Effects of Tai Chi and Western Exercise on Physical and Cognitive Functioning in Healthy Community-Dwelling Older Adults

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Abstract

Objective—To compare the effects of Tai Chi (TC, $n = 37$) and Western exercise (WE, $n = 39$) with an attention-control group (C, $n = 56$) on physical and cognitive functioning in healthy adults age 69 ± 5.8 yr, in a 2-phase randomized trial.

Methods—TC and WE involved combined class and home-based protocols. Physical functioning included balance, strength, flexibility, and cardiorespiratory endurance. Cognitive functioning included semantic fluency and digit-span tests. Data were analyzed using intention-to-treat analysis.

Results—At 6 mo, WE had greater improvements in upper body flexibility ($F = 4.67$, $p = .01$) than TC and C. TC had greater improvements in balance ($F = 3.36$, $p = .04$) and a cognitive-function measure ($F = 7.75$, $p < .001$) than WE and C. The differential cognitive-function improvements observed in TC were maintained through 12 mo.

Conclusion—The TC and WE interventions resulted in differential improvements in physical functioning among generally healthy older adults. TC led to improvement in an indicator of cognitive functioning that was maintained through 12 mo.

Keywords

mind–body therapy; physical activity; executive function; aged adult

Healthy aging is an important public health issue, given the increasing number of older adults worldwide. They account for the greatest proportion of chronic-disease burden, which often contributes to impaired physical and cognitive functioning, loss of independent living, and increased disability ("Trends in Aging," 2003). Conversely, regular physical activity is a critical element of an overall healthy lifestyle that can extend years of independent living, reduce disability, and improve physical and cognitive functioning among older adults (Colcombe & Kramer, 2003; Hogan, 2005; King et al., 2000; Mazzeo et al., 1998). Physical activity recommendations for older adults include moderate-intensity aerobics and muscle-strengthening and flexibility activities, along with balance exercises, to improve and maintain health (Nelson et al., 2007). Despite the widely reported benefits of regular physical activity (Colcombe & Kramer, 2003; Netz, Wu, Becker, & Tenenbaum, 2005; Whelton, Chin, Xin, & He, 2002), most older adults do not achieve recommended levels (Centers for Disease Control and Prevention, 2004, 2005). The challenge and opportunity are to make physical activity long lasting and more attractive to older adults of all ages, interests, and abilities (King, 2001).

Among older adults, research examining Western forms of exercise (WE) such as walking or calisthenics has reported improvements in cardiorespiratory endurance, muscle strength, flexibility, balance, and cognitive functioning (American College of Sports Medicine [ACSM], 2004; Colcombe & Kramer, 2003; Mazzeo et al., 1998; Nelson et al., 2007). Prior studies indicate that a 6-month moderate-intensity aerobic-exercise program is adequate for significant improvements in cognitive function, with the greatest benefit occurring in executive-control processes (Colcombe & Kramer, 2003). Improvements in cardiovascular-disease biomarkers, such as blood pressure, atherogenic lipid profiles, and heart-rate variability, resulting from participation in regular physical activity are thought to contribute to improvements in cognitive function (Physical Activity Guidelines Advisory Committee, 2008).

Tai Chi is an Eastern form of exercise that appeals to a growing number of older adults, with somewhat similar improvements in physical functioning reported when compared with WE (Hartman et al., 2000; Lan, Lai, Chen, & Wong, 1998, 2000; Wolf et al., 1996; Wong, Lin, Chou, Tang, & Wong, 2001). Tai Chi is a gentle, low-impact exercise that has been practiced in China for hundreds of years (Galante, 1981; Taylor-Piliae, 2003). "The Compendium of Physical Activities" (Ainsworth et al., 2000) classifies Tai Chi as a moderate-intensity exercise, at 4 metabolic equivalents similar in intensity to brisk walking. In addition, Tai Chi may provide benefits beyond traditional forms of WE (Galante, 1981; Lan, Lai, & Chen, 2002). During the performance of Tai Chi exercise, individuals are taught to be mindful of what their bodies are doing and how it feels. The goal is for the whole body

to remain relaxed while practicing TC, integrating mental concentration and breathing control (Galante, 1981).

Most research on Tai Chi among older adults has focused on balance, flexibility, postural control, muscle strength, and fall-risk reduction, although various styles of Tai Chi were used in these studies (Hartman et al., 2000; Lan et al., 1998, 2000; Wolf et al., 1996; Wong et al., 2001) that can represent different exercise intensities and durations, making comparisons difficult. Anecdotal evidence suggests that Tai Chi may also improve cognitive function, but experimental evidence in this area is not well documented (Galante, 1981; Lan et al., 2002). Given this, the major objective of the Wellness Interventions for Self Enrichment (WISE) study was to evaluate the effects of Tai Chi versus a standard program of WE consisting of cardiorespiratory-endurance, strength, and flexibility training on physical and cognitive functioning in healthy, community-dwelling adults age 60 years and older.

