Fall-related injuries and fear of falling can further inhibit the daily activities of older people, while physical activity can promote their quality of life when performed safely (Schoenfelder & Rubenstein 2004).

Prospective community studies have identified individual predisposing risk indicators for falls in older people, including chronic diseases and medication, sensations of staggering and imbalance, depressive symptoms, visual disturbances, and muscular weakness (Era 1988, Kron *et al.* 2003). Environmental factors can also increase the probability of falls, including poor condition of sidewalks and steps, wet or icy walking surfaces, loose carpets, and inadequate lighting (Baumann 1999). Some of the identified risk factors, such as imbalance, muscular weakness, and lack of flexibility, are potentially modifiable, and can be changed to reduce the incidence of falls and fall-related injuries and thereby improve the functional independence of older adults.

Intervention strategies have been developed for older adults to help them prevent falls, using resistance, endurance, balance, and feedback training (Wu 2002). Randomized controlled studies have identified regular exercise as a useful tool in fall prevention in older adults, because of improvements in strength and balance (Carter *et al.* 2001, Gardner *et al.* 2001). Walking as a common form of exercise also decreased fall episodes in older nursing home residents and improved their ambulatory independence (Koroknay *et al.* 1995). Applying regular, scheduled exercise programmes with this older population can reduce falls and improve functional abilities (Schoenfelder & Rubenstein 2004).

However, the effectiveness of fall prevention programmes in reducing the risk of falls in older adults has varied between studies, probably because of inconsistencies in the measurement of major variables (Carter *et al.* 2001) and focusing on a single risk factor or physical function rather than a comprehensive investigation of factors related to falls (Wu 2002). A meta-analysis of randomized clinical trials for the prevention of falls in older adults also revealed that a multifactorial fall-risk assessment and exercise programme were the most effective interventions in reducing the risk of falling (Chang *et al.* 2004).

Tai Chi movements incorporate elements of strengthening, balance, postural alignment, and concentration, and hence Tai Chi exercise has been recently used with older adults for fall prevention (Wu 2002). Tai Chi is an ancient Chinese martial art consisting of a series of slow but continuous movements of many parts of the body. Older adults enjoy Tai Chi exercise because it can be performed at any time and place without special equipment. The forms of Sun-style Tai Chi exercise are characterized by slow, continuous, and gentle motions with a higher stance than other Tai Chi styles, and hence are more suitable to the physical condition of older adults (Song *et al.* 2003).

There is experimental evidence from both cross-sectional and longitudinal studies that Tai Chi exercise has beneficial effects on cardiovascular fitness (Lan *et al.* 1999), balance control (Tse & Bailey 1992, Wolfson *et al.* 1996), and psychological well-being (Kutner *et al.* 1997). Postural stability is improved more by Tai Chi exercise than by other types of exercise (Wolf *et al.* 1997). In view of these findings, Tai Chi exercise has great potential for health promotion and rehabilitation, particularly for the maintenance of good mental and physical conditions in older people.

Because Tai Chi exercise is a relatively new intervention, only a few longitudinal studies have specifically examined its effects on fall-related risk factors in fall-prone older adults. The specific form of Tai Chi exercise used has frequently been omitted from descriptions of interventions, which hinders standardization of intervention programmes.

The study

Aim

The aim of the study was to examine physical fitness (muscle strength of knee and ankle, mobility, balance, and flexibility), fall avoidance efficacy (perceived confidence to avoid falling), and fall episodes after implementing a 12-week Sun-style Tai Chi exercise programme to older adults in residential care facilities with risk factors for falling.

Design

A quasi-experimental design using a non-equivalent control group was used. According to Cohen's power analysis for a *t*-test between two independent samples having parameters of alpha = 0·05 and *d* (the effect size) = 0·80, a power value of 0·80 is predicted for a study involving 30 subjects in the experimental group and 30 subjects in the control group

(Bonrenstein *et al.* 1997). The effect size was quantified based on a pilot study on Tai Chi exercise for improving physical fitness (knee muscle strength) as one of the major outcome variables (difference between the means = 18 ft-lb, SD = 22·5) (Lan *et al.* 1998).

