Tai Chi: Improving Functional Balance and Predicting Subsequent Falls in Older Persons

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ABSTRACT

LI, F., P. HARMER, K. J. FISHER, and E. MCAULEY. Tai Chi: Improving Functional Balance and Predicting Subsequent Falls in Older Persons. *Med. Sci. Sports Exerc.*, Vol. 36, No. 12, pp. 2046–2052, 2004. **Purpose:** To determine whether improved functional balance through a Tai Chi intervention is related to subsequent reductions in falls among elderly persons. **Methods:** Two hundred fifty-six healthy, physically inactive older adults aged 70–92 (mean age ± SD = 77.48 ± 4.95), recruited from a local health system in Portland, OR, participated in a 6-month randomized controlled trial, with allocation to Tai Chi or exercise stretching control, followed by a 6-month postintervention follow-up. Functional balance measures included Berg balance scale, dynamic gait index, and functional reach, assessed during the 6-month intervention period (baseline, 3-month, and 6-month intervention endpoint) and again at the 6-month postintervention follow-up. Fall counts were recorded during the 6-month postintervention follow-up period. Data were analyzed through intention-to-treat analysis of variance and logistic regression procedures. **Results:** Tai Chi participants who showed improvements in measures of functional balance at the intervention endpoint significantly reduced their risk of falls during the 6-month postintervention period, compared with those in the control condition (odds ratio (OR), 0.27, 95% confidence interval (CI), 0.07–0.96 for Berg balance scale; OR, 0.27, 95% CI, 0.09–0.87 for dynamic gait index; OR, 0.20, 95% CI, 0.05–0.82 for functional reach). **Conclusions:** Improved functional balance through Tai Chi training is associated with subsequent reductions in fall frequency in older persons. **Key Words:** BALANCE, FALL PREVENTION, AGING

With increasing age there is a significant loss of functional balance in older persons, particularly among those who are physically frail. This loss of balance is brought on by specific deterioration in the function of various neural and musculoskeletal systems (21), placing older persons at higher risk for falling, injury from fractures, and loss of functional independence. Fortunately, loss of balance has been shown to be reversible through exercise training. In fact, a number of randomized controlled trials have shown that properly designed exercise programs can improve balance (2,15,30) and reduce both the risk of falling and the rate of falling (2,4,14,17,28). The training effects of exercise, however, are usually observed during the active phase of intervention. A central question of this study was whether improving balance through structured exercise is related to subsequent reduction in falls following the termination of an active exercise intervention period.

Despite the established evidence of the relationship between exercise and improvements in balance and between exercise and reductions in falls and risk of falling (6,9), there is a lack of empirical evidence linking improvements in functional balance resulting from exercise to subsequent reductions in falls after exercise intervention. Although it is reasonable to presume that exercise interventions designed to prevent falls may actually promote balance control, studies using either exercise or multifactorial approaches have had conflicting results. For example, Lord et al. (15) reported a 12-month multidimensional program that improved balance/strength measures but resulted in no reductions in the frequency of falls, although adherence to exercise was associated with fewer falls. Another home-based exercise study from New Zealand has shown that a mixed strength-training program (muscle building and walking) reduced falls and injurious falls and improved balance in frail elderly individuals (4). Although some results are encouraging, it is not evident from the extant literature whether improved balance through exercise is in fact related to reduced fall frequency when the intervention is over.

Tai Chi, as a balance-enhancing exercise, has received considerable attention in the exercise and fall-prevention literature (6,9). Both cross-sectional and controlled studies

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have provided evidence that Tai Chi, which consists of a series of self-initiated slow but continuous rhythmical movements, is associated with improved functional balance in older persons (10,13,26). The particular characteristics of Tai Chi, including control over the displacement of body mass over one's base of support, postural orientation, range of motion (ankle, knee, and hip), and emphasis on abdominal and lower-extremity muscle function, may be part of a larger mechanism responsible for specific gains in postural stability. Although it remains to be scientifically evaluated, this theoretical mechanism might help prevent older adults from losing their balance, thereby reducing the propensity to fall and the likelihood of injury resulting from a fall.