Methods

Study Design

The WISE study was a randomized clinical trial with two phases: The first 6 months were designated as an adoption phase during which Tai Chi, WE, and attention-control groups were compared. During the second 6 months, designated as the maintenance phase, the two exercise groups (Tai Chi and WE) continued to be compared. Once volunteers completed the baseline evaluation and were deemed eligible for the study, they were randomized to one of the three groups. Because the programs were taught in classes, participants were entered in cohorts of 20–30 so that 8–10 participants could start a class together to help facilitate instruction. Over the course of the study, five cohorts were enrolled between April 2000 and September 2001. Major follow-up evaluations were completed at 6 and 12 months, with a limited evaluation performed at 3 months. Data were collected through October 2002. The WISE protocol was approved by the Panel on Human Subjects in Medical Research at Stanford University.

Study Sample

Men and women living at home or in a community residential setting in either Santa Clara County or San Mateo County in northern California were eligible to participate in WISE. Inclusion criteria were being age 60 years or older, living within a reasonable commute to Stanford University and the community exercise facilities, understanding the English language sufficiently to give study consent and follow intervention instructions, signed written consent, being sedentary (no regular exercise >60 min/week), and being able to walk without assistive devices. Exclusion criteria included major medical diagnoses that would interfere with participation in moderate-intensity exercise, for example, myocardial infarction, cardiac surgery, or stroke in past 3 months; congestive heart failure, angina pectoris, serious cardiac arrhythmias, or blood pressure >160/100 mm Hg; or active treatment for cancer, alcoholism, recreational drug abuse, or severe cognitive impairment (ACSM, 2005; King et al., 2005).

Participant Recruitment and Randomization

The recruitment plan included newspaper and radio advertisements, flyers, and brochures placed in senior centers, retirement residences and clubs, pharmacies, and primary-care offices. Presentations about the project were made to members of senior centers and senior residences. Interested individuals completed a telephone interview and, if still interested and apparently eligible, were invited to a group or individual orientation session. At the orientation session the study was described in detail, the requirements for participation were explained, and study-related questions were answered. Participants still interested and eligible were scheduled for baseline evaluations. After screening for eligibility and baseline measurements, participants were randomly assigned to Tai Chi, WE, or control. A decision was made to randomize participants in a disproportionate manner, with approximately 30% assigned to each of the two exercise groups and 40% to control. The larger number of participants randomized to control at baseline provided more participants for rerandomization after the adoption phase (first 6 months) of this study to interventions in a subsequent supplemental study. Data from the supplemental study are not reported in this article.

Interventions

After randomization, initial individual counseling sessions were provided to participants by their respective class instructor, including program schedule, safety issues, and intervention procedures. The two exercise interventions involved a combined class- and home-based protocol to maximize long-term participation (King et al., 2000). A social-cognitive approach to the acquisition and maintenance of physical activity was employed that included personalized feedback, specific structuring of expectations, consciousness raising regarding the benefits of physical activity, realistic and individualized goal setting, encouragement from staff, reinforcement of successful change, and monitoring of adherence (Bandura, 1997; King, 2001; King et al., 2000). Classes lasted approximately 60 min and were no more than moderate in intensity. During the adoption phase, participants in the exercise groups were assigned two class-based and three home-based exercise sessions per week, and the attention-control group met once a week for approximately 90 min. During the maintenance phase, participants in the exercise groups were instructed to engage in one class-based and three home-based exercise sessions per week.

Tai Chi—The Tai Chi classes were held in the community room of a local church that provided privacy and a relaxing atmosphere. All Tai Chi classes were taught by a Tai Chi grand master. Participants were taught 12 postures of the Yang short-form style of Tai Chi (Lee, Lee, & Johnstone, 1989). A new posture was taught each week during the first 12 weeks, with the entire sequence of postures practiced together during the remainder of the adoption phase. During the maintenance phase 12 additional postures were taught, with participants learning a total of 24 postures during the study (Lee, Lee, Lee, & Lee, 2002). The postures were practiced with continuous movement from one to the next, in a slow and rhythmic motion. Each class consisted of 45 min of instruction including warm-up exercises, with chairs available for participants to rest as needed. Participants were provided with written instructions, illustrations of the postures, and a videotape (Lee & Lee, 1989) for use during practice on home-based exercise days. In addition to the Tai Chi postures, they were

taught essential elements of performing Tai Chi, such as body orientation, relaxation, breathing, attention to feeling, inattention to thoughts, upright and relaxed posture, symmetry, weight shifting, and a slow and relaxed pace. Daily practice was encouraged.

Western Exercise—The WE program incorporated endurance, resistance/strength, and flexibility exercises. Participants attended supervised classes held at a YMCA exercise facility and led by certified exercise leaders. Each class started with 8–10 min of warm-up activities consisting of stretching, light calisthenics, and slow walking. This was followed by cardiorespiratory-endurance activities lasting for 15–25 min consisting of more vigorous walking and calisthenics performed to music and then a session of both resistance/strength and flexibility exercises lasting 15–20 min. The resistance exercises included selected calisthenics and the use of light hand weights and rubber exercise bands. Home-based exercise sessions included   30 min of walking and 10–25 min of resistance and flexibility exercises three times per week. The intensity of the exercise was gradually increased over time using heart-rate monitoring and ratings of perceived exertion. A 1-year YMCA senior membership was provided to all the WE participants.

