

Functional Benefits of Tai Chi Training in Senior Housing Facilities

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OBJECTIVES: To determine the effects of tai chi training on functional performance and walking with and without the addition of the performance of a cognitive task, in older adults living in supportive housing facilities.

DESIGN: Secondary data analysis comparing a single-blind, randomized controlled trial of tai chi training with an attention-matched educational control intervention with crossover to tai chi.

SETTING: Two supportive housing facilities.

PARTICIPANTS: Sixty-six men and women living in supportive housing facilities entered the study, and 57 aged 87 ± 7 completed all study procedures.

INTERVENTION: Interventions consisted of two 1-hour-long instructor-led group sessions per week for 12 weeks. Tai chi training consisted of movements based upon the Yang-style short form. Educational sessions consisted of lectures and discussions of age-related health topics.

MEASUREMENTS: Subjects were tested for physical function (Short Physical Performance Battery, SPPB), balance (Berg Balance Scale, BBS), mobility (timed up-and-go, TUG), and walking speed under normal and cognitive dual-task conditions.

RESULTS: The tai chi group exhibited greater improvement in SPPB scores (baseline 8.1 ± 2.9 , follow-up 9.0 ± 2.6) than controls (baseline 8.2 ± 2.6 , follow-up 8.2 ± 2.6) ($P = .005$). Tai chi also increased normal and dual-task walking speed ($P < .001$) yet did not affect BBS ($P = .02$) or TUG ($P = .02$) after accounting for multiple comparisons. The dual-task cost (percentage change) to walking speed was unaffected. After the crossover tai chi intervention, the control group improved performance in

the SPPB, BBS, and TUG, and increased walking speed under normal and dual-task conditions ($P = .008$).

CONCLUSION: Tai chi training may be a safe and effective therapy to help improve physical function and dual-task walking in very old adults living in supportive housing facilities. *J Am Geriatr Soc* 62:1484–1489, 2014.

Key words: tai chi; frailty; mobility; gait; randomized controlled trial

Aging is often associated with multiple functional impairments that are characteristic of frailty and may diminish the ability to adapt to common stressors in daily life.^{1,2} Tai chi is a Chinese martial arts form that engages multiple physiological systems^{3,4} and thereby has the potential to overcome impairments associated with frailty.⁵ Tai chi's emphasis on the integration of mind and body may also make it particularly well suited to improving one's ability to adapt walking to concurrent performance of cognitive "dual" tasks. Still, its effectiveness as a low-cost intervention to improve physical function and dual-task capacity in very old adults living in supportive housing facilities is largely unknown. A study was therefore conducted comparing 12 weeks of tai chi training with an education attention-control intervention with crossover to tai chi for their effects on physical function and dual-task walking in adults aged 70 and older living in supportive housing facilities. It was hypothesized that tai chi training would result in greater improvement in physical function and ability to maintain walking speed during a cognitive stressor than the control intervention.

METHODS

Trial Design

A single-blind randomized controlled trial was conducted to compare the effects of tai chi exercise with those of an educational control intervention on cardiovascular and balance system function in older people at risk of

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DOI: 10.1111/jgs.12946

developing frailty (NCT01126723). Secondary study outcomes related to balance and physical function are reported herein. Primary outcomes of frailty status and nonlinear dynamics will be reported elsewhere.

Eligible participants were assessed at baseline and randomly assigned to a tai chi or educational control group. Study personnel blinded to group assignment conducted assessments. Upon completion of follow-up testing, control group participants completed the tai chi intervention and a final “crossover” assessment.

Participants

Men and women were recruited between 2010 and 2013 from two supportive housing facilities owned by Hebrew Senior Life. Each site houses individuals aged 70 and older in need of supportive services for instrumental activities of daily living. The study was advertised in each facility in flyers and a presentation by study personnel. Interested individuals were screened in telephone interviews. Potentially eligible individuals then completed in-person evaluations. Written informed consent was obtained from all participants. The Hebrew Senior Life institutional review board approved the study.

