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The Influence of Intense Tai Chi Training on Physical Performance and Hemodynamic Outcomes in Transitionally Frail, Older Adults

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Background. Few data exist to evaluate whether Tai Chi (TC) training improves physical performance and hemodynamic outcomes more than a wellness education (WE) program does among older fallers transitioning to frailty.

Methods. This 48-week randomized clinical trial was provided at 10 matched pairs of congregate living facilities in the Atlanta metropolitan area to 291 women and 20 men, who were transitionally frail, ≥70 years old, and had fallen at least once within the past year. Pairs of facilities were randomized to either TC exercise ($n = 158$) or WE (control) interventions ($n = 153$) over 48 weeks. Physical performance (freely chosen gait speed, reach, chair-rises, 360° turn, picking up an object from the floor, and single limb support) and hemodynamic outcomes (heart rate and blood pressure) were obtained at baseline and after 4, 8, and 12 months.

Results. Mean percent change (baseline to 1 year) for gait speed increased similarly in both cohorts (TC: 9.1% and WE: 8.2%; $p = .78$). However, time to complete three chair-rises decreased 12.3% for TC and increased 13.7% for WE ($p = .006$). Baseline to 1 year mean percent change decreased among TC and increased within WE cohorts for: body mass index (–2.3% vs 1.8%; $p < .0001$), systolic blood pressure (–3.4% vs 1.7%; $p = .02$), and resting heart rate (–5.9% vs 4.6%; $p < .0001$).

Conclusions. TC significantly improved chair-rise and cardiovascular performance. Because TC training reduced fall occurrences in this cohort, factors influencing functional and cardiovascular improvements may also favorably impact fall events.

EXERCISE programs can decrease falls (1–3), improve muscle strength (4–6), and enhance gait and postural stability (7,8) in healthy older persons. The Frailty and Injuries: Cooperative Studies on Intervention Techniques (FICSIT) Trial (9) showed that Tai Chi (TC) exercise at a modest intensity produced a 47.5% reduction in risk of multiple falls (10) and participants were less fearful of falling (11). In contrast, transitionally frail older adults participating in a 1-year program of TC training experienced a reduction in their risk by 25% compared to that of participants in a wellness education WE program (12). Fall rates were reduced by 40% from 12 weeks to 48 weeks of training suggesting that a latency period exists before the benefits of training are appreciated. Moreover, older adults who are physically active for less than an hour per week (13) can also reduce the risk of falls over a 6-month follow-up period.

Although reducing falls is important to older adults who are becoming frail, exploring the extent to which TC will affect hemodynamic outcomes and physical performance in this cohort is also important, because mobility and health-related quality of life are also impacted by these outcomes. This article explores the extent and time course over which TC impacts measures of physical performance and cardiovascular function in this cohort.

Methods

Research Design and Participants

Data were collected from 311 participants (age range: 70–97 years; mean age: 80.9 years) recruited from 20 independent congregate living facilities in the greater Atlanta area. Details regarding the design, methodology, and inclusion exclusion criteria have been reported previously (14). Sites were randomized in pairs with each pair receiving either the TC or WE intervention and enrolled 15–19 participants. All participants provided written informed consent.

Medical history and physical examinations were obtained at baseline to rule out the possibility of occult cardiovascular disease or other medical or psychological conditions that could adversely influence participation. Participants averaged 5.6 comorbidities, the most prevalent of which included osteoarthritis, visual dysfunction, and hypertension.

Interventions

The TC intervention consisted of 1-hour group exercise conducted twice weekly. Participants were asked to complete and return weekly exercise logs and were taught behavioral skills and strategies relevant to each movement form. Six of the 24 simplified TC forms were used. All TC exercise was standardized by having the two instructors practice with one another until their execution of the movement forms to be taught in each class were identical.

Participants progressed from often being dependent on assistive devices for upright support to performing 2 continuous minutes of TC without support. "Intense" TC was defined as two sessions per week at increasing durations starting at 60 minutes of contact time and progressing to 90 minutes over 48 weeks. In addition, participants were asked to supplement their TC training with home-based exercise, with the goal of exercising 4–5 days per week, 10–30 minutes per day. The actual "work" time, exclusive of warm-up and cool-down, progressed from approximately 10 to 50 minutes.