Control Group—Throughout the 6-month adoption phase, participants in the attention-control group attended "healthy aging" classes to control for time, attention, support, or additional factors that could potentially influence the study outcomes, independent of the exercise interventions. Experienced professionals provided information on a number of topics, for example, healthy eating, elder hostels, forgiveness, elder law, and appropriate foot and eye care. Classes met once a week for approximately 90 min and included visits to markets to learn about reading food labels and selecting produce. Controls were provided with the opportunity to participate in one of the exercise interventions after completion of the study.

Measurements

Measurements were made at the outpatient clinical research facility operated by the Stanford Prevention Research Center. Trained and certified staff obtained baseline and all follow-up data and were blinded to participants' group assignment. Adoption-phase data were collected at baseline, 3 months, and 6 months for all three groups. Maintenance-phase data were collected at 12 months for the two exercise groups. The full measurement battery was collected at baseline and at 6 and 12 months. At 3 months, a subset of these measures was collected. The data collected at 3 months are not included in this report.

Physical Functioning—Physical-functioning measures included balance, muscle strength and endurance, flexibility, and cardiorespiratory endurance. Balance measures included the single-leg-stance and functional-reach tests. The single-leg-stance test is frequently used in studies evaluating health-related fitness in older adults (Bohannon, 2006; Suni et al., 1996). Participants are timed on their ability to stand on a single leg with their eyes open, up to a 1-min maximum. The better of two trials for each leg is recorded. Functional reach assesses dynamic balance by measuring the maximal distance a participant can reach forward beyond arms' length, while maintaining a fixed base of support in the standing position (Duncan, Weiner, Chandler, & Studenski, 1990). The better of two trials is recorded.

Upper and lower body muscle-strength and -endurance measures included 30-s timed arm-curl and chair-stand tests, respectively (Rikli & Jones, 1999a, 1999b). For the arm-curl test, participants perform a full range of motion using a hand weight (5 lb for women, 8 lb for men). The number of arm curls completed in 30 s is recorded. For the chair-stand test participants rise to a full standing position and then return to a seated position, with arms folded across their body, as many times as possible within the 30-s time limit. The number of stands completed within the time limit is recorded (Rikli & Jones, 1999a, 1999b).

Upper and lower body flexibility measures included the back-scratch (Rikli & Jones, 1999a, 1999b) and sit-and-reach tests (Minister of Supply and Services Canada, 1986; Jackson & Langford, 1989), respectively. For the back-scratch test, participants stand and then raise one arm above the head, bend the elbow, and reach down across the back as far as possible. Simultaneously, the opposite arm is extended up along the back as far as possible to meet or overlap the fingers of both hands. The distance of overlap (plus score) or the distance between (minus score) the tips of the middle fingers is measured in centimeters. The better of two trials is recorded. The sit-and-reach test was performed using the Accuflex I Sit and Reach Box (Novel Products, Rockton, IL) with the participant sitting on the floor, head and back against a wall, legs outstretched, and feet against the box. They were instructed to reach as far forward as possible with their arms stretched out in front and fingertips lightly sliding along a ruler. After a practice trial, participants perform the procedure three times and the best score is used.

Cardiorespiratory endurance was assessed by treadmill testing. At baseline, participants performed a clinical maximal treadmill exercise test using a Balke-type protocol (1- to 2-MET increase every 2 min) with continuous monitoring of a 12-lead ECG, with blood pressure and rating of perceived exertion recorded at the end of each stage and at peak exercise (ACSM, 2005). This test was used to provide medical clearance for the exercise programs and as a baseline measure of cardiorespiratory fitness. At 6 and 12 months a submaximal treadmill test was performed with an intensity target of 85% of estimated age-predicted maximal heart rate. Changes in heart rate, systolic blood pressure, and rating of perceived exertion at a set submaximal work rate (treadmill speed and grade) have been identified as reliable measures of changes in cardiorespiratory fitness (ACSM, 2005). The treadmill protocol (progression of workloads and measurements) remained the same, which enabled us to use changes in submaximal heart rate, systolic blood pressure, and rating of perceived exertion as indicators of changes in cardiorespiratory endurance.

Cognitive Functioning—Age-related cognitive changes are thought to be associated in part with a decline in executive functions (Lezak, 1995; Spreen & Strauss, 1998). Measures of executive function assessing specific processes, such as goal-directed behavior, information-processing speed, or working memory, have been reported to be sensitive to change after aerobic-exercise interventions (Colcombe & Kramer, 2003). In this study, a 60-s animal-naming test was used to assess semantic fluency (verbal retrieval and recall; Lezak, 1995; Tombaugh, Kozak, & Rees, 1999), and forward and backward digit-span tests were used to assess attention, concentration, and mental tracking (Bopp & Verhaeghen, 2005; Spreen & Strauss, 1998). There is no strong consensus as to what cognitive measures to use as outcomes of physical activity, but the measures selected have been reported to be

sensitive to change after an exercise intervention and were easy to administer with only minor staff and participant burden (Colcombe & Kramer, 2003).

Additional Measures—At the study orientation session, participants were provided questionnaires to record demographics, medical history, health behaviors, and psychosocial status. These questionnaires were brought to the baseline visit and reviewed for completeness by study staff.

