Dynamic Balance and Stepping Versus Tai Chi Training to Improve Balance and Stepping in At-Risk Older Adults

Joseph O. Nnodim, MD, PhD,[*][†] *Debra Strasburg, MS,*[*] *Martina Nabozny, BA,*[*] *Linda Nyquist, PhD,*[‡] *Andrzej Galecki, PhD, MD,*[‡] *Shu Chen, MS,*[‡] *and Neil B. Alexander, MD*[*][‡][†]

OBJECTIVES: To compare the effect of two 10-week balance training programs, Combined Balance and Step Training (CBST) versus tai chi (TC), on balance and stepping measures.

DESIGN: Prospective intervention trial.

SETTING: Local senior centers and congregate housing facilities.

PARTICIPANTS: Aged 65 and older with at least mild impairment in the ability to perform unipedal stance and tandem walk.

INTERVENTION: Participants were allocated to TC (n = 107, mean age 78) or CBST, an intervention focused on improving dynamic balance and stepping (n = 106, mean age 78).

MEASUREMENTS: At baseline and 10 weeks, participants were tested in their static balance (Unipedal Stance and Tandem Stance (TS)), stepping (Maximum Step Length, Rapid Step Test), and Timed Up and Go (TUG).

RESULTS: Performance improved more with CBST than TC, ranging from 5% to 10% for the stepping tests (Maximum Step Length and Rapid Step Test) and 9% for TUG. The improvement in TUG represented an improvement of more than 1 second. Greater improvements were also seen in static balance ability (in TS) with CBST than TC.

CONCLUSION: Of the two training programs, in which variants of each program have been proven to reduce falls, CBST results in modest improvements in balance, stepping, and functional mobility versus TC over a 10-week period. Future research should include a prospective comparison of fall rates in response to these two balance training programs. **J Am Geriatr Soc 54:1825–1831, 2006.**

Key words: balance; exercise; tai chi; falls; aged

From the *Mobility Research Center, Division of Geriatric Medicine, Department of Internal Medicine and ‡Institute of Gerontology, University of Michigan, Ann Arbor, Michigan; and †Geriatric Research, Education and Clinical Center, VA Ann Arbor Health Care System, Ann Arbor, Michigan.

Address correspondence to Neil Alexander, MD, Geriatrics Center, 1500 East Medical Center Drive, Ann Arbor, MI 48109. E-mail: nalexand@umich.edu

DOI: 10.1111/j.1532-5415.2006.00971.x

Falls are common in older adults and lead to significant morbidity. Based on a consensus panel[1] and meta-analysis,[2] multifactorial strategies to reduce falls are effective, and of the components of multifactorial interventions, exercise is the most crucial element. One meta-analysis demonstrated a 10% reduction in fall risk with exercise and a 17% reduction for balance training exercise.[3] Of these balance training programs, tai chi (TC) yielded a 48% decline in fall risk in independent community-dwelling older adults.[4] TC is a Chinese martial art form consisting of slow, rotational, multisegmental movements with sequential weight shifting. A subsequent randomized controlled trial (RCT) of TC in a similar community group demonstrated a 54% reduction in fall risk,[5] whereas an RCT of TC in a group of older adults with impaired balance and gait reduced fall risk 25%, but this effect was not statistically significant.[6] The reduction in fall risk is likely clinically significant in the latter study,[6] but given the level of physical impairment in the participants, a multifactorial intervention may have been needed to achieve statistical significance.[7] Methodological problems, such as lack of randomization and inclusion of long-time TC practitioners, have limited other TC studies.[8,9] An individualized program involving balance, walking, and strengthening exercise reduced falls and fall-related injuries 35% in a meta-analysis of independent community dwellers.[10] Many of the balance exercises were dynamic (such as sideways walking) or involved reduced base of support (such as tandem walk) and stepping tasks;[11] a limitation of these studies is that the control groups did not undergo an active equivalent intervention, receiving no intervention, a limited education intervention, or limited exercise (such as seated stretching). The optimal type, intensity, and duration of an exercise program to reduce fall risk has yet to be determined.[1]

Recovery from an imminent fall has been shown to be dependent on the ability to take a rapid and adequately long step in the direction of the fall.[12–14] It has previously been shown that measures of maximal and rapid stepping correlate with measures of fall risk, gait, and mobility.[15,16] Recently, healthy older adults underwent a stepping training program and were found to improve in step initiation

speed.[17] An exercise intervention with a focus on stepping might thus be feasible and useful in fall risk reduction.