Exclusion criteria included the inability to stand or ambulate unassisted; symptomatic cardiovascular or respiratory disease; history of myocardial infarction or stroke; self-reported painful arthritis, spinal stenosis, amputation, painful foot lesions, or neuropathy; systolic blood pressure >160 mmHg; diastolic blood pressure >100 mmHg; known abnormal cardiac rhythm or presence of cardiac pacemaker; Parkinson's disease; metastatic cancer; and immunosuppressive therapy.

Thirty-five participants were assigned to the tai chi group and 31 to the control group (Figure 1). All participants completed the baseline assessment. Six withdrew from the tai chi group before follow-up and three from the control group. Reasons for withdrawal included injury unrelated to the study ($n = 1$) and diminished interest in participation ($n = 8$). Upon completion of follow-up, 26 of 28 remaining control group participants completed the crossover tai chi intervention and assessment.

Interventions

Tai Chi Intervention

This 12-week intervention was conducted in a common area of each facility. One of three instructors taught two 1-hour group training sessions per week to a maximum of 12 participants per group. The certified instructors had more than 5 years of tai chi teaching experience with older health-impaired adults. Training was based upon a program initially developed for individuals with heart disease and balance disorders^{6–9} and focused on traditional tai chi warm-up exercises and five core movements from the Cheng Man-Ch'ing's Yang-style short form (raising the power, withdraw and push, grasp the sparrow's tail, brush knee twist step, wave hand like clouds). Participants were also provided with an instructional DVD of the entire protocol and instructed to practice at home for 20 minutes at least 3 days per week. Home practice was tracked using

participant diaries. Participants were instructed to report any adverse event to the tai chi instructor.

Educational Control Intervention

A time-matched attention control intervention was used in which participants attended 1-hour group sessions twice weekly. Research personnel led sessions, which included lectures, discussions, and patient education handouts produced by the American Geriatric Society Public Education Committee (available at <http://www.americangeriatrics.org>).

Assessments

Participants were assessed for physical function, balance, mobility, and walking with and without performance of a cognitive task.

The Short Physical Performance Battery (SPPB) is a valid and reliable test of physical function that includes measures of standing balance, 4-m walking speed, and the ability to rise from a chair five times.^{10,11} The Berg Balance Scale (BBS) assesses static and dynamic balance. Participant performance is graded on a 5-point ordinal scale on 14 separate tasks.¹² A BBS score <45 has been linked with high fall risk.¹³ The Timed Up-and-Go Test (TUG) is a validated test of mobility¹⁴ in which the participant must rise from a chair, walk 3 m, and return to a seated position. Walking was assessed at preferred speed along a 30-m course in a hallway of each facility. Two, 90-second trials were completed in random order: walking normally and walking while verbalizing serial subtractions of five from a random 3-digit number. Walking speed was determined by dividing total distance by trial duration.

Frailty status was calculated based on previously reported cutoffs for unintentional weight loss, exhaustion, physical activity level, walking speed, and grip strength.^{15–17} Participants with three or more deficits were classified as frail, one or two deficits as prefrail, and no deficits as non-frail.

Study Outcomes

Outcomes included SPPB and BBS scores, TUG time, and average walking speed during normal and dual-task conditions. The “dual-task cost” to walking speed was calculated as percentage change in speed between normal and dual-task conditions.

Statistical Analysis

Analyses were performed using JMP software (SAS Institute, Inc., Cary, NC). Descriptive statistics were used to summarize group characteristics and study outcomes. An initial analysis examined the characteristics of the nine individuals who withdrew during the study. Their age, sex, height, body mass index (BMI), and baseline performance on each study outcome were similar to those of the individuals who completed the study. Subsequent analyses were therefore based on those who completed all study procedures.

Potential between-group differences in demographic and baseline characteristics were tested with one-way analyses of variance or chi-square tests.