Participants

After the initial contact to explain the study purpose, the Korean Council on Social Welfare approved the study and provided a list of facilities for older adults in Korea. Based on the number of residents, location and facilities, two facilities with similar characteristics were selected and randomly assigned to either the experimental or control group by coin tossing. The assignment was carried out by facility rather than each individual to avoid contamination of intervention effects. All residents from both facilities were assessed prior to the study to determine the fall-prone population. We targeted ambulatory adults aged 60 years or over who had at least one of the following fall-related risk factors: (1) impaired gait [score <10 on the gait subscale (maximum 12) of the Performance Oriented Assessment of Mobility (POAM; Tinetti *et al.* 1986)]; (2) impaired balance [score <14 on the POAM balance subscale (maximum of 16)]; (3) history of falling in the previous year; (4) postural hypotension, as indicated by a drop in systolic blood pressure of $\geq$20 mmHg from lying to standing; and (5) use of four or more prescription medications that may affect balance.

Exclusion criteria were (1) severe dementia (score <20 on the Folstein Mini-Mental State Examination); (2) inability to complete 12 weeks of Tai Chi exercise due to physical illness; and (3) current involvement in any type of regular exercise.

A total of 68 older adults who agreed to participate in the study conformed to the inclusion criteria, of whom 29 in the Tai Chi group and 30 controls completed the post-test measures. While the experimental group participated in the Tai Chi exercise programme three times a week, the control group maintained their routine activities without participating in any regular exercise classes. All other daily activities in both groups were not controlled.

Tai Chi exercise programme

The Tai Chi exercise programme was provided to residents of the facility assigned as the experimental group three times per week for 12 weeks. The group came to the auditorium at the facility each morning and performed the intervention programme. A certified Tai Chi exercise leader taught the 12 forms of Sun-style Tai Chi exercise to the group throughout the exercise period.

The Tai Chi exercise programme consisted of 10 minutes of warming-up exercise, 20 minutes of 12 Tai Chi movements, and 5 minutes of cooling-down exercise. The warming-up exercise comprised walking around with moving hands and greeting each other in the group, followed by exercises with two ranges of motion on each joint of the neck, shoulders, trunk, hip, knees, and ankles. Lam (2000) developed forms of Tai Chi exercise specifically for patients with arthritis that consisted of slow and continuous movements with a great deal of moving forward and backward. The 12 forms of the Tai Chi exercise involved the bending of knees in wide steps. The cycle of 12 movements was repeated for 20 minutes while listening to traditional instrumental music in order to maintain slow and continuous movements, as well as to provide a soothing effect. The exercise session was always completed with a cooling-down exercise involving the stretching of arm and leg muscles and breathing exercises.

Instruments

Trained research assistants measured all outcome variables before and after the 12-week Tai Chi exercise programme. Blind measurements were not feasible because of the non-random participant assignment at each facility, and hence a measurement team from the physical-strength examination centre for older people at Honam University performed objective and consistent measurements of physical fitness at both pretest and post-test. The variables measured were physical fitness (knee and ankle muscle strength, balance, flexibility, and mobility), fall avoidance efficacy, and fall episodes.

Muscle strength

Knee and ankle muscle strength was measured using a manual muscle tester (EG-230, Sakai 2000, Japan). Each person sat on a tall chair that ensured that the foot was not touching the floor, and was asked to raise the limb to specified heights against maximal resistance provided by the research assistants. Both extension and flexion of knees and ankles were measured. The members of the measurement team were trained prior to the study to confirm inter-examiner reliability by measuring muscle strengths of the same person. The same member of the measurement team performed both pretest and post-test measurements on each older person in the study.

Balance

Balance was assessed by how long (in seconds) the person could stand on one foot either with eyes closed or eyes opened. Flexibility was measured by asking them to bend

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forward at the waist and stretch both hands toward the feet without bending the knees, and the distance (in centimetres) between the hands and the feet was measured. Mobility was measured by the time taken (in seconds) to walk 6 m on a marked floor.

Fall episode

A fall was defined as a sudden and unintentional change in position from an upright posture – with or without loss of consciousness – that caused the person to land on the ground. Participants were asked to report any fall episode during the previous year, and weekly fall episodes were closely monitored during the study period.

Fall avoidance efficacy

Fall avoidance efficacy was assessed using a scale (Tinetti *et al.* 1990) based on the perceived confidence that the person would be able to avoid falling, with 1 indicating not confident at all and 10 indicating very confident of avoiding falling. The internal consistency of the 10-item scale was indicated by a Cronbach alpha value of 0·82 for the present study.