An exercise program (Combined Balance and Stepping Training (CBST)) was designed to focus on improving dynamic balance responses, increasing step length and speed, and responding safely to posturally challenging situations. With its emphasis on speed, CBST differs fundamentally from TC, in which movements are slow. The goal was to compare CBST with a program of TC to test the hypothesis that CBST participants would have greater improvement at 10 weeks in measures of balance, stepping, and functional gait than at baseline and than TC participants. To the authors' knowledge, this is the first comparison of two balance training programs in which variants of each program have been proven to reduce falls. Data from this study can help determine which balance training program may be most optimal to improve balance and eventually reduce falls.

METHODS

Participants

The participants in the present study were recruited from nine congregate housing facilities and six senior centers in the greater Washtenaw County area in Michigan as part of a 1-year prospective study comparing CBST and TC in reducing falls. Advertisements were posted at each site and in the media (such as newspapers), inviting residents aged 65 and older to a recruitment seminar. Because others from the community were allowed to participate at the congregate housing facility, only 35% of the congregate housing participants were actually congregate housing residents. A nurse practitioner screened volunteers and excluded those with significant cognitive impairment (Mini-Mental State Examination score < 24) and unstable medical conditions precluding participation such as active cardiopulmonary symptoms or severe pain with weight-bearing activity. The goal was to recruit participants with at least mild balance impairment but who were not too impaired to benefit from the program. Operationally, participants were included who were unable to stand unipedally for more than 25 seconds or had at least one error in a 10-step tandem walk. To perform the stepping outcome tests and to participate in a stepping exercise program, enrollees had to be able to stand and take one step unsupported by a device or person. Because of the possible confounding effect, those who engaged in regular, structured physical exercise (≥3 times/wk) or were receiving physical therapy for musculoskeletal, neuromuscular, or functional mobility or balance impairments were excluded.

Four hundred fifty-one potential participants attended the recruitment seminars, and 340 agreed to be screened. Sixty-four of the 340 (19%) were excluded for the medical reasons cited above. An additional 63 of those eligible did not proceed further, because they declined participation (n = 62) or became ill (n = 1). The remaining 213 (63% of the 340) participants were allocated to the CBST or TC arms using a minimization procedure[18] to ensure equivalence in key potential confounding variables, namely age, sex, and extent of balance impairment (represented by unipedal stance time). Minimization is especially useful because the number of stratification cells generated by these factors is large, and a small number of participants is recruited from each site. Minimization stipulates that the next participant to enter the trial is assigned to a group with a probability greater than 0.5 in favor of the treatment that minimizes group imbalance on a particular variable. A computer generated the group assignment for each participant after input of the appropriate strata level. Based on pilot data for intervention-induced changes in stepping performance, it was determined that a sample size of 80 per group would allow detection of a difference between intervention groups corresponding to an effect size of 0.45 with an alpha of 0.05 and power of 0.80. With an anticipated 25% dropout rate, the plan was thus to train at least 105 participants per group.

Upon screening, overall self-reported disability or difficulty with daily mobility tasks was assessed using the Established Populations for Epidemiologic Studies in the Elderly (EPESE) self-report battery. The EPESE battery[19] is scored as disability or difficulty present or absent using 15 Katz activity of daily living and Rosow-Breslau and Nagi items that are relevant for mobility (such as inability to climb stairs or carry groceries), with a score ranging from 0 to 15 (higher score signifies greater disability or difficulty).

Interventions

The duration of both training programs was 10 weeks, with three 1-hour sessions per week. Each session began and concluded with 5 minutes of warm-up and cool-down stretching exercises, respectively. A trainer experienced in leading community-based exercise programs at congregate housing facilities led each group. The TC trainer also received additional instruction in leading TC from an experienced TC group leader. All participants were exposed to all training tasks presented in a particular session but performed them as tolerated and modified as necessary (such as modification of the base of support) to facilitate safe and successful task completion.