From a fall-prevention intervention perspective, gains in balance control may be best considered as proximal or intermediate clinical outcomes of sustained Tai Chi practice. In contrast, reductions in falls may be not an immediate or direct outcome of Tai Chi, but perhaps a more distal outcome. Indeed, the latent effect of Tai Chi in reducing falls has been indicated by two recent randomized controlled trials (13,29), which showed that several months of practice were needed before significant reductions in the number of falls occurred. A possible explanation for this observation may come from the fact that several weeks or months are needed for a progressive increase in movement repertoires and exercise intensity to take effect; therefore, it is likely that little improvement in function and reduction in fall events will occur during the initial acclimation/learning period of Tai Chi exercise. This suggests that, from a clinical standpoint, no tangible results in falls reduction should be expected from short-term exposure to Tai Chi (i.e., less than 3 months).

One Tai Chi study (13) showed that Tai Chi improved functional balance, reduced subjects' fall occurrence, and provided other health outcomes during a 6-month intervention period. However, the extent to which improvements in functional balance reduce falls frequency after an active (intervention) training period remains to be determined. Because fall interventions are often targeted at improving balance as a clinical outcome rather than falls occurrence *per se*, it is important, from a clinical standpoint, that we determine whether change in functional balance brought about by Tai Chi is related to subsequent reductions in falls. Should this be the case, Tai Chi training should be considered an important component of interventions for fall prevention in older persons (1).

Therefore, the purpose of this study was to determine whether changes (i.e., improvements) in functional balance outcome measures (operationalized by three well-established clinical tests of functional balance) resulting from a 6-month Tai Chi intervention were predictive of subsequent falls during a 6-month postintervention follow-up period, where no structured exercise regime was provided. It was hypothesized that improved functional balance through Tai Chi would be predictive of subsequent reductions in fall frequency in older persons.

METHODS

Study Design and Participants

Details of the study design, eligibility criteria, and recruitment procedures are described elsewhere (13), and are briefly summarized here. The 26-wk randomized controlled trial with a parallel group design was conducted between March 2001 and May 2002, using a staggered recruitment protocol. Participants aged 70 yr and over were randomly assigned to receive either Tai Chi or an exercise stretching control condition. Both groups participated in a 60-min exercise session conducted $3\times\ \text{wk}^{-1}$ for six consecutive months. The intervention phase was followed by a 6-month (postintervention) follow-up period where no structured exercise classes were provided. The intervention outcome measures of functional balance were assessed at baseline, 3 months, 6-month termination of the intervention, and at a 6-month postintervention follow-up. Fall occurrences were recorded throughout the intervention and during the 6-month postintervention period.

Study Procedures

The study was conducted in Portland, OR, and participants were recruited from a pool of community-dwelling elderly patients enrolled in the Legacy Health System. Study eligibility criteria included the following: being 70 yr of age or older; being inactive (defined as not being involved in any regular, moderate, or strenuous physical activity program in the previous 3 months); being an independent ambulator not fully dependent on an assistive device; being free of chronic medical problems that would limit participation in low- to moderate-intensity exercise; having a physician's clearance to participate; and having no cognitive impairments (16). The study was approved by the institutional review boards of Oregon Research Institute and the Legacy Health System, and written informed consent was obtained from all participants.

Elderly patients (aged 70 yr and over) enrolled in the Legacy Health System received a letter signed by their primary care physician encouraging participation in an exercise trial. Research staff made an initial follow-up phone contact and screened potential participants to establish their interest in and eligibility for the study. Those who met the study criteria and agreed to participate ($N = 256$; males = 77; females = 179; mean age $\pm$ SD = 77.48 $\pm$ 4.95) were scheduled for a baseline assessment. Participants then underwent baseline assessments, after which they were randomized to experimental conditions (described below). Upon completion of the 6-month intervention, all participants were given information regarding local physical activity resources if they wished to continue to exercise during the 6-month postintervention follow-up period.

