A Randomized, Controlled Trial of tai chi for the Prevention of Falls: The Central Sydney tai chi Trial

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OBJECTIVES: To determine the effectiveness of a 16-week community-based tai chi program in reducing falls and improving balance in people aged 60 and older.

DESIGN: Randomized, controlled trial with waiting list control group.

SETTING: Community in Sydney, Australia.

PARTICIPANTS: Seven hundred two relatively healthy community-dwelling people aged 60 and older (mean age 69).

INTERVENTION: Sixteen-week program of community-based tai chi classes of 1 hour duration per week.

MEASUREMENTS: Falls during 16 and 24 weeks of follow-up were assessed using a calendar method. Balance was measured at baseline and 16-week follow-up using six balance tests.

RESULTS: Falls were less frequent in the tai chi group than in the control group. Using Cox regression and time to first fall, the hazard ratio after 16 weeks was 0.72 (95% confidence interval (CI) = 0.51–1.01, $P = .06$), and after 24 weeks it was 0.67 (95% CI = 0.49–0.93, $P = .02$). There was no difference in the percentage of participants who had one or more falls. There were statistically significant differences in changes in balance favoring the tai chi group on five of six balance tests.

CONCLUSION: Participation in once per week tai chi classes for 16 weeks can prevent falls in relatively healthy community-dwelling older people. **J Am Geriatr Soc 55:1185–1191, 2007.**

Key words: falls; balance; tai chi; community-based

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In recent years, preventing falls in older people has become an increasingly important public health issue.[1–3] Approximately 30% of people aged 60 and older will fall in any 12-month period.[4,5] Physical activities enhancing balance and strength are among the most promising intervention strategies for preventing falls in older people.[6] An advantage of physical activity as a falls prevention strategy is that physical activity has many health benefits[7] and can form a component of an individual's healthy lifestyle rather than targeting one particular health problem.

Numerous studies have investigated the effect of tai chi on balance.[8–16] Some have found that tai chi improves postural sway, single leg stance, tandem stance, lateral stability, and reaching,[9,11,14,16] although other studies have failed to report improvements in these measures or in assessments of sit-to-stand ability and gait.[9,10,13] Two randomized trials have shown tai chi to be an effective way of reducing falls in community-dwelling older people.[8,17] Another randomized trial found that tai chi reduced falls in people transitioning to frailty,[18] but tai chi was not found to be effective for falls prevention in a randomized trial involving people living in long-term care facilities.[19]

Previous trials of tai chi for falls prevention have all involved tai chi classes at least twice per week. This level of commitment might be difficult for many older people to sustain. The quality of tai chi instruction in previous studies was probably higher than might be found in many tai chi classes in the general community. The current study involved just one tai chi class per week and a large number of tai chi instructors, all of whom were currently offering tai chi classes in the study community. Participants in the study tended to be younger than those in previous studies.

The main hypothesis that this study investigated was that a community-based weekly tai chi program of 16 weeks duration would reduce falls in people aged 60 and older. The study also investigated whether any effect on falls was still evident 8 weeks after the end of the tai chi program. Because tai chi is thought to act through improving balance, the effects of the tai chi program on balance were also investigated.

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METHODS

This study was a randomized, controlled trial. The intervention was a 16-week community-based tai chi program. Participants randomized to the control group were placed on a 24-week waiting list. Fall outcomes were analyzed after 16 and 24 weeks. Balance was assessed at baseline and 16 weeks.

Recruitment of Study Participants

Recruitment was staggered across 10 periods between June 2001 and March 2003, with each period targeting a different geographical region in central and southeastern Sydney. Recruitment during each period involved advertisements placed in local community newspapers.

Participants were eligible for the trial if they were aged 60 and older, were living in the community, and had not practiced tai chi in the previous 12 months. Participants were excluded if they had a degenerative neurological condition such as Parkinson's disease, dementia, a severely debilitating stroke, severe arthritis, or marked vision impairment or if they were unable to walk across a room unaided.

Baseline assessments were conducted 2 weeks before the beginning of the tai chi program. Each participant was interviewed using a structured questionnaire to assess sociodemographic variables, falls history, adequate physical activity (defined as $\geq$30 minutes of moderate physical activity on $\geq$5 days a week),[7] health-related quality of life,[20] independent activities of daily living,[21] and falls efficacy.[22] Balance was assessed as described below.