Combined Balance and Stepping Training

Using a motor-skill training approach,[20] CBST participants worked on dynamic balance and stepping responses through structured practice with a focus on speed of step initiation and appropriate toe clearance and step length. A circuit of progressive challenges to upright static and dynamic balance were presented by narrowing the base of support (bipedal to tandem to unipedal), moving from symmetrical to asymmetrical base of support, providing external challenges to balance that required a response (e.g., moving the upper extremities and bouncing and catching a ball), narrowing the base of support while responding to the external challenge (e.g., standing in semitandem while catching a ball), and increasing the complexity of ambulatory tasks (e.g., changing direction (walking backward or laterally), changing speed, walking with reduced base of support (walking on a plank), turning, bending, stepping on and off curbs, braiding/grapevine steps, walking while carrying a ball, or stepping over obstacles (e.g., small hurdles)). Functional ankle, knee, and hip strengthening activities (such as heel and toe rises and rising from a chair) were also included. Many of the tasks were simple and required no substantial apparatus. The use of a relatively large range of these exercises allowed progressive delivery of different levels of balance and stepping challenge.

Tai Chi

As per previous studies, the TC group performed a series of standard movements and positions that focused on body alignment (including upright and rotated trunk), weight shifts (up to and including unipedal stance), and reciprocal arm movements. The movements and positions included typical TC forms: weight shifts in multiple directions; hip and ankle rotations; ankle and knee flexion; trunk rotation; and stepping motions forward, backward, and laterally. Emphasis was on awareness of body alignment, distribution of weight, and relaxation. To simplify task complexity and to address participant safety concerns initially, the lower body movements were taught first. When correct lower body movements were achieved, participants were encouraged to add arm movements, visual focus, and breathing techniques. Arm motions were usually asymmetrical and lower than shoulder height. Twelve unique sequences selected from the TC Yang Short Form were progressively practiced, including three variations of unipedal stance.

Outcome Measures

Performance time was measured using a handheld stopwatch, and distances were read off adhesive-backed ruler tapes affixed to the floor. Eyes were open and arms were crossed in front of the chest for all balance and stepping measures. Assessors were blinded to group assignment and training.

Static Balance Measures

For Tandem Stance (TS), participants placed their preferred foot forward and were timed for up to 60 seconds for three trials. For Unipedal Stance (US), participants stood up to 30 seconds on their preferred leg for the first and third trial and their nonpreferred leg for the second trial. Trials ended at maximum time or if the participant uncrossed their arms, changed foot position (TS), contacted the stance leg with the non-weight bearing foot (US), or lost balance. Longest-duration stance time was taken for the analysis. Inability to perform TS or US was defined as the inability to reach and hold the specified configuration.

Stepping Measures

For the Maximal Step Length (MSL) test, participants were tested in the forward, side, and backward directions for each lower extremity. Participants were instructed to step maximally without moving the stance foot and then return to the initial position in one movement. After three practice trials of submaximal stepping in each test direction, MSL was defined for each leg direction as the average step length over a series of five trials. The measurements were normalized according to subject height by using lower extremity length measured from the floor to the greater trochanter. The longest average MSL, usually the right leg forward step, was used for analysis. For the Rapid Step Test (RST), participants were instructed to take one step out and return as quickly as possible to the initial starting position in response to a command by the experimenter. A practice session of a six-step random sequence was performed using the right leg only and then the left leg only for the three directions (front, back, side) and was then followed using a 12-step sequence using both legs in all directions. A step length of at least 80% of the participant's MSL for all leg-directions was required. After this practice, a command for each leg and direction (e.g., "left-front") was given in a random order that included four steps in each of six leg directions for a total of 24 repetitions. Total time to complete the 24 repetitions was analyzed.

Timed Up and Go

As a global measure of balance and gait, the Timed Up and Go (TUG) test was used.[21] The participants were timed as they rose from a 45-cm-high straight-backed chair, walked 3 meters, turned, and returned to their original sitting position. After one practice trial, the next trial was used for analysis.

Data Analysis

To characterize data at baseline, frequencies and percentages were used for categorical data. For continuous variables, means and standard deviations were used for variables with approximately normal distributions (age), and medians and confidence intervals were used to summarize variables with skewed distributions.