The WE program was given at participating facilities for an hour each week and consisted of prepared lectures on falls prevention; exercise and balance; diet and nutrition; pharmacological management; legal issues relevant to health; age-related changes in body function; and mental health (stress, depression). The total time for individual attention from each instructor to participants in each group was comparable. All outcome measures were obtained at baseline and after 4, 8, and 12 months of the interventions.

Physical Performance

The participants' physical status was measured by performance-based tests, chosen because of their previously established reliability and validity, simplicity to administer, and clinical utility and included gait speed, functional reach test, time to rise from a chair three times, time to complete a 360° turn, time required to pick up an object from the floor, and duration of single limb support with eyes open and closed. All tests were performed within a single testing session with adequate rest between tests. The average of three measurements was recorded for each task. All testing was undertaken by evaluators who were not involved in either the TC or WE interventions and who were blinded to intervention allocation. Participants were instructed not to disclose the intervention they received to the evaluators.

Dropouts

Dropouts were defined as participants who missed more than 8 consecutive weeks of the intervention. Of 311 participants randomized, 12 individuals randomized to TC and 12 randomized to WE chose not to participate after randomization. One individual with Parkinson's did not contribute data beyond baseline. The remaining 286 participants (92%) provided longitudinal data, but 69 participants did not complete the 48-week intervention. Baseline characteristics of the study completers and noncompleters for the two intervention groups have been previously reported (15).

Statistical Analysis

The primary analyses of the data were performed according to participants' original treatment assignment for all 311 participants randomized. Baseline measurements of TC and WE participants were compared using a permutation test in which the unit of randomization was the independent living facility pair.

Repeated-measures analysis included participant level characteristics and congregate living facilities clustering. Participants were clustered within living facilities with living facility pairs as a random effect and the participant as the experimental unit. Repeated-measures analyses, using mixed linear models, were performed for six physical performance, three hemodynamic, and three anthropomorphic measurements and percent change from baseline with a means model using SAS Proc Mixed (version 8; SAS Institute, Cary, NC). An unstructured variance–covariance form in repeated measurements was assumed for each outcome. Variance components included the cluster and the between- and within-participant components (16). The intraclass correlation coefficient (ICC) ranged from 0.005 (functional reach) to 0.12 (gait speed). Because the data for chair-rises were right-skewed, natural log transformations were performed prior to analysis and results were reported based on back transformation of the log values to the usual arithmetic scale. Sensitivity analyses to evaluate the implications of missing observations included "completers" analysis—that is, an analysis including only participants who completed follow-up, (for chair-rise data) last observation carried forward, and baseline observation carried forward. These analyses showed similar results to intent-to-treat repeated-measures analyses which suggest that the missing data were noninformative.

Statistical tests were two-sided. A Bonferroni adjustment ($p < .0125$) was used to compare TC versus WE at each of the four time points. Statistical tests were not adjusted for multiple outcomes.

Results

There were few differences between participant groups at baseline (Table 1). TC participants used fewer assistive devices ($p = .02$) and had slightly greater functional reach ($p = .06$).

Body Mass Index

Body mass index (BMI) changed significantly in different directions for the two study cohorts ($p < .0001$, Table 2), declining linearly in the TC cohort (0.74 kg/m^2, $p = .0003$) and increasing linearly in the WE cohort (0.47 kg/m^2, $p = .015$). The mean percent change from baseline declined by 2.3% at 1 year for the TC cohort and increased by 1.8% for the WE cohort (Figure 1A). The mean difference in percent change from baseline to 1 year was 4.1% (95% confidence interval [CI], 2.1%–6.1%; $p < .0001$).

Height and Total Body Weight

Height decreased by 0.016 m ($p < .0001$) in the WE group. The mean percent change from baseline to 1 year was 0.3% and –1.0% in the TC and WE cohorts, respectively ($p = .0001$, Figure 1B).

Mean total body weight for TC participants decreased by 1.49 kg ($p < .0001$) and by only .29 kg ($p = .39$) for WE individuals. The mean percent change from baseline to 1 year was –2.2% and –0.40% in the TC and WE cohorts, respectively ($p = .01$, Figure 1C).