Intervention

Tai Chi. The Tai Chi classes were taught by experienced Tai Chi instructors who followed the classical 24-Form

Yang style (7), which emphasizes multidirectional weight shifting, awareness of body alignment, and multisegmental (arms, legs, and trunk) movement coordination. Synchronized breathing (aligned with each Tai Chi movement) was also emphasized and integrated into the Tai Chi movement routine. Sessions included 5–10 min of warm-up, 30 min of Tai Chi practice, and 5–10 min of cool-down. Instruction covered learning new movements and reviewing movements learned in previous sessions. Each practice session included musical accompaniment.

Stretching control. This program consisted predominantly of seated and standing stretches for the trunk and upper body, accompanied by deep abdominal breathing, and relaxation. The design rationale for this condition was to provide participants with a structured, low-intensity, and low-impact exercise program that would contain comparable attention, social interaction, and enjoyment, without providing the lower-extremity strength- and balance-training benefits of Tai Chi. The weekly schedule and class format were identical to that of Tai Chi.

Outcome Measures

Functional balance. Three balance-related measures were used: (a) Berg balance scale (BBS) (3), (b) dynamic gait index (DGI) (20), and (c) functional reach (FR) (8). These measures were chosen based on their clinical relevance in assessing balance and postural control in older persons (18,21).

The BBS consists of 14 different physical tasks that simulate activities common in everyday life. The test evaluated the participant's ability to perform movements of increasing difficulty. Tasks progressed from a sitting position to bilateral stance, to a tandem stance, and then to a single-leg stance. The ability to change position was also assessed. Each task was graded on a scale of 0–4, yielding a total score ranging from 0 to 56, with higher scores indicating better balance. The internal consistency for this measure was satisfactory, ranging from 0.74 to 0.86 (mean = 0.80) across all four assessments. The DGI evaluated the participant's ability to modify gait in response to changing task demands. Participants were evaluated on their walk performance on a four-point scale from 0 (severe impairment) to 3 (normal) on eight different gait tasks: on even surfaces, changing speeds, with head turns in a vertical or horizontal direction, while stepping over or around obstacles, and with pivot turns and steps. Scores on the DGI range from 0 to 24, with higher scores indicating better balance. The internal consistency for this measure was satisfactory, ranging from 0.66 to 0.81 (mean = 0.77) across all four assessments. The FR test assessed the maximal distance that a participant could reach forward beyond arm's length while maintaining a fixed base of support in the standing position. The average of three trials was used, with higher values indicating better balance.

Falls. The measure of falls was assessed using fall counts, recorded by each participant in a daily "fall calendar." Participants were asked to record any fall event and to indicate whether the fall caused them to seek medical attention. A fall was defined as "when you land on the floor or the ground, or fall and hit objects like stairs or pieces of furniture, by accident." Falls were monitored for all participants throughout the 6-month intervention and the 6-month postintervention periods. For the purpose of this study, only postintervention period data were used and analyzed. Participants' fall count data were collected on a monthly basis during the entire study period, or until they withdrew from the study. Falls data were also obtained from those who dropped out of the study during the postintervention period.

Statistical Analyses

The overall analyses were conducted with intention to treat and performed in two stages. In stage 1, changes from baseline balance scores across the 6-month intervention period were compared between intervention groups using the repeated-measures analysis of variance (ANOVA) model. Intervention assignment was included in the model as a fixed effect to compare the mean difference in these changes between intervention groups across the 6-month intervention period. A similar method was used to evaluate changes in these measures from postintervention to the end of the 6-month follow-up. Upon establishing change in these outcome measures, individual slope scores were calculated via the method of ordinary least squares (OLS) regression analysis. These scores quantified information about change attributable to intervention on the three functional balance measures collected at three study assessment points (baseline, 3 months, and at the 6-month termination). In stage 2, logistic regression analyses were performed using each of the functional balance slope scores to predict the probability of having a fall during the 6-month postintervention period. For the purposes of logistic regression, a binary variable was constructed and used as an independent variable. Specifically, participants with a positive change (positive slope) were assigned a value of 1 (improved), and those with no change or improvement were assigned a value of 0 (not improved). To examine the group status on falls, an interaction term was made using the group status (1 = Tai Chi; 0 = stretching control) and the dichotomous balance slope scores described previously. The dependent measure of the postintervention fall status was coded as 1 (fallers) or 0 (nonfallers). For study dropouts, fall status at each assessment point was determined using the last available fall information. This method assumed that missing data on falls during the follow-up period were considered lost to follow-up, not as an intervention failure (i.e., a fall event during the intervention). All logistic regression analyses included control variables of age, gender, health status, medication use, past fall history, and fear of falling. All analyses, with the exception of OLS regression (which was analyzed using SAS) (19), were conducted using SPSS (22). A two-tailed 0.05 significance level was used for all parameters.