In the main analysis, analysis of covariance was used to test the effect of CBST and TC interventions for dependent variables measured on the continuous scale, including TUG, MSL, and RST. Timed measures (RST, TUG) were logarithmically transformed in order for the residuals to satisfy assumptions of a normal distribution and constant variance. For the dependent measures MSL, RST, and TUG, the extent of improvement in CBST versus in TC was adjusted in the analysis for values of the dependent variable measured at baseline. In addition to adjusting for baseline, intervention effects were adjusted for minimization variables (age, sex, US time) and key covariates (use of an assistive device, inability to stand unipedally).

Variables TS and US had truncated distributions, with a substantial percentage of those unable to perform the test as well as exceeding the respective 60- and 30-second ceilings (Table 1), so that analysis of covariance could not be used. Logistic regression was used to test whether there was a significant difference between intervention groups at 10 weeks in the ability to perform TS or US. In the logistic model, the postintervention ability to perform TS or US in both intervention groups was adjusted for the ability to perform at baseline and for the minimization variables.

Analysis of covariance and logistic regression assumed an intention-to-treat analysis. To address possibly varying effects of CBST and TC interventions in different subgroups, such as those using an assistive device, those unable to stand unipedally, or having various values of the outcome variable at baseline, interactions between intervention group and covariates were included in analysis of covariance and logistic models. None of these interactions were statistically significant, and they were thus omitted from the final model. Calculations were performed using PROC MIXED (SAS Institute, Inc., Cary, NC). *P*-values are reported using the stepdown Bonferroni correction for multiple comparisons as specified in PROC MULTTEST (SAS).

RESULTS

Participant Characteristics at Baseline

As a result of the allocation strategy (i.e., minimization), the CBST (n = 106) and TC (n = 107) groups were similar in

Table 1. Group Baseline Characteristics

Characteristic	Tai Chi (n = 107)	Combined Balance and Stepping Training (n = 106)
Age, mean ± SD	78 ± 7	78 ± 7
Female, %	75	75
Use of assistive device, %	24	25
Established Populations for Epidemiologic Studies in the Elderly score, mean ± SD	4 ± 3	4 ± 3
Unable to perform TS, %	36	30
Unable to perform US, %	36	35
TS time, seconds, median (95% CI)	38.2 (1.2–60)	34.6 (3.0–60)
Median US time, seconds (95% CI)	9.2 (1.3–30)	8.8 (1.3–30)
Maximal Step Length, median (95% CI)*	0.3 (0.2–0.4)	0.3 (0.1–0.4)
Rapid Step Test, seconds, median (95% CI)	56 (44–102)	56 (41–117)
Timed Up and Go, seconds, median (95% CI)	13 (7–36)	13 (8–45)

* Normalized for limb length.
SD = Standard Deviation; TS = Tandem Stance; US = Unipedal Stance; CI = confidence interval.

mean age ± standard deviation (78±7) and sex (three quarters female). A substantial percentage of both groups used an assistive device at least occasionally for community ambulation (25% of CBST, 24% of TC) and were unable to stand unipedally (35% of CBST, 36% of TC). Mean self-reported disability was similar in both groups (EPESE score 4 ± 3). Median TS time, US time, and TUG score were also similar between groups (Table 1).