Ethical considerations

Since there was no institutional review board at the selected facilities, the purpose of the study was explained to the manager of each facility and all participants gave written consent once approval had been granted to conduct the study.

Data analysis

Data were analysed using the SPSS (Windows V10.0, SPSS Inc., Chicago, IL, USA) program. Descriptive statistics were used for demographic variables. The homogeneity test was used to detect any significant group differences in the demographic data and pretest measures. The independence *t*-test was used to examine group differences in outcome variables.

Results

Demographic characteristics and baseline measures

A total of 68 older adults participated in the study, and 29 people in the Tai Chi group and 30 controls completed the post-test measures, corresponding to dropout rates of 14·7% and 11·8%, respectively. The reasons for dropping out from the exercise group were hospitalization ($n = 1$), transfer to another facility ($n = 2$), and less than 70% attendance at the 36 exercise sessions ($n = 2$). The reasons for dropping out from the control group were death ($n = 1$), admission to hospital ($n = 2$), and transfer to another facility ($n = 1$). The mean attendance rate for the Tai Chi exercise group was 80·3%.

Demographic data, muscle strength, flexibility, balance, mobility, and falls avoidance efficacy at pretest are summarized in Table 1. The mean age of participants was 77·86 years (range 61–91 years), and they had resided at their facility for a mean of 5·4 years. Most participants were female (75%) and had received no formal education (64%). More than half (61%) experienced a fall during the previous year.

The only significant baseline differences in demographic characteristics and outcome measures between the exercise and control groups were for the strength of ankle dorsiflexors and in balance and mobility. In the final analysis of post-test measures, difference scores between pretest and post-test measures were used for the group comparison which allows for the pre-existing group differences in these variables.

Table 1 Demographic characteristics and baseline measures of subjects by group

Variable	Exercise ($n = 29$) Frequency (%)	Control ($n = 30$) Frequency (%)	χ^2/*t*-test
Gender			
Male	6 (21)	9 (30)	0·67
Female	23 (79)	21 (70)	
Educational level			
No formal education	18 (62)	20 (67)	2·16
Primary school	7 (24)	8 (27)	
Middle school or higher	4 (14)	2 (7)	
Fall in the past year			
Yes	19 (66)	17 (57)	0·48
No	10 (34)	13 (43)	
	Mean (SD)	Mean (SD)	
Age (years)	76·96 (7·7)	78·73 (6·9)	0·92
Residence period (years)	5·53 (5·64)	5·22 (4·74)	0·23
Muscle strength (kg)			
Knee flexors	7·68 (4·07)	9·94 (4·73)	−1·96
Knee extensors	11·57 (5·85)	12·44 (4·62)	−0·63
Ankle dorsiflexors	10·23 (4·11)	12·81 (5·05)	−2·15*
Ankle plantarflexors	17·70 (6·58)	20·47 (6·21)	−1·66
Flexibility (cm)	−3·11 (6·66)	−3·47 (7·45)	0·20
Balance: standing on one leg			
Eyes open (seconds)	1·37 (0·98)	3·03 (4·23)	−2·08*
Eyes closed (seconds)	1·28 (0·84)	1·93 (1·46)	−2·09*
Mobility: 6-m walk (seconds)	10·04 (3·77)	7·10 (2·35)	3·59*
Falls efficacy (10–100)	87·93 (12·81)	88·97 (10·29)	−0·34

*$P < 0·05$.

Table 2 Mean group comparisons of score changes in muscle strength, flexibility, balance, mobility, and falls efficacy between pretest and post-test

Variable	Exercise ($n = 29$) Mean* (SD)	Control ($n = 30$) Mean* (SD)	*t*-test	*P*-value
Muscle strength (kg)				
Knee flexors	2·00 (2·69)	−1·66 (4·11)	4·04	< 0·001
Knee extensors	5·35 (3·24)	2·09 (4·71)	3·11	0·003
Ankle dorsiflexors	2·22 (4·01)	−2·56 (4·87)	4·11	< 0·001
Ankle plantarflexors	0·22 (6·38)	−6·87 (6·94)	4·08	< 0·001
Flexibility (cm)	4·10 (5·86)	−0·37 (5·66)	2·98	0·004
Balance: standing on one leg				
Eyes open (seconds)	1·65 (2·30)	−0·44 (3·41)	2·75	0·008
Eyes closed (seconds)	0·99 (2·68)	−0·14 (1·59)	1·98	0·052
Mobility: 6-m walk (seconds)	−2·51 (3·17)	1·04 (3·38)	−4·16	< 0·001

*Mean scores were computed as differences between post-test and pretest.