A randomization list, whose details remained unknown to the research assistants, was prepared for each venue using randomly permuted blocks of four or six. After the baseline assessments had been conducted, the research assistants randomized participants into the intervention tai chi program or the waiting list control group. The Central Sydney Area Health Service Human Ethics Committee gave approval for this study, and informed consent was obtained from all subjects before their participation.

tai chi Intervention

The tai chi intervention consisted of a 16-week program of weekly 1-hour tai chi classes. All classes were community based and operated as normal, without any modification for this research project. Classes were restricted in size to between eight and 15 participants. tai chi instructors were recruited from among those running classes in the local community and were allocated to classes according to their availability. To be eligible to instruct a study tai chi program, instructors had to have at least 5 years experience teaching tai chi or have completed an accredited tai chi trainers' course, as well as having previously taught tai chi or other gentle exercise programs to older people. No restriction was made on the tai chi style taught by the instructors.

Twenty-two tai chi instructors, who conducted a total of 38 tai chi programs for the study, conducted classes at 24 community venues. The majority of classes involved Sun-style tai chi (83%), two classes involved Yang-style tai chi (3%), and the remainder involved a mixture of several styles (14%). Participants were not given any particular instructions about doing tai chi outside class time. Those who missed classes did not have extra catch-up classes, but instructors typically reviewed previous lessons at the start of each new class.

Participants were asked to pay AU\$44 for the 16-week tai chi program. It was hoped that making this financial commitment would increase the likelihood of attendance at classes.

Control participants were instructed not to do any tai chi elsewhere during the 24 week study period. At the end of the study period, control participants were offered a 16-week tai chi program.

Falls Surveillance

Falls were defined as "unintentionally coming to rest on ground, floor, or other lower level."[23] Falls were monitored for 24 weeks. Participants were given a falls calendars and were instructed to record on the calendar each day for 24 weeks whether they had a fall. At the end of each month, participants were required to mail the prepaid-postage calendars to the study center. Participants who had not returned calendars within 2 weeks of the end of each month were contacted to establish their falls status.

Balance Measures

Four trained research assistants, blind to intervention status, administered six balance tests at baseline and 16 weeks later, at the conclusion of the tai chi program. These tests of balance have been used in a wide range of falls research studies and have good validity and test–retest reliability.[24–26]

The balance tests have been described in detail elsewhere.[24–29] Sway was measured using a swaymeter that measured displacement of the body at the level of the waist.[25,26] Two conditions were tested: participants standing on the floor and then standing on a foam rubber mat (40 cm $\times$ 40 cm $\times$ 15 cm thick). Leaning balance was measured using maximal balance range and coordinated stability tests—balance tests that require subjects to adjust their balance in a controlled manner when near the limits of their base of support.[25,27] Lateral stability was assessed by measuring maximal lateral sway with feet placed in a near-tandem position with eyes open.[25,28] Choice stepping reaction time was determined by assessing subjects' ability to step as quickly as possible onto one of four rectangular panels that were illuminated in a random order.[25,29] The average time for 20 steps was used in the analysis.

Statistical Power and Data Analysis

Previous studies of tai chi programs in the community have found relative reductions in falls and fallers of approximately 40%.[8,17] The total period for which participants were under observation for falls in the current study was 24 weeks ($\sim$ 6 months). Although most studies describe the incidence of falls over a 12-month period, one study found that 24% of older people will fall in a 6-month period.[30] The current study was designed to detect a 40% relative reduction (from 24% to 15%) in the proportion of people who have at least one fall during follow-up. A sample size of 284 per group ($\alpha = .05$, power = 80%) was necessary. With an estimated dropout rate of 25%, a final sample size of 379 per group was required.

The primary study outcome was falls during 16 weeks of follow-up. Secondary outcomes were falls during 24 weeks of follow-up and changes in balance during 16 weeks of follow-up. Data were analysed on an intention-to-treat basis. Analyses were done using STATA 8.2 statistical software (Stata Corp., College Station, TX).