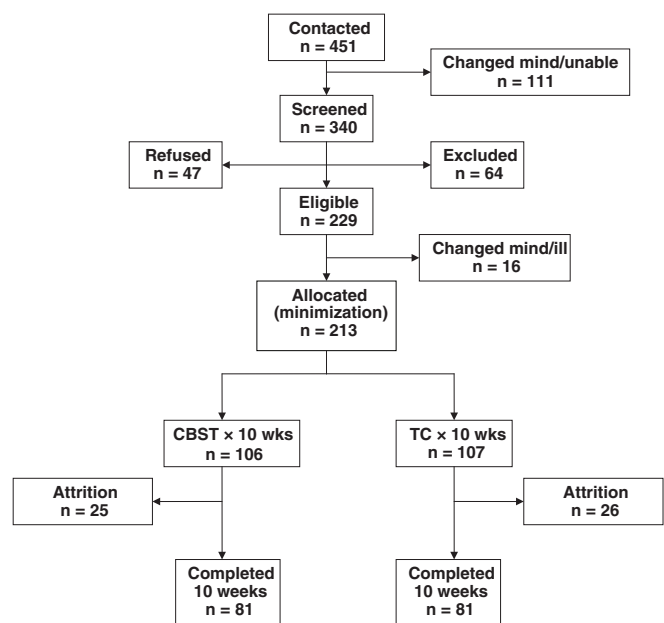**Participant Attendance and Attrition**

One hundred sixty-two of the 213 participants (76%) completed the 10-week study—81 in each arm. To complete the study, participants had to attend at least two-thirds of the exercise sessions. Attrition by 10 weeks affected both intervention arms equally: 25 in CBST and 26 in TC. Reasons for attrition in the CBST arm were did not meet the minimum two-thirds total session attendance requirement in the first few weeks of the study and were asked to discontinue (n = 5), dropped out because of other time commitments (n = 11), could not continue because of unrelated medical illness (n = 7), and experienced program-induced exacerbation of chronic musculoskeletal conditions that could not be alleviated through program alterations (n = 2). TC corresponding numbers were similar: poor attendance (n = 8), time commitments (n = 12), and unrelated medical illness (n = 6). There was no TC group attrition due to musculoskeletal complaints. Of those who dropped out before study completion, there was a difference between CBST and TC according to age, such that the early dropouts (before Week 5) tended to be younger in TC than CBST (P < .03 according to logistic regression analysis). Specifically, by Week 5, approximately 19% of those aged 85 and older in CBST (compared with 4% in TC) dropped out, whereas 34% of those aged 65 to 74 in TC dropped out (compared with 11% in CBST). Group differences in additional attrition at 10 weeks were no longer significant. There were no significant differences in any of the baseline balance, stepping, or mobility performance measures presented below between dropouts and those who completed the study. Of those who completed the study, mean sessions attended was 25.7 ± 2 (range 20–30) for CBST and 25.0 ± 2 (range 20–30) for TC,

for a mean percentage training attendance rate of 86% for CBST and 83% for TC. The flow of participants through the study is summarized in Figure 1.

Measures

Stepping and TUG

Table 2 displays the extent of improvement in CBST and TC for TUG, MSL, and RST. Regression coefficients provide an estimate of the effect favoring CBST over TC. The corresponding ratio of TC to CBST is the antilog of the regression coefficient. The percentage improvement in CBST versus TC uses the corresponding ratio estimate, yielding 9.4% improvement in TUG and 5.4% improvement in RST compared with TC. The percentage improvement of MSL uses the coefficient 0.0294 divided by the baseline 0.3 (from Table 1), yielding 9.8% improvement in CBST versus TC.

Figure 1. Participant enrollment, attrition, and follow-up.

Table 2. Comparison of Extent of Improvement in Combined Balance and Stepping Training (CBST) and Tai Chi (TC): Timed Up and Go (TUG), Maximum Step Length (MSL), and Rapid Step Test (RST) (n = 213)

Dependent Variable	Regression Coefficient (Standard Error)	Corresponding Ratio TC vs CBST (95% CI)	P-value	Improvement CBST versus TC, %
TUG, seconds	0.0899 (0.03)	1.094 (1.041–1.149)	.001	9.4
MSL	0.0294 (0.01)	N/A*	<.001	9.8
RST, seconds	0.0522 (0.02)	1.054 (1.003–1.106)	.02	5.4

Note: Regression coefficients were estimated using analysis of covariance in PROC MIXED (SAS Institute, Inc., Cary, NC), adjusting for minimization variables (age, sex, Unipedal Stance time), baseline, and key covariates (use of an assistive device, inability to stand unipedally).
Corresponding ratio CBST vs TC is the antilog of the regression coefficient.
Percentage improvement of CBST versus TC uses the corresponding ratio estimate, yielding 9.4 % more improvement in TUG and 5.4% more improvement in RST, in CBST than in TC. The percentage improvement of MSL uses the coefficient 0.0294 divided by baseline 0.3, yielding 9.8 % improvement.
* 95% confidence interval (CI) for MSL regression coefficient is 0.019–0.040.

Static Balance

In Table 3, odds ratios favoring CBST over TC ranged from 2.2 to 3.5, reaching statistical significance for the ability to perform TS.

DISCUSSION

In this cohort with at least mild balance impairment, two balance training paradigms in which variants of each program have been proven to reduce falls, CBST and TC, were compared. In general, performance improved in CBST than in TC, ranging from 5% to 10% for the stepping tests (MSL and RST) to 9% for TUG. Finally, TS ability improved more in CBST than TC. The magnitude of improvement in CBST versus TC might be expected to be small, given that variants of both intervention programs improve balance.