Physical Activity Assessment—Class attendance was recorded by the instructors to track adherence to the Tai Chi and WE interventions. In addition, to assess overall participation in physical activity during the study, participants completed the Community Healthy Activities Model Program for Seniors (CHAMPS) physical activity questionnaire (Stewart et al., 2001) at baseline and 6 and 12 months. Time spent and calories expended during moderate- and vigorous-intensity physical activity were determined from the CHAMPS. The CHAMPS has been shown to detect changes in physical activity among older adults in response to an intervention (Stewart et al., 2001).

Data Analysis

Frequency distributions were run on every variable to check for extreme values. Data were analyzed using the Statistical Analysis System (Version 9.1, SAS Institute Inc., Cary, NC). Descriptive statistics were calculated for all variables. Intention-to-treat analysis was performed, with all participants randomized to the study included in the analysis (Kraemer, 2003; Newell, 1992). Missing data were replaced using the last observation carried forward (Nich & Carroll, 2002; Streiner & Geddes, 2001). For the adoption-phase data, analysis of variance was performed on baseline to 6-month change data to determine which group had significantly better outcomes in physical and cognitive functioning after 6 months. If the overall ANOVA was significant, Tukey's pairwise comparisons were performed to determine where the mean difference was. For the maintenance-phase data, independent-sample *t* tests were performed comparing change scores to determine which exercise group had significantly better outcomes in physical and cognitive functioning, by subtracting baseline from 12-month scores, using intention-to-treat analysis. In addition, because declines in physical and cognitive functioning are associated with aging, we calculated dependent-sample *t* tests to determine whether there were statistically significant changes in physical and cognitive functioning in each exercise group after 12 months.

Results

The recruitment, randomization, and retention flowchart for the study is shown in Figure 1. A total of 383 people were screened by phone for eligibility, 243 attended an orientation session, and 196 were invited for a baseline assessment. Approximately 34% (132) of the 383 people assessed for eligibility enrolled in the study. Major reasons for loss of participants between initial identification and randomization included scheduling conflicts (97), medical ineligibility (88), transportation issues (22), randomization refusal (21), and other reasons (23). A total of 115 (87%) participants completed the adoption phase of the study. The number of early dropouts in this study was not significantly different between

groups (Fisher's exact test, $p = .08$). Six-month study completers were more likely to be married and have fewer chronic health problems than those dropping out of the study earlier (Fisher's exact test, p .01).

Baseline Characteristics

Baseline characteristics of participants are presented in Table 1. Participants were on average 69 ($\pm$ 5.8) years old (range = 60–84 years), college educated, with good perceived health. Most were married (56%), White (85%), and women (70%). Hypertension (42.5%) was the most commonly self-reported medical problem, followed by chronic back pain (17.4%) and an irregular heartbeat (14.2%). There were no statistically significant differences between the groups at baseline, except for self-reported history of angina ($p = .01$; Table 1).

Intervention Adherence

Adoption Phase—The median adherence rate was highest in the Tai Chi group (77%), with slightly lower rates for the WE (68%) and control (67%) groups (between-groups differences, $p > .05$). In the Tai Chi group 75% of participants attended more than 66% of the class sessions, and 56% of WE participants attended 66% of prescribed classes (between-groups differences, $p = .007$). CHAMPS 6-month data indicated that WE participants significantly increased the number of moderate-intensity exercise sessions per week (4.6 ± 5.1) relative to baseline compared with the Tai Chi (1.6 ± 3.6, $p < .05$) and control groups (0.9 ± 3.3, $p < .05$).

Maintenance Phase—Class adherence was higher in participants assigned to Tai Chi than those in WE (65% vs. 53%, respectively; between-groups differences, $p > .05$). During the maintenance phase, 50% and 28% of participants attended more than 66% of assigned classes in Tai Chi and WE, respectively. CHAMPS 12-month data showed a significant increase in the number of moderate-intensity exercise sessions per week for both WE (4.6 ± 4.5, $p = .006$) and Tai Chi (2.2 ± 5.0, $p = .003$) groups compared with baseline. There were no statistically significant between-groups differences ($t = 1.99$, $p = .051$).

Physical and Cognitive Functioning

Participants in this study had generally good baseline physical- and cognitive-functioning scores (Table 2). Reported age-specific normative physical-functioning data indicate that they were higher than the 50th percentile for functional reach and upper and lower body strength (Duncan et al., 1990; Rikli & Jones, 1999a, 1999b). Similarly, reported age-specific cognitive-functioning data indicate that participants in this study were higher than the 50th percentile for semantic fluency (Tombaugh et al., 1999) and the digit-span tests (Bopp & Verhaeghen, 2005).

Adoption Phase

Physical Functioning—At baseline, participants were able to stand on one leg on average for 30 s before losing their balance (single-leg stance, Tables 2 and 3), which is below the 50th percentile for reported age-specific normative data. Tai Chi participants had

greater improvements than WE and control participants after the 6-month adoption phase, $F(df\ 3, 129) = 3.36$, $p = .038$. Tukey's pairwise comparisons of the mean differences revealed that Tai Chi participants had significantly more improvement in balance than controls (mean difference = 5.5 s, $p < .05$).