Negative binomial regression models were used to calculate incidence rate ratios (IRRs) comparing falls rates in intervention and control groups during 16 and 24 weeks of follow-up.[31] The risk of falling was analysed using Cox regression models for one or more falls and the Andersen-Gill extension of the Cox model for two or more falls. The negative binomial and Cox models were repeated with adjustment for age, sex, venue, falls history, baseline sway on the foam mat, and adequacy of physical activity. The last two variables were the only baseline characteristics that differed appreciably between study groups. History of falls was included in multivariable models, because this is an established risk factor for future falls. Cumulative incidence ratios (relative risks) and chi-square tests were used to compare the proportions of fallers (participants who had $\geq$1 falls) and multiple fallers (participants who had $\geq$2 falls) in each group after 16 and 24 weeks.

Changes in balance over 16 weeks were assessed using forced-entry multiple linear regression analysis, with experimental group, age, sex, venue, falls history, and baseline adequacy of physical activity included as independent variables in the models.

RESULTS

A total of 702 people were randomized: 353 into the intervention group and 349 into the waiting list control group (Figure 1). The average age of participants ± standard deviation was 69 ± 6.5 (range 60–96); 84% were female. Participant characteristics are shown in Table 1. The only statistically significant ($P<.05$) difference between study groups at baseline was sway on the foam mat (which was