The relatively broad entry criteria for balance impairment enabled enrollment of participants with a broad range of balance function. These broad criteria ultimately resulted in 63% of those screened being enrolled, thereby increasing the generalizability of these data. This relatively liberal inclusion may also have led to a relatively high (24%) attrition rate over the 10-week period. This attrition rate may be comparable with those in other impaired or higher fall risk cohorts with an on-site exercise program and a high enrollment rate after screening; for example, a previous study[22] compared two on-site balance training protocols in previous fallers, enrolling 78% of those screened and losing 38% to attrition after 10 weeks. Long-term exercise-based fall risk reduction studies with at-risk cohorts have similar attrition rates but over a longer period of follow-up (e.g., a previous[6] TC study had a 24% dropout rate over 48 weeks). The definition of dropout in that study[6] seemed broad (noncompliant or missed more than 8 consecutive weeks of training). In the present study, attrition in TC occurred in those who were younger at baseline, although no age differences in attrition existed by 10 weeks. Perhaps younger participants preferred the faster CBST pace to the slower TC pace.

It is not surprising that greater improvement in the stepping measures (MSL, RST) was found in CBST than TC, because the training in CBST was clearly task specific. Nevertheless, CBST did not replicate the testing conditions, and effort was made to preserve the novelty of the outcome measures. CBST participants did not practice the outcome measures, although the skills learned (e.g., increasing step

length) were fundamental to balance responses and would likely lead to improved test performance. The RST was markedly different from training, adding a level of complexity in requiring participants to perform the stepping task as cued, thereby requiring a cognitive component while stepping. Prolongation in RST, particularly in those with balance impairments, is generally due to increased postural adjustments before step initiation.[23] Thus, a training-induced reduction in RST suggests fewer postural adjustments and perhaps a better sense of stability during task performance. That neither group improved substantially in unipedal stance is somewhat surprising, particularly given the emphasis on unipedal stance in TC. A nonstatistically significant trend in functional mobility (including unipedal stance) improvement was noted in a 12-week TC intervention in older adults with osteoarthritis,[24] and a significant improvement in unipedal stance (but not walking speed) was noted after an intensive (daily) 8-week program.[25]

The link between balance improvement and fall reduction is present in some but not all TC RCTs. Significant TC-induced clinical balance and gait improvements occurred in one study[5] at 6 months and were associated with lower fall risk,[26] although the published figures suggest improvements already at 3 months. Measures of balance platform performance did not improve after 15 weeks of TC,[27] despite the concurrent reduction in fall rate.[4]

In other fall reduction RCTs using dynamic balance and stepping training, balance improvement also is not clearly linked with fall reduction. Studies included in the previously mentioned meta-analysis[10] did not report intermediate functional mobility outcomes. Two recent studies embedded balance exercises in a program for at-risk older adults that included aerobic and walking exercises and

Table 3. Effect of Combined Balance and Stepping Training versus Tai Chi (TC) on Ability to Perform Tandem Stance (TS) and Unipedal Stance (US) (n = 169)

Variable	Odds Ratio Estimate	95% Confidence Interval	P-value
TS, seconds	3.5	1.32–9.06	.01
US, seconds	2.0	0.76–5.17	.16

Note: Estimates were determined using logistic regression with TC as the referent and adjusted by baseline and minimization variables (age, sex, US time).

strengthening, coordination, and flexibility training. These exercises were performed twice weekly, 1 hour per session, over a 12-month period in retirement care villages[28] or once weekly with a home program in a community setting.[29] Compared with controls (either seated flexibility or no intervention), exercise group fall risk was reduced 22%[28] and 40%.[29] The main functional improvements at 6 months were in postural sway and stepping reaction time, a measure that relates directly to the present study. In other RCTs more focused on balance training, composite functional balance measures improved after 10 weeks of balance strategy[22] or 25 weeks of agility training,[30] although the improvements in the latter study were seen at 13 weeks.