The back-scratch test was used to assess upper body flexibility. At baseline, participants were below the 50th percentile for reported age-specific normative data (Tables 2 and 3). WE participants had greater improvements than Tai Chi and control participants after the 6-month adoption phase, $F(df\ 3, 129) = 4.67$, $p = .011$. Tukey's pairwise comparisons of the mean differences revealed that WE participants had significantly more improvement in upper body flexibility than the other two groups (mean difference WE vs. control = 2.5 cm, $p < .05$; mean difference WE vs. Tai Chi = 2.9 cm, $p < .05$).

Cognitive Functioning—An indicator of cognitive functioning, the backward digit-span test, is thought to assess attention, concentration, and mental tracking (Lezak, 1995). At baseline, participants were below the 50th percentile for reported age-specific normative data (Bopp & Verhaeghen, 2005; Table 2). Tai Chi participants had greater improvements than WE and control participants after the 6-month adoption phase, $F(df\ 3, 129) = 7.75$, $p < .001$. Tukey's pairwise comparisons of the mean differences revealed that Tai Chi participants had significantly more improvement in cognitive functioning than the other 2 groups (mean difference Tai Chi vs. control = 0.9 digits, $p < .05$; mean difference Tai Chi vs. WE = 1.5 digits, $p < .05$; Table 3).

Maintenance Phase

Physical Functioning—After the 6-month maintenance phase (i.e., Months 7–12), participants in the Tai Chi and WE groups had statistically significant within-group improvements in several measures of physical functioning compared with their baseline values (Table 4). However, there were no longer significant physical-functioning differences between the two exercise groups by Month 12 ($p > .05$).

Cognitive Functioning—Similar to the results after the adoption phase, Tai Chi participants maintained their improvements in backward digit span compared with WE participants (Table 4). Tai Chi participants also had a statistically significant within-group improvement in the backward digit-span test (Table 4). An independent-sample t test examining the 12-month change in cognitive functioning was statistically significant between groups, with Tai Chi participants performing better than those in WE, $t(df\ 2, 74) = 2.52$, $p = .014$. Participants in both Tai Chi and WE had statistically significant within-group improvements in semantic fluency after the maintenance phase, although between-groups differences did not reach statistical significance.

Discussion

This was a two-phase randomized clinical trial and, to our knowledge, the first to examine the effect of Tai Chi on cognitive functioning. The major objective of the WISE study was to evaluate the effects of Tai Chi versus a standard program of Western exercise consisting of endurance, strength, and flexibility training on physical and cognitive functioning in

healthy, community-dwelling adults age 60 years and older. Participants in this study were on average healthy, college-educated White women, which is fairly representative of older adults living in San Mateo and Santa Clara counties in northern California (San Francisco Bay Area Census, 2002) with only minimal medical exclusions, so findings in this study mainly apply to healthy, college-educated White women. Despite the general age-associated declines in physical and cognitive functioning, WISE participants had baseline values greater than the 50th percentile on many of the physical- and cognitive-function variables measured, making it difficult to elicit statistically significant improvements and thus decreasing the likelihood that participation in either of the exercise programs would lead to significant improvements in these variables (i.e., a ceiling effect could have occurred; King, Haskell, Young, Oka, & Stefanick, 1995).

Class instruction was provided by highly trained instructors, and there were conveniently located community-based facilities willing to accommodate the exercise groups. Adherence to the two exercise interventions was good (adoption-phase median = 71%, maintenance-phase median = 59%) and similar to that of previous community-based exercise trials among older adults (King et al., 1995). Tai Chi participants on average attended more exercise classes than those assigned to WE, which may have affected the results. Exercise preference may partly explain the difference in intervention adherence rates; some previous research has indicated that some groups of women may prefer group-based exercise programs like Tai Chi (Kutner, Barnhart, Wolf, McNeely, & Xu, 1997; Taylor-Piliae & Froelicher, 2007) rather than exercising in a traditional gym-type setting (Moore, 1996; Ruland & Moore, 2001).

The observed improvements in physical functioning in this study are consistent with previous studies that showed that participants assigned to WE had greater improvements in upper body flexibility than the other two groups, and participants assigned to Tai Chi had greater improvements in static balance (Wolf et al., 1996). In addition, the statistically significant 12-month improvements in both exercise groups for measures taken during the submaximal treadmill testing, an indicator of cardiorespiratory endurance (Table 4), support the adequacy of intervention exercise dose for each group. Furthermore, data from the CHAMPS indicated that, on average, participants in both the Tai Chi and WE groups increased their frequency of moderate-intensity activities between baseline and 6 and 12 months, with greater increases reported in the WE group.

On the other hand, cognitive functioning in WE participants was not significantly better than in the other two groups. This finding is in contrast with previous reported research among older adults examining the effect of WE on cognitive functioning compared with controls (Fabre, Chamari, Mucci, Masse-Biron, & Prefaut, 2002; Molloy, Beerschoten, Borrie, Crilly, & Cape, 1988; Weuve et al., 2004). Executive functions are high-level skills (e.g., planning) that influence more basic skills such as attention, memory, and motor skills. A person may perform well on a simple task, such as naming as many animals as possible in 1 min, but struggle with more complex tasks such as repeating a sequence of numbers in reverse order (Angevaren, Aufdemkampe, Verhaar, Aleman, & Vanhees, 2008). In addition, the relationship between regular physical activity and cognitive function could potentially be modified by factors other than improvements in cardiovascular biomarkers, such as genetic

predispositions or various comorbidities, which may in part explain the results obtained in this study.