The effects of the intervention on study outcomes were first analyzed using data from the parallel-group randomized controlled trial using two-way repeated-measures analyses of covariance (ANCOVAs). Model effects were group, time, and their interaction. Models were completed with and without adjustments for age, sex, BMI, and attendance. Significance was set at $\alpha = .01$ (Bonferroni adjusted) for each of the five outcomes. Tukey post hoc testing was used to compare factor means of significant models.

The effects of each intervention were also analyzed by examining the control-crossover data. One-way repeated-measures ANCOVAs were used to determine whether performance on each outcome differed over time (baseline, follow-up, crossover). Models were completed with and without adjustments for age, sex, BMI, and attendance. Tukey post hoc testing was used to compare factor means of significant models. Significance was set to that described above.

As a secondary analysis, the influence of age on tai chi effectiveness was examined using linear regression. Data from both groups were included. Dependent variables were

percentage change from the prior assessment in each outcome after the original or crossover tai chi intervention. Model effects included age, group, and their interaction. Each model was adjusted for tai chi attendance.

RESULTS

Baseline Participant Characteristics

Fifteen participants were classified as frail, 36 as prefrail, and six as nonfrail. Groups had similar sex distribution, age, height, and BMI (Table 1). The control group exhibited slower normal and dual-task walking speeds ($P = .02$). Baseline performance on other functional tests did not differ between groups.

Attendance and Adverse Events

Attendance was similar between groups. Participants randomized to tai chi completed 20.9 ± 2.6 of 24 classes and 20.1 ± 6.4 hours of home practice. Participants randomized to the control intervention completed 21.0 ± 2.6 of

Table 1. Group Characteristics and Functional Outcomes of the Randomized Controlled Trial

Characteristic and Outcome	Tai Chi Group, n = 29		Control Group, n = 28		P-Value ^a		
	Baseline	Follow-Up	Baseline	Follow-Up	Group Effect	Time Effect	Interaction
Sex, n							
Male	5	7					
Female	24	21					
Age, mean \pm SD (range)	87 \pm 5 (75–95)	86 \pm 6 (71–98)	.21				
Height, meters	1.5 \pm 0.1	1.6 \pm 0.1	.76				
Weight (kg)	66 \pm 11	67 \pm 11	68 \pm 14	69 \pm 15	.31	.91	.26
Frailty Index, n ^b							
Frail	9	7	6	4			
Prefrail	16	16	20	17			
Nonfrail	4	6	2	7			
Short Physical Performance Battery, total score, mean \pm SD	8.1 \pm 2.9	9.0 \pm 2.6	8.2 \pm 2.6	8.2 \pm 2.6	.60	.32	.005
4-m gait speed, m/s, mean \pm SD	1.02 \pm 0.26	1.11 \pm 0.28	0.94 \pm 0.30	0.93 \pm 0.28	.08	.67	.009
Chair stand time, seconds, mean \pm SD	14.5 \pm 4.7	12.6 \pm 2.9	14.2 \pm 3.6	14.3 \pm 2.9	.46	.30	.01
Side-by-side stand, seconds, mean \pm SD	60.0 \pm 0.0	60.0 \pm 0.0	59.9 \pm 5.8	59.6 \pm 2.1	.55	.40	.55
Semi-tandem stand, seconds, mean \pm SD	15.3 \pm 12.1	16.4 \pm 12.6	14.5 \pm 10.2	14.1 \pm 11.6	.60	.30	.11
Tandem stand, seconds, mean \pm SD	9.2 \pm 1.3	10.0 \pm 1.5	9.1 \pm 2.5	9.0 \pm 2.4	.60	.31	.01
Normal walking speed, m/s, mean \pm SD	0.98 \pm 0.23	1.05 \pm 0.28	0.91 \pm 0.23	0.88 \pm 0.21	.02	.12	<.001
Dual-task walking speed, m/s, mean \pm SD	0.87 \pm 0.22	0.94 \pm 0.24	0.80 \pm 0.25	0.76 \pm 0.21	.02	.08	<.001
Dual-task cost, % change, mean \pm SD	–11.8 \pm 8.6	–12.8 \pm 8.3	–14.1 \pm 9.2	–13.9 \pm 8.6	.19	.54	.27
Berg Balance Scale score, mean \pm SD	45.6 \pm 6.8	47.3 \pm 6.4	44.4 \pm 6.5	44.0 \pm 6.7	.23	.08	.02
Timed Up-and-Go, seconds, mean \pm SD	12.0 \pm 4.2	11.2 \pm 3.8	13.9 \pm 5.6	14.4 \pm 6.5	.09	.60	.02