Major strengths of this study include the comparison of two balance exercise programs, variants of which have been proven to reduce falls. Moreover, the frequency of CBST and TC training were similar (1 hour, 3 d/wk), unlike previous studies in which education controls had a lower frequency of intervention contact.[4,6] The apparent intensity of CBST and TC in providing an hour of a stance-based movement program is also equivalent, whereas in a previous RCT of TC, the stretching control group performed minimal weight-bearing exercise.[5] Another strength is that the CBST benefit generalized to a key functional mobility measure that was clearly not part of the CBST paradigm—the TUG. Furthermore, at baseline before allocation, the median TUG score of either group was 13 (i.e., half of each cohort had a TUG greater than 13) and more than one-third of each group was unable to stand unipedally, suggesting that a substantial proportion of each group was at high risk for falls[31] and fall-related injury[32] at the beginning of the study.

The lack of a non- or limited-exercise control group limited the present study. Greater apparent improvement in CBST would have resulted with the use of such a control group but would not advance understanding of what the most optimal balance training program for fall reduction is.

Another possible weakness is the frequency and duration of the formal TC exercise program: 3 hours per week for 10 weeks, resulting in 30 total hours of training. Of the three TC RCTs highlighted above, the less physically impaired cohorts had 11 hours of training over 15 weeks (not including daily encouraged home practice[4]) and 78 hours of training over 26 weeks.[5] A third but more physically impaired TC cohort had a minimum of 96 hours over 48 weeks.[6] That study found that at least 3 months of TC training is recommended to reduce dependency on assistive devices.[6] In a previous study,[25] TC attendees completed a mean 32 hours of group instruction, similar to the present study. Moreover, balance improvements can be noted in TC and non-TC balance training after 8 to 10 weeks (e.g.,[22,25]).

To the authors' knowledge, this is the first comparison of two balance training programs in which variants of each program have been proven to reduce falls. The results indicate that CBST results in modestly greater improvement in balance, stepping, and functional mobility than TC. The CBST program was practical and required no specialized equipment or advanced specialist for instruction. Future fall-reduction balance exercise studies should focus on who should be targeted for which type of exercise, the manner in which the exercise is provided (frequency, duration, intensity, the setting in which the exercise is presented, the level and type of

supervision), adherence to the program, the effect on fall risk reduction, and the mechanisms underlying this effect.[33]

REFERENCES

1. Guideline for the prevention of falls in older persons. American Geriatrics Society, British Geriatrics Society, and American Academy of Orthopaedic Surgeons Panel on Falls Prevention. J Am Geriatr Soc 2001;49:664–672.
2. Chang JT, Morton SC, Rubenstein LZ et al. Interventions for the prevention of falls in older adults: Systematic review and meta-analysis of randomised clinical trials. BMJ 2004;328:680–686.
3. Province MA, Hadley EC, Hornbrook MC et al. The effects of exercise on falls in elderly patients. A preplanned meta-analysis of the FICSIT Trials. Frailty Injuries: Cooperative Studies of Intervention Techniques. JAMA 1995;273:1341–1347.
4. Wolf SL, Barnhart HX, Kutner NG et al. Reducing frailty and falls in older persons: An investigation of tai chi and computerized balance training. J Am Geriatr Soc 1996;44:489–497.
5. Li F, Harmer P, Fisher KJ et al. Tai chi and fall reductions in older adults: A randomized controlled trial. J Gerontol A Biol Sci Med Sci 2005;60A: M187–M194.
6. Wolf SL, Sattin RW, Kutner M et al. Intense tai chi exercise training and fall occurrences in older, transitionally frail adults: A randomized, controlled trial. J Am Geriatr Soc 2003;51:1693–1701.
7. Lavery LL, Studenski SA. Tai chi, falls, and the heritage of JAGS. J Am Geriatr Soc 2003;52:1804–1805.
8. Verhagen AP, Immink M, van der Meulen A et al. The efficacy of tai chi chuan in older adults: A systematic review. Fam Pract 2004;21:107–113.
9. Wu G. Evaluation of the effectiveness of tai chi for improving balance and preventing falls in the older population—a review. J Am Geriatr Soc 2002;50:746–754.
10. Robertson MC, Campbell AJ, Gardner MM et al. Preventing injuries in older people by preventing falls: A meta-analysis of individual-level data. J Am Geriatr Soc 2002;50:905–911.
11. Campbell AJ, Robertson MC, Gardner MM et al. Randomized controlled trial of a general practice programme of home based exercise to prevent falls in elderly women. BMJ 1997;315:1065–1069.
12. Luchies CW, Alexander NB, Schultz AB et al. Stepping responses of young and old adults to postural disturbances: kinematics. J Am Geriatr Soc 1994;42:506–512.
13. Maki BE, McIlroy WE. The control of foot placement during compensatory stepping reactions: Does speed of response take precedence over stability? IEEE Trans Rehabil Eng 1999;7:80–90.