RESULTS

Participant characteristics at baseline. Participants in this study were primarily white (90%), with 49% being currently married, and about half of the participants reporting living alone (48%). The majority had at least a high school education (92%), but 40% reported an annual income below $15,000. On a self-rated health status measure using a five-point scale (poor = 1, fair = 2, good = 3, very good = 4, and excellent = 5), 84% rated their health as good or better (mean ± SD = 3.24 ± 0.78). From a list of nine common medical conditions (i.e., diabetes, osteoporosis, depression, chronic back pain, cancer, arthritis, heart disease, high blood pressure, and chronic lung disease), the sample had a mean of 2.4 (± SD 1.4) conditions. Fifty study participants reported using a walking aid, such as a cane or walker. Of these 50 participants, 86% were nonfrequent users, and the 14% who were frequent users were not dependent on walking aids to ambulate, as per study entry criteria. Approximately 30% of the participants had hearing impairment in both ears, and their visual acuity was of an average range, that is, 20/9 to 20/40 in both eyes. With respect to falls information, 36% of the participants (N = 92) in the study reported one or more falls in the 3 months before entering the study, and 38% of the participants reported substantial fear of falling on a two-point scale (1 = afraid; 0 = not afraid). The two intervention groups were comparable with regard to demographic descriptors (e.g., age, gender, health status, medication use, past fall history, and fear of falling) and functional outcome variables at baseline.

Attrition, compliance, and adverse events. Thirty-four randomized participants withdrew from the study at the study onset (no-shows). This left a total of 222 class-attending study participants. Of these participants, 47 (21%) withdrew (N = 24 in Tai Chi, N = 23 in control) during the intervention period. Major reasons for withdrawal were health-related causes (60%), time conflict or other commitment (30%), and miscellaneous (10%), including relocating. The overall dropout rate during the 6-month intervention was 21% (Tai Chi, 24 of 115; control, 23 of 107), excluding no-shows (N = 34). No statistical differences in the above baseline variables were found between those who attended intervention classes (N = 222) and those who did not attend (N = 34). Similarly, no statistical differences were found between dropout participants (N = 47) and the remaining participants (N = 175).

Class compliance rates across the 26-wk period (78 sessions) were calculated for all class-attending participants (N = 222). Median compliance was 61 sessions for both groups, ranging from 30 to 77 sessions for Tai Chi participants and from 35 to 78 sessions for the controls. Ninety-two (80%) Tai Chi participants and 87 (81%) stretching control participants attended 50 or more sessions.

Exercise training sessions were closely monitored by the research staff during the course of the intervention. The exercise instructors were first-aid certified and were encouraged to report any negative signs or symptoms resulting from exercise in their classes. No exercise-related injuries occurred among study participants during the 6-month trial.

Exit surveys. Exit surveys at the end of the 6-month postintervention period indicated that about 43% of study participants maintained some level of weekly physical activity involvement. With respect to frequency of physical activity, about 66% of Tai Chi participants reported doing Tai Chi and/or other exercise activity at least once or twice a week, whereas about 20% of control participants reported doing low-impact exercise activity at least 1–2× wk^{-1} ($P <$ 0.001). The data on the exercise distribution across intervention conditions is presented in Table 1.