Table 1. Baseline Characteristics of the Study Participants ($N = 311$)

Characteristics	N		TC (N = 158)	WE (N = 153)	p Value
			N (%)	N (%)	
Sex	311	Male	10 (6%)	10 (7%)	.99
		Female	148 (94%)	143 (93%)	
Race	311	Caucasian	126 (80%)	124 (81%)	.77
		Non-Caucasian*	32 (20%)	29 (19%)	
Education	311	<12 years	31 (20%)	35 (23%)	.80
		12+ years	127 (80%)	118 (77%)	
Use of mobility aid	310	No	88 (56%)	66 (43%)	.02
		Yes	69 (44%)	87 (57%)	
Activity level	311	Sedentary	86 (54%)	80 (52%)	.88
		Active	72 (46%)	73 (48%)	
Alcohol use ever	310	No	92 (59%)	100 (65%)	.18
		Yes	65 (41%)	53 (35%)	
			Mean (SD)	Mean (SD)	
Age (y)	311		81.0 (6.4)	80.8 (5.9)	.81
Height (m)	309		1.6 (0.1)	1.6 (0.1)	.13
Weight (kg)	310		69.1 (14.8)	67.4 (15.5)	.26
Body Mass Index (kg/m^2)	309		26.9 (5.8)	26.6 (5.7)	.53
Blood pressure (mmHg)	300	Systolic	147 (20)	150 (19)	.42
	299	Diastolic	76 (11)	78 (9)	.16
Resting heart rate (bpm)	293		74 (11)	73 (11)	.22
Gait speed (m/s)	305		1.02 (0.34)	0.94 (0.30)	.14
Three chair-stand (s)	252		11.10 (4.43)	10.32 (3.95)	.19
Functional reach (in)	305		11.63 (3.02)	10.63 (2.94)	.06

Notes: *55 African American and 6 Other.
TC = Tai Chi; WE = wellness education; *SD* = standard deviation.

Hemodynamic Changes

Systolic blood pressure (SBP) also changed in significantly different directions during the interventions ($p = .005$, Table 2). Mean SBP declined over the intervention for the TC cohort ($p = .0002$) but not for the WE cohort ($p = .09$). Mean SBP was significantly lower in the TC cohort than in the WE group at 1 year ($p < .0001$, Table 2). The mean percent change from baseline to 1 year was –3.4% in the TC cohort and 1.7% in the WE cohort ($p = .017$, Figure 1D).

Diastolic blood pressure (DBP) in the study cohorts was consistently different ($p = .0009$), with TC participants having lower mean DBP than WE participants at every follow-up time point. Figure 1E indicates a significant decline in the percent change from baseline to 4 months in both cohorts ($p < .0001$).

Resting heart rate changed in significantly different directions for the two study cohorts ($p < .0001$, Table 2). Mean heart rate was significantly lower in the TC cohort than in the WE cohort at 4 months ($p < .0001$). The mean difference at 4 months was 6 bpm (95% CI, 4 bpm–9 bpm). The mean percent change from baseline to 4 months in resting heart rate was –6.5% for the TC cohort and 4.9% for the WE cohort ($p < .0001$, Figure 1F), and remained stable thereafter.

Physical Changes

Mean gait speed increased over time in both cohorts (Table 2, $p < .0001$). Mean gait speed at 4 months was 1.08 m/s in the TC cohort and 0.99 m/s in the WE cohort (mean difference = 0.09 m/s; 95% CI, 0.02–0.17; $p = .017$), and persisted through 8 months. However, when expressed as a mean percent change over time, the increases from baseline to 4 months were 9.4% for the TC cohort and 6.0% for the WE cohort ($p = .20$, Figure 1G) and 9.1% and 8.2%, respectively, at the 12-month evaluation ($p = .78$).

The mean time necessary for completion of the three chair-stands was similar at baseline (Table 1) and at each follow-up visit for the two cohorts (Figure 1H, Table 2). Expressed as a mean percent change from baseline, the three chair-stands time decreased in the TC cohort ($p = .005$, Figure 1F) and was substantially different after 8 months. At month 12, the mean percent change from baseline was –12.3% in the TC cohort and 13.7% in the WC cohort ($p = .006$). Thirty TC and 29 WE participants could not complete the chair-stands at baseline. At a subsequent evaluation after the baseline session, eight of the TC and five of the WE individuals within this subgroup were able to do so. Despite the missing data, sensitivity analyses consistently found that TC improved chair-rise performance.