Group comparisons of muscle strength, mobility, flexibility, and balance

Group comparisons were made on score changes in the outcome variables between pretest and post-test measures to assess the effects of the Tai Chi exercise (Table 2). At the completion of 12 weeks of Tai Chi exercise, the experimental group showed significantly improved muscle strengths in knee and ankle flexors ($P < 0·001$) and extensors ($P < 0·01$), and improved flexibility ($P < 0·01$) and mobility ($P < 0·001$), indicating significantly better physical fitness than the control group. The experimental group showed significantly improved balance with their eyes open ($P < 0·01$) than the control group, but the group difference was not significant when the eyes were closed. In terms of mobility, the time taken for the exercise group to walk 6 m reduced from 10·0 to 7·5 seconds, while in the control group the time increased from 7·1 to 8·1 seconds ($P < 0·001$).

Group comparisons on fall avoidance efficacy and fall episode

Table 3 lists the group comparisons on fall episodes and fall avoidance efficacy on completion of the 12-week Tai Chi exercise programme. During the 12-week study period, nine people (31%) in the exercise group and 15 controls (50%) experienced falls, but the group difference in fall episodes was not statistically significant. The relative risk ratio for the Tai Chi exercise group compared with the control group was 0·62 (confidence interval 0·32–1·19). In addition, the experimental group reported significantly more confidence in avoiding falling after the programme, while in the control group fall avoidance efficacy decreased ($P < 0·001$).

Table 3 Group comparisons on falls efficacy and fall episodes

Variable	Exercise ($n = 29$) Frequency (%)	Control ($n = 30$) Frequency (%)	χ^2	*P*-value
Fall episode				
Yes	9 (31·03)	15 (50·0)	2·198	0·187
No	20 (68·97)	15 (50·0)		
	Mean* (SD)	Mean* (SD)	*t*-test	
Falls efficacy	5·62 (10·35)	−4·17 (8·65)	3·95	< 0·001

*Mean scores were computed as differences between post-test and pretest.

Discussion

A Sun-style Tai Chi exercise programme was administered to older adults in residential care facilities who were at risk of falling. The physical fitness of the exercise group was significantly improved after a 12-week programme, in terms of improved knee and ankle muscle strengths, mobility, flexibility, and balance with eyes open. Muscle strength is lost at an annual rate of 1–2% in healthy women older than 65 years, and exercise training can strengthen older adults (Skelton *et al.* 1995). Intervention studies consistently demonstrate the efficacy of exercise on muscle strength, especially the effects of squatting on knee extensors and plantar flexors (Flanagan *et al.* 2003). A study of 26 healthy older adults also showed that the strength of knee extensors was significantly increased at the completion of 20 weeks of Tai Chi exercise (Christou *et al.* 2003). A period of 12 weeks appears to be long enough to show significant improvements in muscle strength for healthy older adults, but not for patients with arthritis (Song *et al.* 2003).

In association with muscle strength in the low extremities, balance is one of the major factors in fall prevention. The effects of exercise by older adults on balance are equivocal in the literature (Johansson & Jarnlo 1991). In the present study, balance was measured by single stance (standing on one leg) with or without visual feedback. Single-stance time

What is already known about this topic

- The risk indicators for falling in older adults include physical, psychological, and environmental factors, some of which are potentially modifiable so as to reduce the incidence of fall episodes.
- Regular exercise is useful in fall prevention in older adults because of improvements in strength and balance.