Change in functional balance outcomes during the intervention. A significant group-by-time interaction effect was observed in ANOVA for the three functional balance measures ($P < 0.001$ for BBS; $P < 0.001$ for DGI; $P < 0.001$ for FR), indicating that the Tai Chi group performed significantly better than the exercise control on all three functional balance measures during the intervention. Within-group comparisons found significant improvements in BBS scores ($P < 0.001$), DGI scores ($P < 0.001$), and FR scores ($P < 0.001$) for the Tai Chi group over the 26-wk intervention period. In contrast, no changes were observed from baseline for the control group on BBS scores ($P = 0.06$), DGI scores ($P = 0.09$), or FR scores ($P = 0.17$) over the 26-wk intervention period.

Change in functional balance outcomes from intervention termination to 6-month follow-up. The functional balance data showed an overall downward trend from the study termination to the end of the 6-month postintervention follow-up. For each condition, paired t-tests revealed a significant within-group reduction in mean scores on the three balance measures from the 6-month study termination to the 6-month postintervention follow-up ($P <$ 0.001). However, a between-group difference in this trend was also observed. Specifically, the Tai Chi group showed a significantly slower (intervention termination to 6-month postintervention follow-up) deterioration in functional balance measures compared with the control group in BBS ($P = 0.04$), DGI ($P = 0.05$), and FR ($P = 0.02$). Plots containing the functional balance data covering the entire study period are presented in Figure 1.

Falls at the follow-up. Fall data were available for 188 participants (N = 95 in Tai Chi, N = 93 in exercise control) during the 6-month postintervention follow-up. Using intention-to-treat analysis, 28 falls were reported in the Tai Chi group (N = 25), and 74 falls were reported in the control group (N = 68). Table 2 presents fall information during the

TABLE 1. Exercise frequency during the 6-month postintervention follow-up.

Item Category	Tai Chi (N = 125)	Control (N = 131)
Not at all (%)	40 (32)	53 (41)
About 1× $month^{-1}$ (%)	1 (1)	21 (16)
About 2–3× $month^{-1}$ (%)	1 (1)	31 (23)
About 1–2× wk^{-1} (%)	18 (14)	11 (8)
≥ 3× wk^{-1} (%)	65 (52)	15 (12)

256 subjects were included based on intention-to-treat analysis. Dropouts during the intervention period were classified in the category of "Not at all."