^a Models were adjusted for age, sex, body mass index, and class attendance.

^b Adapted from Fried et al.¹⁵

SD = standard deviation.

24 educational classes. After crossover, this group completed 20.4 ± 3.9 tai chi classes and 22.6 ± 8.9 hours of home practice. No adverse events related to tai chi practice were reported.

Effects of Tai Chi on Walking and Physical Function

Parallel-Group Randomized Controlled Trial

Tai chi had beneficial effects on physical function. A group-by-time interaction was observed for SPPB ($F_{1,54} = 13.2$, $P = .005$) that remained significant after adjusting for covariates. Post hoc testing revealed that control group performance did not change after the education intervention, although the tai chi group improved SPPB performance. Further analysis revealed that specific improvements were made on the 4-m gait speed, chair stand time, and tandem stance components of the test (Table 1). Similar trends were observed for the TUG ($F_{1,54} = 5.4$, $P = .02$) and BBS ($F_{1,54} = 5.7$, $P = .02$), yet neither model reached significance after accounting for multiple comparisons.

Tai chi training increased walking speed. Group-by-time interactions were observed under normal ($F_{1,54} = 12.0$, $P < .001$) and dual-task conditions ($F_{1,54} = 12.2$, $P < .001$). Each interaction remained significant after adjusting for covariates. At baseline, the control group walked more slowly in both conditions than the tai chi group. Whereas the control group did not demonstrate a change in walking speed at follow-up, the tai chi group walked significantly faster—under normal and cognitive dual-task conditions.

At baseline, performing the cognitive task while walking resulted in a $14 \pm 8\%$ (0.13 ± 0.81 m/s) reduction in walking speed across all participants. This dual-task “cost” was similar in both groups. Because tai chi training increased walking speeds under normal and dual-task conditions, it did not affect the dual-task cost to this variable.

Baseline group differences ($P = .02$) in these outcomes may have confounded the effects of intervention on walking speed. Closer inspection of the data revealed that two control group participants walked significantly more slowly than average (0.42 and 0.39 m/s under normal conditions and 0.30 and 0.34 m/s under dual-task conditions). Because each participant performed similarly at follow-up and exhibited lower than average performance in the other study outcomes, these participants were not deemed to be outliers, although each ANCOVA was repeated with these two participants removed. In each case, baseline group differences were no longer present, yet similar interactions were observed (walking speed increased after tai chi training only).

Crossover Group

Upon completion of initial follow-up testing, 26 of 28 participants from the control group completed 12 weeks of tai chi training followed by a “crossover” assessment. Significant effects of time were observed for the SPPB ($F_{2,26} = 12.9$, $P < .001$), BBS ($F_{2,26} = 6.6$, $P = .004$), and TUG ($F_{2,26} = 5.6$, $P = .008$). In each case, post hoc testing