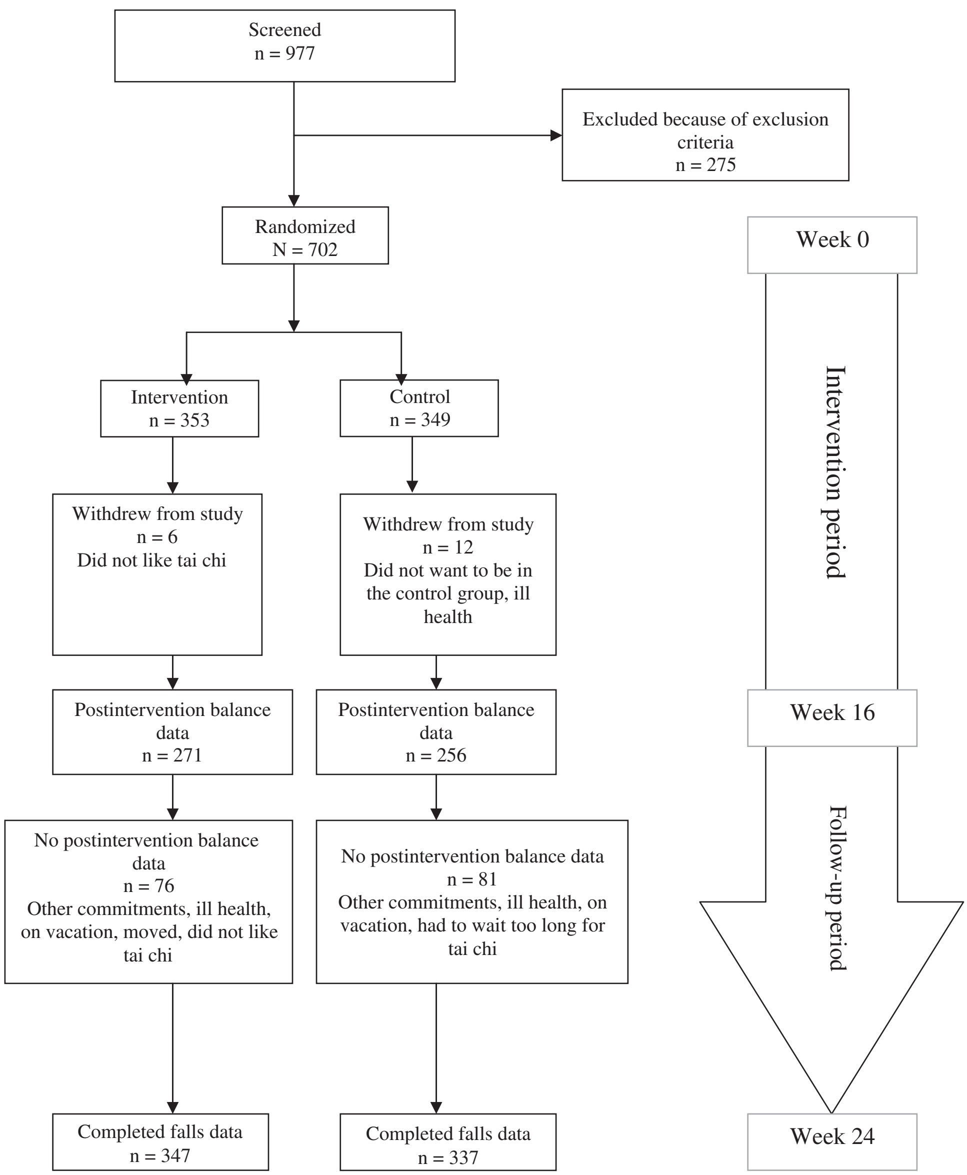

Figure 1. Flow chart of study participants.

worse in the intervention group). The difference in adequacy of physical activity (which was better in the intervention group) approached conventional statistical significance ($P = .07$). More participants in the control group reported two or more falls in the previous year (13% vs 10% in the intervention group). Although this difference was not statistically significant ($P = .2$), history of falls was included as a covariate in adjusted models.

Eighteen participants dropped out of the study altogether and did not undertake the postintervention balance assessments or complete any falls calendars: six from the intervention group and 12 from the control group. A further 157 participants (76 intervention participants and 81 controls) provided falls data but did not have follow-up balance measures. These participants tended to be older and less well educated and have poorer self-rated health and more difficulties with activities of daily living than participants who completed the follow-up balance assessments (Table 1).

Two hundred seven participants (58.6%) in the tai chi group attended at least 13 of 16 tai chi classes, with 278 (78.8%) attending at least half the classes. Overall, subjects attended 71% of the tai chi classes offered. Reasons given for not attending classes included losing interest in tai chi, class times clashing with other commitments, and illness.

The number of falls during follow-up in each study group after 16 and 24 weeks are shown in Table 2. After 16 weeks, 19% of participants had at least one fall, and 3% had two or more falls. After 24 weeks, 22% had at least one fall, and 6% had two or more falls. There was no difference in the percentage of participants who had one or more falls, but there was nearly a 50% relative risk reduction of two or more falls (multiple falls) for the tai chi group at 16 and 24 weeks. The relative risk for multiple falls at 24 weeks (0.54, 95% confidence interval (CI) = 0.28–0.96) was just statistically significant ($P = .05$) (Table 3).

The fall rate was lower in the tai chi group than in the control group. Using negative binomial regression, the incidence rate ratio (IRR) after 16 weeks was 0.72(95% CI = 0.48–1.10, $P = .1$) and after 24 weeks it was 0.67 (95% CI = 0.46–0.96, $P = .03$) (Table 3). The reduced falls

Table 1. Baseline Characteristics of Study Subjects According to Study Group and Subjects without Follow-Up Balance Data

Variable	Intervention (n = 353)	Control (n = 349)	P-Value*	Participants with Missing Follow-Up Balance Data (n = 175)	P-Value†
Age, %					
60–64	22	26		22	
65–69	29	27	.65	19	.03
70–74	24	23		29	
≥75	25	24		30	
Female, %	85	83	.56	86	.52
Level of education, %					
<Intermediate	16	12	.49	24	<.001
Intermediate	43	41		39	
Secondary	13	14		15	
Technical college	14	16		10	
University	14	17		13	
Current psychotropic medication use, %	7	6	.86	5	.39
Falls in previous year, %					
≥1	31	36	.15	35	.73
≥2	10	13	.21	12	.86
Falls requiring medical treatment, %	47	40	.33	48	.46
Health Status SF-36, %					
Excellent	11	9		8	
Very good	35	35	.85	27	.09
Good	40	40		48	
Fair/poor	14	16		17	
Instrumental activity of daily living scale score of 16/16, %	68	67	.92	39	.05
Falls Efficacy Scale score of 8/8 (high efficacy), %	48	53	.34	43	.04
Adequate physical activity, % ‡	31	25	.07	24	.29
Able to walk for >1 hour, %	42	44	.54	42	.73
Age, mean	69	69	.62	69	.62
Sway on mat, mm, mean	186	172	.03	184	.38

* *P*-value refers to a statistical test comparing intervention and control groups.
† *P*-value refers to a statistical test comparing the group of participants with missing postintervention balance data and the group with completed balance data.
‡ At least 30 minutes of moderate physical activity on at least 5 days a week.