Functional reach was consistently different between cohorts ($p = .002$, Table 2) with TC participants having a significantly greater functional reach than WE participants, but the percent increase at 12 months was similar for the two cohorts (Figure 1I).

Among other physical measures, the percent change from baseline to 12 months was similar for the two cohorts ($p = .95$ for 360° turn; $p = .23$ for pick up an object, data not shown), with no differences between groups seen across time for the single limb support data.

Discussion

This study is the first to evaluate the hemodynamic and functional changes associated with TC training in a cohort of older adults operationally defined as transitionally frail who participated in a 48-week intervention program. This intervention had a positive impact on three physiological parameters (BMI, SBP, and heart rate) and on chair-standing that became apparent after 4 or 8 months of training and persisted through the completion of the intervention.

After 4 months, TC participants demonstrated a reduced BMI with a loss in total body weight of almost 1.5 kg, whereas no decrease was observed in the WE participants. A decrease in height was seen among the WE group but remained unchanged in TC participants suggesting that the training contributed to participants' standing tall and losing weight. This notion seems plausible because TC has been shown to improve static and dynamic postural control in older persons with less (10,17–19) or more (20,21) experience in practicing TC.

The significant decreases in SBP and resting heart rate among our participants are comparable to those from Hong and colleagues (22), who reported that the average resting heart rates for older healthy TC practitioners with at least 10 years of experience and inactive age- and body-type matched controls were 69.01 ± 9.6 and 76.88 ± 9.32, respectively. These remarkably similar findings suggest that transitionally frail older persons retain the ability to

Table 2. Physical Performance and Hemodynamic Measurements for TC and WE Participants

	Baseline		4 Months		8 Months		12 Months				
Measure	*N*	Mean (*SE*)	*N*	Mean (*SE*)	*N*	Mean (*SE*)	*N*	Mean (*SE*)	Intervention *p* Value	Time *p* Value	Intervention by Time *p* Value
BMI, kg/m^2									.57	.56	<.0001
TC	157	27.06 (0.74)	125	26.48 (0.74)	116	26.46 (0.75)	107	26.32 (0.75)			
WE	152	26.67 (0.74)	129	26.92 (0.75)	116	26.99 (0.75)	106	27.14 (0.75)			
p value: TC vs WE		.53		.48		.41		.20			
Height, m									.002	.006	.003
TC	157	1.60 (0.01)	125	1.61 (0.01)	116	1.61 (0.01)	107	1.60 (0.01)			
WE	152	1.59 (0.01)	129	1.58 (0.01)	116	1.58 (0.01)	106	1.57 (0.01)			
p value: TC vs WE		.18		.003		.0007		.0001			
Weight, kg									.51	.001	.05
TC	157	69.30 (1.81)	125	68.57 (1.81)	116	68.28 (1.82)	107	67.81 (1.82)			
WE	153	67.58 (1.82)	129	67.59 (1.82)	116	67.15 (1.83)	106	67.29 (1.83)			
p value: TC vs WE		.30		.56		.50		.76			
SBP, mmHg											
TC	155	147 (2.0)	127	142 (2.2)	116	139 (2.1)	108	140 (2.2)			
WE	145	150 (2.1)	129	146 (2.2)	116	149 (2.1)	107	150 (2.2)			
p value: TC vs WE		.22		.11		<.0001		<.0001			
DBP, mmHg									.0009	<.0001	.39
TC	154	76 (1.1)	127	73 (1.1)	116	72 (1.1)	108	72 (1.2)			
WE	145	78 (1.1)	129	75 (1.1)	116	76 (1.1)	107	75 (1.2)			
p value: TC vs WE		.13		.037		.001		.024			
Heart rate, bpm									<.0001	.059	<.0001
TC	149	74 (1.2)	126	69 (1.3)	116	69 (1.3)	107	69 (1.2)			
WE	144	73 (1.2)	126	75 (1.3)	116	77 (1.3)	108	76 (1.2)			
p value: TC vs WE		.38		<.0001		<.0001		<.0001			
Gait speed, m/s									.033	<.0001	.12
TC	155	1.01 (0.04)	120	1.08 (0.04)	112	1.09 (0.05)	99	1.07 (0.05)			
WE	150	0.94 (0.04)	124	0.99 (0.04)	112	0.99 (0.05)	95	1.02 (0.05)			
p value: TC vs WE		.043		.017		.020		.19			
Three chair stand, s									.99	<.0001	.011
TC	129	10.40 (0.38)	101	8.98 (0.32)	100	8.38 (0.28)	83	8.75 (0.30)			
WE	123	9.61 (0.36)	98	8.50 (0.31)	87	9.04 (0.32)	79	9.28 (0.33)			
p value: TC vs WE		.14		.28		.12		.23			
Functional reach, in									.002	.069	.45
TC	155	11.63 (0.25)	122	11.82 (0.25)	112	11.82 (0.26)	98	12.12 (0.27)			
WE	150	10.63 (0.25)	121	11.08 (0.25)	108	11.22 (0.26)	94	11.03 (0.28)			
p value: TC vs WE		.003		.034		.094		.004			