Animal models have shown possible underlying mechanisms for an exercise effect on cognition in older adults. Specifically, exercise decreases amyloid load (Adlard, Perreau, Pop, & Cotman, 2005), positively affects hippocampal neuronal function (Fordyce, Starnes, & Farrar, 1991) and hippocampal and parietal cortical cholinergic function and spatial learning (Fordyce & Farrar, 1991), increases levels of brain-derived neurotrophic factors, and may protect against antioxidant and other forms of neuronal damage (Stummer, Weber, Tranmer, Baethmann, & Kempski, 1994).

Tai Chi participants had a statistically significant improvement in one measure of cognitive functioning, the backward digit-span test, when compared with the other two groups, which is a novel finding. The digit-span tests are considered indicators of attention, concentration, and mental tracking (Lezak, 1995; Spreen & Strauss, 1998). In addition, mental tracking in the backward digit-span test is thought to involve double tracking (Dore, Elias, Robbins, Elias, & Brennan, 2007; Robbins, Elias, Elias, & Budge, 2005). When practicing Tai Chi, participants were taught to be mindful of their movements. During the performance of Tai Chi, paying careful attention to what the body is doing and how it feels is important, for example, relaxation and correct foot placement. Concentration was enhanced during Tai Chi, as participants were instructed to perform at a slow and relaxed pace with inattention to thoughts. Mental tracking during Tai Chi is important so that participants remain relaxed and remember the sequence of postures and the correct arm and leg movements. Double tracking is plausible during Tai Chi when both the mental and physical aspects are performed simultaneously (Lee et al., 2002; Spreen & Strauss, 1998). In contrast, WE groups in the current study were not specifically instructed to mentally focus on exactly how they were moving. However, further Tai Chi research is needed to determine whether this type of improvement in cognitive functioning can be replicated in other populations and why the backward digit-span test in particular may be sensitive to change with this type of activity.

To help achieve "healthy aging," a major goal of exercise conditioning programs, as well as other life-style interventions, is to prevent age-related declines that occur with various aspects of physical- and cognitive-functioning domains (Fries, 1996). In WISE, many participants scored well on a number of tests evaluating physical and cognitive functioning. Thus, for an exercise regimen to be "successful" for this population, it may not need to produce significant increases in functioning but simply prevent or slow its decline so that independence and quality of life are maintained (Fries, 1996). To test such hypotheses, specific interventions will need to be tested for years, not just weeks or months.

We conclude that both Western and Tai Chi exercises can have positive, though somewhat different, impacts on a variety of functional domains, including physical and cognitive function. The potential impact of Tai Chi on cognitive function, in particular, deserves further investigation.

Acknowledgments

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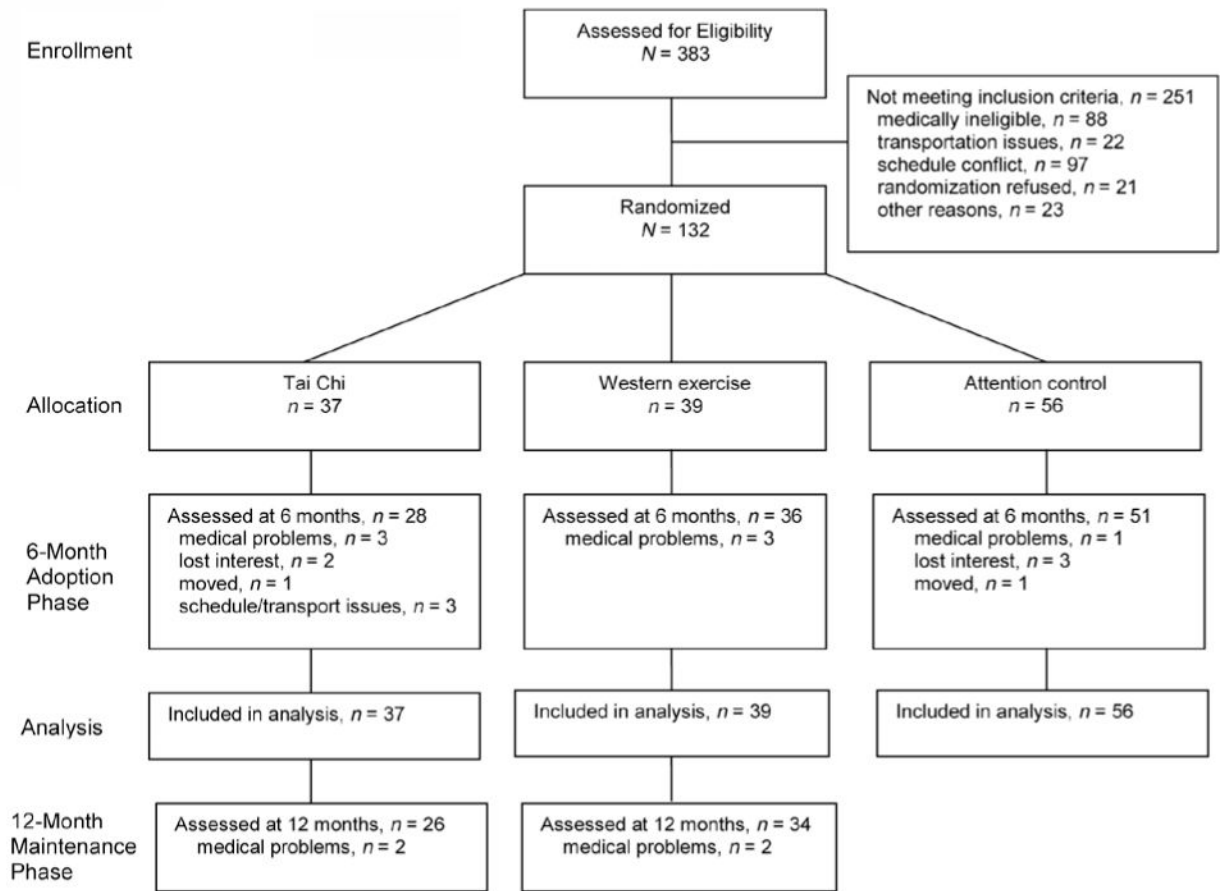
Figure 1.