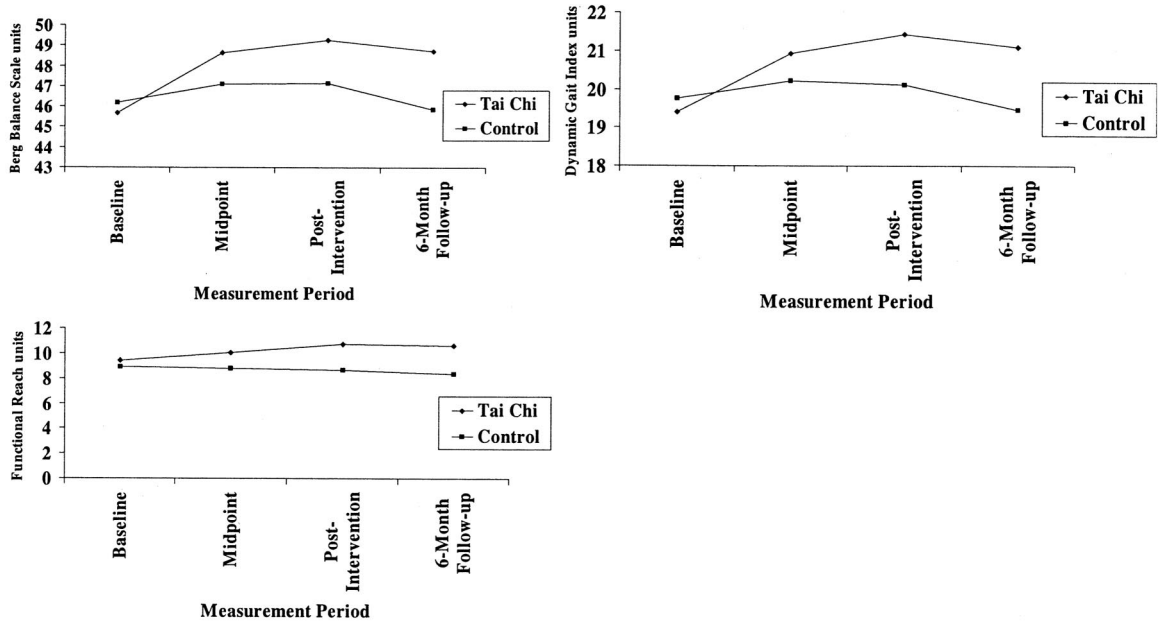

FIGURE 1—Intervention group differences in change in functional balance measures during the 12-month study period. Top left panel: Berg balance scale. Top right panel: dynamic gait index. Bottom left panel: functional reach.

6-month postintervention follow-up period. The number of participants who reported falls in Tai Chi was significantly lower than in the control group ($P < 0.001$) during the 6-month postintervention follow-up.

Prediction of falls from postintervention to 6-month follow-up. Results from logistic regression analyses showed that improved balance among Tai Chi participants significantly reduced the likelihood of falling during the 6-month postintervention period, compared with their counterparts in the stretching control condition. Specifically, after adjusting for baseline variables, including age, gender, baseline fall status, fear of falling, and health status in the logistic equation, improved slope scores for functional balance measures were shown to be predictive of nonfallers among Tai Chi participants (odds ratio (OR), 0.27, 95% confidence interval (CI), 0.07–0.96, $P = 0.04$ for BBS; OR, 0.27, 95% CI, 0.09–0.87, $P = 0.03$ for DGI; OR, 0.20, 95% CI, 0.05–0.82 for FR, $P = 0.03$).

Supplementary analyses. As indicated previously, a majority of Tai Chi participants (66%) remained somewhat active (i.e., reported doing Tai Chi and/or other exercise activity at least 1–2× wk^{-1}) after the supervised in-class exercise intervention period. It is therefore important to disentangle the residual effects of Tai Chi on falls occurrence in the postintervention period from the effect of continued physical activities. To address this issue, a subgroup analysis was conducted in which we examined whether participants who reported any activity differed from those who reported no activity with respect to falls during the postintervention period. The subgroup analysis showed no significant between-group differences, with respect to the number of fall occurrences, among those reporting some or no activity during this postintervention period.

TABLE 2. Falls information during the 6-month postintervention follow-up.

Falls	Tai Chi ($N = 125$)	Control ($N = 131$)
Reporting one fall—*N* (%)	22 (18)	64 (49)
Reporting two falls—*N* (%)	3 (2)	2 (2)
Reporting three falls—*N* (%)	0	2 (2)
Total falls reported	28	74

256 subjects were included based on intention-to-treat analysis. Fall data were available for 188 participants ($N = 95$ in Tai Chi, $N = 93$ in exercise control) during the 6-month postintervention follow-up. For dropouts, fall status was determined using the last available fall information.

DISCUSSION

This study is the first to investigate whether improved functional balance through an exercise program can lead to subsequent reductions in falls in older persons after an active intervention. We found that Tai Chi, a balance-training program, significantly improved functional balance during a 6-month training period, and that these improvements were found to be significantly related to a reduced likelihood of falling during a 6-month nonintervention follow-up in older persons aged 70 yr and older.

The latter finding on falls reduction was found to be unaffected by physical activity during the postintervention period. There was no significant difference in fall occurrence between participants who were active in the postintervention period and those who were not. Apart from the possibility of self-report bias, it is unlikely that participants would have engaged in their reported physical activity at the intensity and frequency comparable to the supervised intervention exercise classes. Therefore, it seems reasonable to assume that the reduced fall occurrence in the postintervention period is at least partially attributable to a sustained effect from the Tai Chi intervention.