Note: *SE* = standard error; BMI = body mass index; TC = Tai Chi; WE = wellness education; SBP = systolic blood pressure; DBP = diastolic blood pressure.

adapt to TC training as well as do experienced robust individuals.

Our TC training protocol was not uniformly effective at improving physical function and mobility. Both cohorts showed comparable changes in gait speed and functional reach over time. In contrast to our observations, Mak and Ng (23) explored the impact of TC on adults (mean age 62 years vs 80.8 years in the present study) who had been practicing for years, and reported that they had faster gait speed (1.11 m/s vs 1.01 m/s), greater functional reach, and improved postural control as measured by sway parameters during single-leg stance than did nonpractitioners. Our participants practiced different forms of TC and had no previous experience with this exercise. Thus the intensity of our TC training may not have been sufficient to elicit significant improvements in gait speed or postural control.

TC training did, however, produce a significant mean percent reduction from baseline in chair-stand time by the eighth month of training but not in other functional measures. However, given that 30 TC individuals could not chair-stand before the intervention, improved chair-rise performance among all TC participants might not apply to the frailest older adults. Among our participants, chair-stands without the use of arm support place a concurrent demand on lower extremity strength and phasic changes in balance that might not be manifest in the other performance measures.

Our participants required more time or intense training to effect behavioral, hemodynamic, functional, or fall-related improvement. This 4-month latency may be related to physical (improved strength and balance) and psychological (a sense of mastery and perceived physical competence) factors known to be associated with latent improvements in physical performance (24–26). Interestingly, 4 months of