Table 2. Fall Frequency After 16 and 24 Weeks Follow-Up According to Study Group

	Falls					
	0	1	2	3	4	5
Duration of Follow-Up	n (%)					
16 weeks						
Control (n = 337)	267 (79.2)	55 (16.3)	8 (2.4)	5 (1.5)	2 (0.6)	0
Intervention (n = 347)	286 (82.4)	53 (15.3)	8 (2.3)	0	0	0
24 weeks						
Control (n = 337)	256 (76.0)	54 (16.0)	14 (4.1)	10 (3.0)	1 (0.3)	2 (0.6)
Intervention (n = 347)	276 (79.6)	56 (16.1)	15 (4.3)	0	0	0

rate persisted after adjusting for age, sex, falls history, baseline balance (sway on mat), and adequacy of physical activity (Table 3).

Using the Andersen-Gill extension of the Cox proportional hazard model, the hazard ratio (HR) for two or more falls in the intervention group compared with the control group was 0.33 (95% CI = 0.14–0.78, $P = .01$) at 16 weeks and 0.33 (95% CI = 0.18–0.62, $P = .001$) at 24 weeks (Table 3). Adjustment for age, sex, falls history, baseline balance (sway on mat), and adequacy of physical activity did not diminish the magnitude and statistical significance of these HRs. HRs were weaker for one or more falls and were only statistically significant after 24 weeks (Table 3).

There was only weak evidence that those who attended more tai chi classes had fewer falls than those who attended less frequently. For example, 18% of those who attended more than eight classes fell at least once during the first 16 weeks of the study, and 2% fell twice or more, compared with 20% and 4%, respectively, of those who attended eight or fewer classes.

Mean scores on the six study balance measures in the intervention and control groups at baseline and follow-up are shown in Table 4. After adjusting for age, sex, falls history, and adequacy of physical activity at baseline, the intervention group performed statistically significantly better on five of the six balance variables than the control group: sway on floor ($P = .02$), sway on foam mat ($P = .004$), lateral stability ($P = .005$), coordinated stability ($P < .001$), and choice stepping reaction time ($P < .001$). All these variables except choice stepping reaction time ($P = .20$) were also statistically significantly different before adjustment. There was no difference between groups for the maximal leaning balance range test, before ($P = .20$) or after adjustment ($P = .50$).

DISCUSSION

It was found that once weekly tai chi classes for 16 weeks reduced falls in a relatively healthy community-dwelling group of people aged 60 and older in Sydney, Australia. This effect was evident at the conclusion of the tai chi program and was maintained for at least another 8 weeks. The tai chi program had no effect on the proportion of people who had one or more falls during follow-up, but tai chi appeared to reduce the proportion of participants who had two or more falls.

There were multiple tai chi instructors teaching a variety of tai chi styles. Although this reflects the situation as currently found in the community in Sydney, Australia, we acknowledge that this is a limitation of the study, because

Table 3. Unadjusted and Adjusted Incidence Rate Ratios (IRRs), Relative Risks (RRs), and Hazard Ratios (HRs) for Falls in Intervention and Control Groups at 16 and 24 Weeks Follow-Up

	16 Weeks		24 Weeks	
Variable	Unadjusted	Adjusted	Unadjusted	Adjusted
Number of falls, IRR (95% CI) *P*-value *	0.72 (0.48–1.10) .10	0.73 (0.50–1.07) .11	0.67 (0.46–0.96) .03	0.67 (0.47–0.94) .02
Participants with ≥1 falls, RR (95% CI) *P*-value†	0.85 (0.62–1.16) .30	—	0.86 (0.65–1.14) .28	—
Participants with ≥2, RR (95% CI) *P*-value†	0.54 (0.23–1.26) .10	—	0.54 (0.28–0.96) .05	—
Survival analysis, HR (95% CI) *P*-value				
≥1 falls‡	0.72 (0.51–1.01) .06	0.72 (0.50–1.03) .07	0.67 (0.49–0.93) .02	0.66 (0.47–0.92) .02
≥2 falls§	0.33 (0.14–0.78) .01	0.25 (0.08–0.83) .02	0.33 (0.18–0.62) .001	0.27 (0.12–0.59) .001