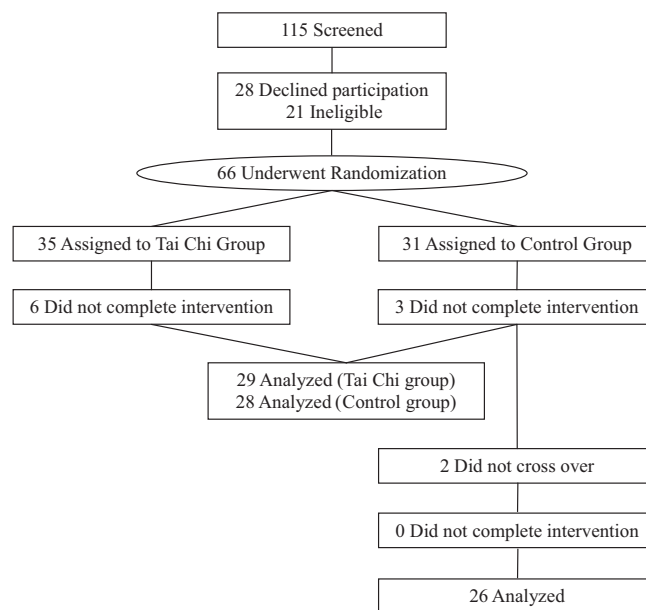


Figure 1. Participant flow diagram.

indicated that performance was better after tai chi training than during the control period. This group demonstrated a $21 \pm 16\%$ increase in SPPB score, an $8 \pm 10\%$ increase in BBS score, and an $18 \pm 21\%$ reduction in TUG time between the assessment completed after the initial control period (immediately before the tai chi intervention) and the assessment after tai chi training.

Significant effects of time were also observed for normal ($F_{2,26} = 8.0$, $P = .001$) and dual-task ($F_{2,26} = 8.1$, $P = .001$) walking speed. In each condition, walking speeds were greater after tai chi training than at either of the first two control assessments, although tai chi training did not reduce the dual-task cost to walking speed.

Each of the two participants who had significantly slower walking speeds than the rest of the cohort at baseline (see previous subsection) demonstrated substantial improvements after the crossover tai chi intervention. For the normal and cognitive task conditions, one participant walked 41% and 34% faster, respectively, after tai chi training than in their prior assessment, and the other walked 20% and 26% faster, respectively.

Influence of Age on Tai Chi Effectiveness

Cohort age ranged from 71 to 98. Secondary analyses revealed that younger participants made more improvement on the SPPB (correlation coefficient (R) = 0.36, $P = .02$), TUG ($R = -0.41$, $P = .01$), and normal walking speed ($R = -0.48$, $P = .001$) (Figure 2). Regression analyses revealed that these relationships were similar in the original tai chi and crossover groups and independent of attendance. Age was not correlated with tai chi–related changes on the BBS or dual-task walking speed.

DISCUSSION

Twelve weeks of tai chi training improved physical function, balance, and walking in very old adults living in

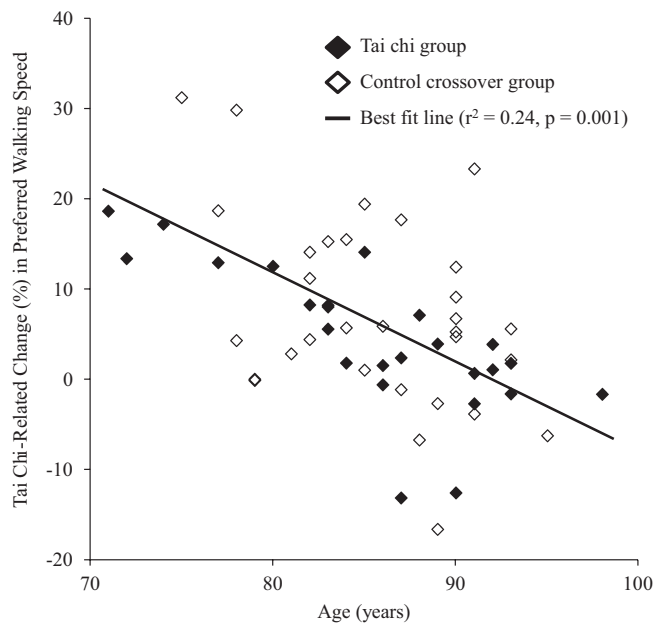


Figure 2. Relationship between participant age and tai chi-related improvement in walking speed. Younger participants tended to exhibit larger percentage changes in normal walking speed than older participants after the 12-week tai chi training intervention. A similar age effect was observed for performance on the Timed Up-and-Go and Short Physical Performance Battery (not pictured). In each case, the relationship was similar between groups and independent of number of classes attended.