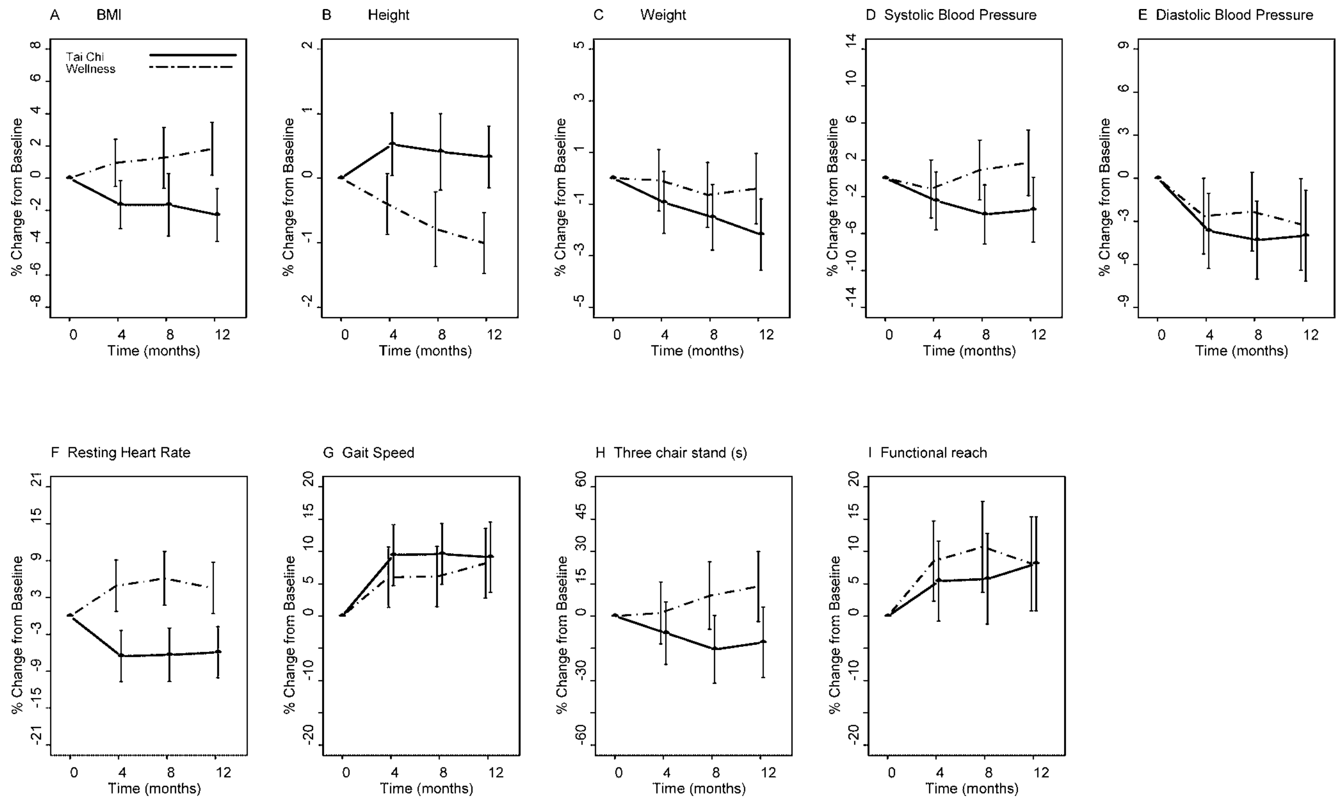

Figure 1. Longitudinal changes in physical performance and hemodynamic measurements by intervention (Tai Chi exercise [*solid line*] program or wellness education [*dotted line*] program). *Vertical bars:* 95% confidence intervals for the mean. Mean percent change from baseline for body mass index (BMI) (**A**), height (**B**), weight (**C**), systolic (**D**) and diastolic (**E**) blood pressure, resting heart rate (**F**), gait speed (**G**), three chair-rises (**H**), and functional reach (**I**).

TC training were required before these participants demonstrated a significant reduction (40%) in fall rates (12) and 8 months were required before significant improvements in balance confidence were achieved (15).

The primary study limitation is missing outcome data. Although changes observed over time in the TC group might be due to differential dropout of more frail participants, the intention-to-treat analyses and sensitivity analyses were consistent and suggested that TC improved chair-rise performance and cardiovascular outcomes. Despite the consistency of study results, the findings may not generalize to the entire population of transitional older people or to those who could not chair-stand at baseline.

Summary

Forty-eight weeks of bi-weekly TC exercise among transitionally frail older adults results in significant, beneficial changes in several physiological parameters that are manifest after at least 4 months of training. Future research examining the effects of TC training designed to slow the progression of frailty should better specify the interrelationships between intensity, duration, and type of TC training and the magnitude of comorbidities confronting participants. Such studies might entertain using a contemporary, operational definition of “intermediate frail” derived from a recent, exploratory study by Fried and colleagues (27) whose participants, like many of our own, were at risk for disability, hospitalization, nursing home placement, and/or adverse health outcomes, such as falls.

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References

1. Tinetti ME, Baker DI, McAvay G, et al. A multifactorial intervention to reduce the risk of falling among elderly people living in the community. *N Engl J Med*. 1994;331:821–827.
2. Robertson MC, Campbell AJ, Garner MM, Develin N. Preventing injuries in older people by preventing falls: a meta-analysis of individual-level data. *J Am Geriatr Soc*. 2002;50:905–911.
3. Rogers ME, Rogers NL, Takeshima N, Islam MM. Method to assess and improve the physical parameters associated with fall risk in older adults. *Prev Med*. 2003;36:255–264.