What this paper adds

- Tai Chi exercise, a Chinese martial art and a low-intensity exercise, was safely applied to fall-prone older people for 12 weeks.
- Tai Chi exercise was effective at improving muscle strengths, flexibility, mobility, balance with eyes open, and fall avoidance efficacy, which could help in the prevention of fall episodes in older adults.
- A fall prevention programme with multiple risk-factor approaches should be incorporated into nursing interventions for older adults to optimize their functional independence and quality of life.

declines with age and is a marker for poor balance (Judge *et al.* 1993). Improved single-stance control is typically important in fall prevention, because the majority of falls occur during walking or turning or on stairs (Judge *et al.* 1993). In the present study, the exercisers significantly improved their eyes-open static balance, but not their balance with eyes closed. Standing on one leg with eyes closed is associated with fear of falling, and is considered one of the most difficult tasks because of a lack of visual feedback, especially in older adults (Johansson & Jarnlo 1991, Topp *et al.* 1993). Our participants were able to balance on one leg with eyes closed only for short periods of time, and this resulted in insignificant differences between the groups.

Participants in Tai Chi exercise also showed significant improvement in their fall avoidance efficacy (from 87·9 to 93·5) after 12 weeks. Mean score at pretest was similar to previously reported scores in women aged 80 years and over, who improved their fall avoidance efficacy to 93·3 after 2 years of exercise (Campbell *et al.* 1999). In the present study, the experimental group felt more confident in avoiding falling after Tai Chi exercise, while among controls fall avoidance efficacy decreased by 4·7%. Improvement of fall avoidance efficacy is important to the functional independence of older adults who are afraid of going out because of the fear of falling.

We found that nine members (31%) of the Tai Chi exercise group and 15 members (50%) of the control group fell during a period of 16 weeks, giving a relative risk ratio of 0·62, although group comparison did not reveal a statistically significant difference. A previous study with 59 fall-prone older men also showed that a 3-month intervention programme had no significant effect on the incidence of falls (Rubenstein *et al.* 2000). In contrast, Campbell *et al.* (1999) reported that 2 years of continuous individualized exercise by 213 older women resulted in a significant reduction in fall risk (relative risk ratio = 0·69, 95% confidence interval = 0·52–0·97). In the present study, the magnitudes of the achieved effects of the Tai Chi exercise in reducing falls were comparable with those in previous studies, but failed to reach statistical significance. The inconsistent results may be attributable to the relatively short follow-up period (4 weeks) during which fall incidence was measured, and to the small sample size ($n = 59$). The effects of Tai Chi exercise on fall prevention may be clinically relevant and should be investigated in a larger study with a longer follow-up period.

Study imitations

Random assignment was not possible in the present study because of the potential risk of contaminating intervention effects. Efforts were made to reduce selection bias by considering similarities of each facility in number of residents, location, and facilities, as well as assigning each facility to either the experimental or comparison group by coin tossing. However, differences in events or episodes may have been present between the two facilities during the study period, and may have acted as confounding factors to the intervention effects.

The second limitation is related to the absence of a blind process for the application of the intervention as well as in the measurements. The participants were aware of their group assignment, which may have influenced their effort or intention to perform better on post-test measures. To reduce this type of confounding factor, a professional team rather than the research team measured physical fitness using standardized equipment. Since the investigators were not blind to treatment status, research assistants were recruited for the pretest and post-test measures and were trained by the investigators prior to each measurement.

Practice implications

The study provides new evidence of the complex relationship between low-intensity exercise and fall prevention. It shows that older adults with multiple risk factors for falling can

reduce their fall incidence by enhancing their confidence to avoid falling, muscle strength of lower extremities, mobility, and balance. A fall-prevention programme with multiple risk-factor approaches should be incorporated into nursing interventions for older adults to optimize their functional independence and quality of life. A randomized clinical study with a larger sample size and longer follow-up period should be designed to confirm the effects of Tai Chi exercise on fall prevention in older adults. Also, different forms of exercise need to be tested to compare the effects on fall prevention.

Conclusions

The present study reveals that a Tai Chi exercise programme can improve the strength of postural muscles in the lower extremities, mobility, and flexibility. Muscle strength and balance are important limiting factors in the maintenance of a functionally independent lifestyle for older adults (Skelton *et al.* 1995). Tai Chi exercise is recognized as a low-intensity exercise that can be safely and easily applied to older adults to prevent falls in the long-term.

Author contributions

JHC and JSM performed the study conception and design. JHC, JSM and RS performed critical revisions of the manuscript for important intellectual content. JHC and RS drafted the manuscript. JHC collected the data. RS undertook data analysis. RS provided statistical expertise and gave administrative, technical or material support. JSM supervised.

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