Flowchart of participants throughout the study. Recruitment and enrollment took place between April 2000 and September 2001. Data were collected through October 2002.

Table 1

Baseline Characteristics of Participants in the Wellness Interventions for Self Enrichment

	Tai Chi	Western exercise	Control	Group comparisons, p^a
% (*n*)	28% (37)	30% (39)	42% (56)	.19
Age in years, *M* (*SD*)	70.6 (5.9)	68.5 (5.0)	68.2 (6.2)	.14
Education in years, *M* (*SD*)	15.9 (2.7)	16.1 (1.9)	16.3 (1.6)	.61
Perceived health,[b] *M* (*SD*)	1.9 (0.8)	2.0 (0.8)	2.3 (0.7)	.11
Women, %	65	72	73	.69
Regular physical activity, %	19	26	27	.69
Previous Tai Chi experience, %	19	26	25	.80
Married or living together, %	42	62	60	.16
White, %	81	89	85	.81
Self-reported medical history, %				
hypertension	47	35	45	.55
irregular heartbeat	13	22	10	.26
angina	13	3	0	.01
previous myocardial infarction	6	0	0	.07
circulation problem in legs	6	6	8	1.00
ever smoked	20	14	10	.46
current smoker	0	2	2	1.00
asthma	6	16	6	.26
diabetes	0	3	4	.79
chronic back pain	13	19	19	.75
arthritis	3	0	2	.74
major depression	3	3	6	.86

[a]Analysis of variance or Fisher's exact test group comparisons.

[b]Possible range 1 = *excellent* to 5 = *poor*.

Table 2

Baseline Physical- and Cognitive-Functioning Measures of Central Tendency and Normative Data

| | | | Baseline | | | | Normative Data at 50th Percentile, 69 Years | | |
	$M \pm SD$	Median	Observed range	Skewness	Kurtosis	Women	Men	Reference
Physical Functioning								
Balance								
single-leg stance (s)	30.7 ± 20.7	25.7	1–60	0.23	−1.42	27	27	Bohannon, 2006
functional reach ($n = 103$; in.)	16.8 ± 2.8	17.0	8.5–27.5	0.19	2.43	14	14	Duncan et al., 1990
Strength								
arm curls (no. in 30 s)	16.1 ± 5.1	15.0	8–38	0.97	1.55	15	18	Rikli & Jones, 1999a, 1999b
chair stands (no. in 30 s)	14.2 ± 4.9	14.0	4–33	1.15	2.6	14	15	Rikli & Jones, 1999a, 1999b
Flexibility ($n = 130$)								
back-scratch test (cm)	-3.6 ± 9.7	−1.0	−30–20	−0.58	−0.11	−1.0	−4.0	Rikli & Jones, 1999a, 1999b
sit-and-reach test (cm)	19.3 ± 9.6	19.0	0–17	−0.14	0.11	24	17	Minister of Supply and Services Canada, 1986
Cognitive Functioning								
Animal-naming test ($n = 131$; no. in 60 s)	20.7 ± 5.3	20.0	11–38	0.42	−0.12	19	19	Tombaugh et al., 1999
Digits forward (sequence length)	9.7 ± 2.1	10.0	4–15	0.09	−0.18	7	7	Bopp & Verhaeghen, 2005
Digits backward (sequence length)	6.3 ± 2.1	6.0	2–11	0.41	−0.39	5	5	Bopp & Verhaeghen, 2005

Table 3

Adoption-Phase (Baseline to 6 Months) Comparisons Between Groups[a]