4. Chandler JM, Duncan PW, Kochersberger G, Studenski S. Is lower extremity strength gain associated with improvement in physical performance and disability in frail, community-dwelling elders? *Arch Phys Med Rehabil.* 1998;79:24–30.
5. DeVito CA, Morgan RO, Duque M, Abdel-Moty E, Virnig BA. Physical performance effects of low intensity exercise among clinically defined high-risk elders. *Gerontology.* 2003;49:146–154.
6. Seynnes O, Fiatarone Singh MA, Hue O, Pras P, Legros P, Bernard PL. Physiological and functional responses to low-moderate vesus high-intensity progressive resistance training in frail elders. *J Gerontol Biol Sci Med Sci.* 2004;59A:503–509.
7. Buchner DM, Cress ME, de Lateur BJ, et al. The effect of strength and endurance training on gait, balance, fall risk, and health services use in community-living older adults. *J Gerontol Med Sci.* 1997;52A: M218–M224.
8. Conn VS, Minor MA, Burks KJ, Rantz MJ, Pomeroy SH. Integrative review of physical activity intervention research with aging adults. *J Am Geriatr Soc.* 2003;51:1159–1168.
9. 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. *JAMA.* 1995;273:1341–1347.
10. Wolf SL, Barnhart HX, Kutner NG, McNeely E, Coogler C, Xu T. Reducing frailty and falls in older persons: an investigation of Tai Chi and computerized balance training. *J Am Geriatr Soc.* 1996;44:489–497.
11. Kutner NG, Barnhart H, Wolf SL, McNeely E, Xu T. Self-report benefits of Tai Chi practice by older adults. *J Gerontol Psychol Sci.* 1997;52:P242–P246.
12. Wolf SL, Sattin RW, Kutner M, O'Grady M, Greenspan AI, Gregor RJ. 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.
13. Li F, Harmer P, Fisher KJ, Mcauley E. Tai Chi: improving functional balance and predicting subsequent falls in older adults. *Med Sci Sports Exerc.* 2004;36:2046–2052.
14. Wolf SL, Sattin RW, O'Grady M, et al. A study design to investigate the effect of intense tai chi in reducing falls among older adults transitioning to frailty. *Control Clin Trials.* 2001;22:689–704.
15. Sattin RW, Easley KA, Wolf SL, Chen Y, Kutner MH. Reduction in fear of falling through intense Tai Chi exercise training in older, transitionally frail adults. *J Am Geriatr Soc.* 2005;53:1168–1178.
16. Donner A. Some aspects of the design and analysis of cluster randomization trials. *Appl Stat.* 1998;47:95–113.
17. Tse SK, Bailey DM. Tai Chi and postural control in well elderly. *Am J Occup Ther.* 1992;46:295–300.
18. Wolfson L, Whipple R, Derby C, et al. Balance and strength training in older adults: intervention gains and Tai Chi maintenance. *J Am Geriatr Soc.* 1996;44:498–506.
19. Jacobson BH, Chen HC, Cashel C, Guerrero L. The effect of Tai Chi Chuan training on balance, kinesthetic sense, and strength. *Percept Mot Skills.* 1997;84:27–33.
20. Lan C, Lai JS, Wong MK, Yu ML. Cardiorespiratory function, flexibility, and body composition among geriatric Tai Chi Chuan practitioners. *Arch Phys Med Rehabil.* 1996;77:612–616.
21. Tsang WW, Hui-Chan CW. Effects of tai chi on joint proprioception and stability limits in elderly subjects. *Med Sci Sports Exerc.* 2003;35: 1962–1971.
22. Hong Y, Li JX, Robinson PD. Balance control, flexibility, and cardiorespiratory fitness among older Tai Chi practitioners. *Br J Sports Med.* 2000;34:9–34.
23. Mak MK, Ng PL. Mediolateral sway in single-leg stance is the best discriminator of balance performance for Tai-Chi practitioners. *Arch Phys Med Rehabil.* 2003;84:683–686.
24. Lan TY, Deeg DJ, Guralnik JM, Melzer D. Responsiveness of the index of mobility limitation: comparison with gait speed alone in the longitudinal aging study Amsterdam. *J Gerontol Biol Sci Med Sci.* 2003; 58A:721–727.
25. Cress ME, Schechtman KB, Mulrow CD, Fiatarone MA, Gerety MB, Buchner DM. Relationship between physical performance and self-perceived physical function. *J Am Geriatr Soc.* 1995;43:93–101.
26. Kempen GI, Stevernik N, Ormel J, Deeg DJ. The assessment of ADL among frail elderly in an interview study: self-report versus performance-based tests and determinants of discrepancies. *J Gerontol Med Sci.* 1996;31A:M254–M260.
27. Fried LP, Tangen CM, Walston J, et al. Frailty in older adults: evidence for a phenotype. *J Gerontol Med Sci.* 2001;56A:M146–M157.

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