supportive housing communities more than did an attention-matched educational intervention. Training sessions were well attended and did not lead to adverse events. Tai chi training may therefore be a safe, inexpensive, and feasible therapeutic option to help maintain functional independence of vulnerable older individuals.

Tai chi training improved performance in the SPPB, a test of physical function. A previous study^{10,11} reported that a summary score <9 predicted subsequent disability in adults aged 70 and older. In the current study, average baseline SPPB scores were <9. After the original and crossover tai chi training, average SPPB scores increased to above this 9-point threshold. In the entire cohort, 17 participants with SPPB scores <9 at baseline exhibited scores of 9 or greater after tai chi training. Previous studies support these clinically significant changes in physical function,^{5,18–21} which warrant larger studies to compare the effectiveness of tai chi with that of other forms of exercise and whether it reduces healthcare use in this costly population.

A common consequence of aging and frailty is reduced capacity to adapt to the stressors of everyday life.¹ Age-related decrements in walking, for example, are exacerbated when individuals are stressed by performing concurrent cognitive tasks.²² Slower walking speed when performing cognitive task is predictive of mobility decline and falls in older adults.^{23,24} In the present study, although tai chi training did not affect the dual-task cost to walking speed, it resulted in faster speeds in the dual-task condition. Thus, although previous research has reported inconsistent results,^{25,26} the current study suggests that 12 weeks of training may be

sufficient to improve the capacity to adapt walking to a cognitive stressor in this population.

The average age of the present cohort was 87. Results indicated that, for the TUG, SPPB, and preferred walking speed, tai chi was generally associated with less improvement in older than in younger participants (Figure 2). Few studies have examined the effect of age on exercise effectiveness. One study reported that 8 weeks of resistance training improved physical function in adults aged 80 to 88,²⁷ but another reported that a similar intervention improved strength but did not alter TUG performance in nonagenarians.²⁸ The “oldest old” may thus be less responsive—in terms of mobility outcomes—to tai chi and other forms of exercise training. Still, the results of this small yet well-controlled trial indicate that tai chi may improve functional performance in very old adults living in supportive housing facilities.

ACKNOWLEDGMENTS

An abstract from this study was presented at the annual meeting of the American Geriatrics Society, May 4, 2012 Seattle, Washington.

This work was supported by a Medical Research Investigator Training award (1KL2RR025757–04) from Harvard Catalyst, a grant from the Harvard Clinical and Translational Science Center (UL1RR025757), and grants from the National Institute on Aging (R37-AG025037, T32AG023480, P01-AG004390).

Conflict of Interest: Dr. Lipsitz holds the Irving and E-dyth S. Usen and Family Chair in Geriatric Medicine at Hebrew SeniorLife. The editor in chief has reviewed the conflict of interest checklist provided by the authors and has determined that the authors have no financial or any other kind of personal conflicts with this paper.

Author Contributions: Lewis A. Lipsitz and Peter M. Wayne had the original idea for the study. All authors contributed to the design of the study and interpretation of the data. Brad Manor wrote the initial draft of the manuscript, and all authors provided intellectual input to subsequent drafts. Lewis A. Lipsitz is the study guarantor. Brad Manor and Adrienne Cupples performed the statistical analyses of the data. All authors approved the final version.

Sponsor's Role: None. The content is solely the responsibility of the authors and does not necessarily represent the official views of Harvard Catalyst, Harvard University, or its affiliated academic health care centers.

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