14. Schulz BW, Ashton-Miller JA, Alexander NB. Compensatory stepping in response to waist pulls in balance-impaired and unimpaired women. Gait Posture 2005;3:198–209.

15. Medell JL, Alexander NB. A clinical measure of maximal and rapid stepping in older women. J Gerontol A Biol Sci Med Sci 2000;55A:M429–M433.

16. Cho BL, Scarpace D, Alexander NB. Tests of stepping as indicators of mobility, balance, and fall risk in balance-impaired older adults. J Am Geriatr Soc 2004;52:1168–1173.

17. Rogers MW, Johnson ME, Martinez KM et al. Step training improves the speed of voluntary step initiation in aging. J Gerontol A Biol Sci Med Sci 2003;58A:M46–M51.

18. Taves DR. Minimization: A new method of assigning patients to treatment and control groups. Clin Pharmacol Ther 1974;15:443–453.

19. Smith LA, Branch LG, Scherr PA et al. Short-term variability of measures of physical function in older people. J Am Geriatr Soc 1990; 38:993–998.

20. Schmidt RA. Motor Control and Learning: A Behavioral Emphasis, 2nd Ed. Champaign, IL: Human Kinetics Publishers, Inc., 1988.

21. Podsiadlo D, Richardson S. The timed 'Up & Go': A test of basic functional mobility for frail elderly persons. J Am Geriatr Soc 1991;39:42–48.

22. Nitz JC, Choy NL. The efficacy of a specific balance-strategy training programme for preventing falls among older people: A pilot randomized controlled trial. Age Ageing 2004;33:52–58.

23. Schulz BW, Ashton-Miller JA, Alexander NB. A kinematic analysis of the rapid step test in balance-impaired and unimpaired older women. Gait Posture 2006 Jul 24 [Epub ahead of print].

24. Hartman CA, Manos TM, Winter C et al. Effects of tai chi training on function and quality of life indicators in older adults with osteoarthritis. J Am Geriatr Soc 2000;48:1553–1559.

25. Zhang JG, Ishikawa-Takata K, Yamazaki H et al. The effects of tai chi chuan on physiological function and fear of falling in the less robust elderly: An intervention study for preventing falls. Arch Gerontol Geriatr 2006;42:107–116.

26. Li F, Harmer P, Fisher KJ et al. Tai chi: Improving functional balance and predicting subsequent falls in older persons. Med Sci Sports Exer 2004;36:2046–2052.

27. Wolf SL, Barnhart HX, Ellison GL et al. The effect of tai chi quan and computerized balance training on postural stability in older subjects. Phys Ther 1997;77:371–381.

28. Lord SR, Castell S, Corcoran J et al. The effect of group exercise on physical functioning and falls in frail older people living in retirement villages: A randomized controlled trial. J Am Geriatr Soc 2003;51:1685–1692.

29. Barnett A, Smith B, Lord SR et al. Community-based group exercise improves balance and reduces falls in at-risk older people: A randomized controlled trial. Age Ageing 2003;32:407–414.

30. Liu-Ambrose T, Khan KM, Eng JJ et al. Resistance and agility training reduce fall risk in women aged 75 to 85 with low bone mass: A 6-month randomized controlled trial. J Am Geriatr Soc 2004;52:657–665.

31. Shumway-Cook A, Brauer S, Woollacott M. Predicting the probability for falls in community-dwelling older adults using the Timed Up & Go Test. Phys Ther 2000;80:896–903.

32. Vellas BJ, Wayne SJ, Romero L et al. One-leg balance is an important predictor of injurious falls in older persons. J Am Geriatr Soc 1997;45:735–738.

33. Howe TE, Waters M, Dawson P et al. Exercise for improving balance in older people. (Protocol). Cochrane Database System Rev 2004: Issue, 4. Art. No.: CD004963.