Implications. Falls remain a major public health problem (11,12,23), and affect the quality of life of many older persons. There is increased evidence that exercise is an important and effective treatment modality for fall prevention among older adults (1,6,9). However, exercise interventions such as Tai Chi often do not provide an immediate treatment effect with respect to fall reductions (13,29). Therefore, it may be inappropriate to simply target fall reduction as a direct intervention outcome for Tai Chi or other similar balance-enhancing exercise. Rather, researchers/clinicians should focus on designing training programs that target specific physiological systems involved in balance control, specifically the visual, vestibular, somatosensory, and musculoskeletal systems. Data from recent studies suggest that Tai Chi training influences these systems (5,24,25,31). The results from this study indicate that a 6-month (60 min, $3\times$ wk^{-1}) Tai Chi training schedule improved functional balance, which, in turn, was predictive of subsequent reductions in falls. These results suggest that improved functional balance may be one of the important proximal outcomes of Tai Chi training. Such gains in functional balance may serve as a mediational mechanism by which Tai Chi prevents or reduces the frequency of subsequent falls.

This study also provides support for the longstanding belief that Tai Chi improves balance as a means to decrease fall risk. Although the biomechanics and neural control mechanisms of Tai Chi affecting balance and postural stability remain to be fully investigated, it is likely that, upon mastery, performance of well-controlled Tai Chi movements (i.e., requiring dynamic weight transition between double-stance and single-stance postures, constant exchange between loading and unloading of two legs, interchange of roles between stabilizers and movers, and coordination between lower-extremity and upper-body movements) may have enhanced particular mechanisms contributing to postural stability in the Tai Chi participants. Some recent evidence provides support that Tai Chi elicits responses in specific musculoskeletal and neural systems involved in postural control, specifically somatosensory and neuromuscular control systems (24,25,31). Therefore, practicing Tai Chi regularly may help develop balance mechanisms and minimize instability to counter potentially destabilizing body positions, or to overcome environmental hazards in older individuals at risk of falling.

This study used a sample of participants aged 70 and over recruited from a local health system. A great amount of enthusiasm and support for this project was evident during the initial recruitment and consent process from physicians/clinicians, indicating increasing acceptance and appeal of Tai Chi as an alternative exercise method for fall prevention. In addition, because the program was implemented in local facilities in the community, it is likely to be sustainable and transferable to other settings. Many older adults stop exercising after research support is removed (27). Our trial indicated that more than 50% of participants remained physically active after the intervention. Considering that this was a sedentary sample at the study onset, this statistic is very encouraging with respect to the potential of Tai Chi in convincing this special population to make an active lifestyle change. Thus, Tai Chi appears to be an appealing exercise program, with benefits that go beyond functional balance improvements and falls reduction, and that can be regarded as a self-regulated, enjoyable, and socially engaging activity.

Study limitations. The current study findings should be interpreted in light of several limitations. First, there is the possibility of experimenter bias, inasmuch as the study assessors were not blind to intervention allocation. One other limitation of the current study is the lack of muscular strength measures, which precludes us from evaluating the contribution of muscle strength to change in balance and, consequently, falls reduction. It is possible that improvements in functional balance measures may have been mediated, at least in part, by concurrent improvements in muscle strength. Similarly, the study did not consider more rigorous laboratory-based balance measures, such as tests of limits of stability and sensory organization, which may be used in elucidating other possible mechanisms by which Tai Chi can improve balance control and prevent subsequent falls. Other questions that remain to be fully explored include the duration of the residual benefits of Tai Chi in reducing falls, and investigation of subgroups defined by clinical characteristics (e.g., level of physical functioning) that are most likely to gain on fall reductions from Tai Chi intervention.

CONCLUSIONS

In conclusion, results from the present study suggest that Tai Chi training improves functional balance which, in turn, is predictive of subsequent reductions in fall frequency in persons aged 70 yr and over, at least in the medium term (i.e., 6 months). Healthcare providers and clinicians contemplating fall-prevention programs for older persons at risk of falling should consider Tai Chi, both as a balance-retraining program, and as part of a multifaceted treatment intervention for fall prevention.

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