Adjusted for age, sex, previous 12-month falls history, venue, baseline adequate physical activity, and baseline sway on mat.
* Negative binomial regression models.
† Cumulative incidence ratios (relative risks).
‡ Cox proportional hazards models.
§ Andersen-Gill extension of Cox model.
CI = confidence interval.

Table 4. Adjusted Values for Balance Variables at Baseline and 16-Week Follow-Up

Variable	Baseline		16-Week Follow-Up		*P*–Value
	Intervention (n = 271)	Control (n = 256)	Intervention (n = 271)	Control (n = 256)	
Sway, mm, mean ± SD					
Floor, eyes open	70 ± 47	66 ± 38	70 ± 40	72 ± 41	.02
Mat, eyes open	189 ± 105	168 ± 89	168 ± 82	174 ± 94	.004
Lateral stability, mm, mean ± SD	19 ± 25	17 ± 19	17 ± 13	17 ± 19	.005
Leaning balance, mm, mean ± SD	157 ± 48	161 ± 49	167 ± 45	165 ± 43	.50
Coordinated stability score, median errors (interquartile ratio)	12 (14)	11 (14)	9 (13)	11 (14)	<.001
Reaction time, ms, mean ± SD	1,094 ± 207	1,100 ± 239	1,081 ± 172	1,100 ± 235	<.001

Analyzed using multiple linear regression on change in scores (follow-up minus baseline) by forced entry adjusting for age, sex, previous 12-month falls history, venue, and baseline adequate physical activity. High scores on the sway, lateral stability, coordinated stability, and choice reaction time tests and low scores in the leaning balance test indicate impaired performance.
SD = standard deviation.

it makes it impossible for others to replicate this tai chi program. Also reflecting the common situation in the community, tai chi classes were only offered once a week in this study. Despite this, the magnitude of the effect of tai chi in this study is comparable to that of previous studies.[8,17]

A weakness of this study is that good measures of physical activity were not available, so potential confounding by differences in physical activity between the tai chi and the control group could not be adequately controlled for. Another limitation was that nearly 30% of participants did not complete the follow-up balance assessments.

Several studies of older people have suggested that the functional performance benefits of physical activity programs decline in as little as 2 weeks after cessation of exercise.[32,33] In contrast, the current study found that reduction in falls from tai chi was maintained for up to 8 weeks after classes finished. This is consistent with a previous study in which gains from a tai chi program lasted up to 6 months.[8] It may be that tai chi is easier to incorporate into daily life than other forms of exercise, so people continue to practice principles of tai chi after ceasing to attend formal classes. For example, some participants indicated informally that they practiced the tai chi walk (being conscious of foot placement and balance) while going about their daily activities.

Unlike other studies that have reported inconsistent effects of tai chi on balance,[9,34] the tai chi group performed significantly better than the controls on five of the six balance measures. This suggests that the intervention was of sufficient duration, and the exercise stimulus sufficiently intensive, to result in improved balance. The performance of the intervention group on the choice stepping reaction time test may be particularly important, because this test is not unlike the step response required to avoid a fall and provides a useful composite measure of falls risk.[30]

The study population was a fairly robust group of older people, with a mean age of 69. Other trials of tai chi for falls prevention have involved subject groups with mean ages of 76 and older.[8,17–19] Most participants rated their health as good, very good, or excellent, and nearly 50% reported that they were able to walk for at least an hour. Two-thirds had no limitations in instrumental activities of daily living. These results should only be generalized to younger groups of relatively healthy older people.

In conclusion, the findings from this study indicate that participation in weekly community-based tai chi classes can reduce falls in relatively healthy, community-dwelling older people. Given that the tai chi program used existing community facilities, the study suggests that tai chi is an effective and sustainable public health intervention for falls prevention for older people living in the community.

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