	Change, M ± SD			ANOVA		Group Comparisons, ES, Mean Difference [CI] if p < .05		
	TC, n = 37	WE, n = 39	C, n = 56	F	p	TC vs. C	WE vs. C	TC vs. WE
Physical Functioning								
Balance								
single-leg stance (s)	6.5 ± 9.4	3.9 ± 13.9	0.9 ± 7.3	3.36	.038	0.54, 5.5 [0.4, 10.7]	0.29	0.25
functional reach (n = 103; in.)	−0.02 ± 1.4	0.4 ± 1.8	0.3 ± 2.9	0.29	.745	−0.15	0.04	−0.19
Strength								
arm curls (no. in 30 s)	3.7 ± 4.5	3.6 ± 4.6	3.5 ± 3.7	0.01	.991	0.03	0.02	0.01
chair stands (no. in 30 s)	3.5 ± 3.8	3.4 ± 3.6	2.0 ± 3.2	3.05	.051	0.46	0.41	0.05
Flexibility (n = 130)								
back-scratch test (cm)	0.8 ± 3.4	3.7 ± 6.7	1.1 ± 3.3	4.67	.011	−0.07	0.55, 2.5 [0.3, 4.8]	−0.62, 2.9 [0.4, 5.4]
sit-and-reach test (cm)	1.4 ± 5.1	2.3 ± 3.5	1.7 ± 3.3	0.49	.613	−0.06	0.16	−0.22
Cardiorespiratory endurance (n = 129)[b]								
heart rate (beats/min)	−3.2 ± 6.3	−4.8 ± 5.6	−3.8 ± 8.5	0.51	.600	0.08	−0.15	0.23
systolic blood pressure, mm Hg	−3.2 ± 15.8	−2.9 ± 15.1	−3.3 ± 17.5	0.01	.993	0.01	0.03	−0.02
rating of perceived exertion	−0.1 ± 1.5	−0.4 ± 1.4	−0.4 ± 1.3	0.80	.454	0.26	0.06	0.20
Cognitive Functioning								
Animal-naming test (n = 131; no. in 60 s)	0.8 ± 4.1	2.0 ± 4.7	0.6 ± 4.1	1.18	.311	0.04	0.31	−0.27
Digits forward (sequence length)	0.03 ± 1.8	−0.5 ± 1.6	−0.05 ± 1.6	1.33	.268	0.05	−0.29	0.34
Digits backward (sequence length)	0.8 ± 1.7	−0.7 ± 1.9	−0.1 ± 1.6	7.75	<.001	0.55, 0.9 [0.1, 1.8]	−0.34	0.90, 1.5 [0.6, 2.5]

Note. ES = effect size; CI = confidence interval; TC = Tai Chi; WE = Western exercise; C = control.

[a] Submaximal treadmill test unadjusted for antihypertensive medication, age, or gender.

[b] Intention-to-treat analysis, missing data = last observation carried forward.

Table 4

Maintenance-Phase (Baseline to 12 Months) Comparisons Within and Between Exercise Groups[a]

	Within-Group Comparisons						Between-Groups Comparisons, vs. 12 Mo	
	Tai Chi, *n* = 37			Western Exercise, *n* = 39				
	TC	Baseline vs. 12 Mo		WE	Baseline vs. 12 Mo			
	M ± *SD*	*t*	*p*	*M* ± *SD*	*t*	*p*	*t*	*p*
Physical Functioning								
Balance								
single-leg stance (s)	7.5 ± 11.3	3.51	.002	1.0 ± 17.5	0.35	.731	1.79	.078
functional reach (*n* = 103; in.)	−0.3 ± 1.4	−0.83	.419	0.4 ± 2.0	0.95	.352	−1.18	.243
Strength								
arm curls (no. in 30 s)	6.0 ± 4.3	7.30	<.001	5.2 ± 4.0	7.82	<.001	0.71	.481
chair stands (no. in 30 s)	5.0 ± 3.3	7.87	<.001	4.0 ± 3.4	7.14	<.001	1.10	.274
Flexibility (*n* = 130)								
back-scratch test (cm)	2.0 ± 4.3	2.51	.018	1.6 ± 4.0	2.35	.025	0.46	.645
sit-and-reach test (cm)	1.6 ± 4.5	1.92	.065	1.7 ± 3.4	2.96	.006	−0.07	.944
Cardiorespiratory endurance (*n* = 129)[b]								
heart rate (beats/min)	−9.3 ± 8.0	−5.94	<.001	−4.5 ± 10.7	−2.38	.024	−1.89	.065
systolic blood pressure, mm Hg	−6.5 ± 18.1	−1.82	.080	−1.8 ± 22.4	−0.46	.650	−0.86	.396
rating of perceived exertion	−0.8 ± 1.9	−2.12	.044	−0.3 ± 1.7	−1.03	.310	−1.03	.306
Cognitive Functioning								
Animal-naming test (*n* = 131; no. in 60 s)	3.7 ± 5.9	3.27	.003	2.3 ± 4.8	2.81	.008	1.03	.308
Digits forward (sequence length)	0.4 ± 2.2	0.09	.932	−0.3 ± 2.1	−0.80	.428	0.59	.561
Digits backward (sequence length)	0.8 ± 1.3	3.26	.003	−0.3 ± 2.1	−0.78	.440	2.52	.014

Note. TC = Tai Chi; WE = Western exercise; = change score.

[a] Intention-to-treat analysis, missing data = last observation carried forward.

[b] Submaximal treadmill test unadjusted for antihypertensive medication, age, or gender.