

Evaluation of the Effectiveness of Tai Chi for Improving Balance and Preventing Falls in the Older Population—A Review

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One of the challenges faced by people with advancing age is decreased postural stability and increased risks for falls. There has been an increased interest over the last decade in using Tai Chi as an intervention exercise for improving postural balance and preventing falls in older people. Despite the increased number of studies in recent years relating Tai Chi to balance and fall prevention, results are scattered and inconsistent. There is wide variation in the use of balance measures, subject population, type and duration of Tai Chi exercise, and type of study. This paper provides a systematic review/analysis of currently available study reports. The goal of the review is to address the following concerns: how the effect of Tai Chi on balance or fall prevention has been evaluated to date, what level of evidence exists supporting Tai Chi as an effective exercise for improving balance or preventing falls, and what factors could possibly affect the benefit of Tai Chi on balance or falls. This review also helps identify directions for future research. *J Am Geriatr Soc* 50:746–754, 2002.

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Approximately 30% of people aged 65 and older in the United States fall at least once a year, and about half that number have multiple falls each year.¹ Falls may result in head trauma, fractures, and even death.² Immobility resulting from falls in older people can lead to severe depression, malnutrition, and increased chance of infection and can have more deleterious effects on physiological structures and functions in older people than in younger people.³

Currently, many programs are available to older people to help them prevent falls and fall-related injuries and thus maintain their highest level of independence. These programs include resistance, endurance, balance, and feed-

back training.^{4–6} Although these training programs have proved to be effective at improving the specific area being trained⁷ (e.g., resistance training improving the strength of the trained muscles^{4,8,9} and balance training improving balance skills¹⁰), the effectiveness of these exercises to reduce the risk of falls in older people has not been demonstrated clearly.^{9,11,12} This may be because these programs are focused only on a single variable, such as resistance, endurance, balance, or gait, rather than physical function as a whole.

Recently, Tai Chi has drawn more and more attention within the rehabilitation/geriatric community. Tai Chi is an ancient Chinese martial art consisting of a series of slow but continuous movements of every body part. Older people usually prefer its nonvigorous and gentle movements. Moreover, it is believed that Tai Chi may benefit older people for fall prevention because Tai Chi movements incorporate elements of strengthening, balance, postural alignment, and concentration.

Over the last decade, the number of studies on the effect of Tai Chi on balance and fall prevention has increased rapidly, although it is still limited. A Medline search since 1966 using the key words “Tai Chi” or “T’ai Chi” resulted in 73 articles. Combining with key words such as “balance” or “fall,” the search was narrowed to 24 articles. Of these 24 articles relating to balance or falls, there were five reviews,^{13–17} two prestudy reports (no results),^{18,19} one meta-analysis,²⁰ and one single-case study.²¹ The remaining 15 articles included three cross-sectional studies,^{22–24} 11 longitudinal studies,^{25–35} and one follow-up study.³⁶

Unfortunately, results from these studies are scattered or inconsistent. This is perhaps due to the wide variations in the use of balance measures, subject population (such as age, gender, sample size, and health status), type and duration of Tai Chi exercise, and type of study. A brief summary of each of the original studies based on these variables is given in Tables 1 through 3.

The goal of this paper is to provide a systematic review/analysis of these study reports based on each of the above variables, in an attempt to address the following concerns: how the effect of Tai Chi on balance or falls has been evaluated, what level of evidence exists supporting Tai Chi as an effective exercise for improving balance or preventing falls, and what factors could affect the benefit

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Table 1. Summary of Longitudinal Studies Relating Tai Chi (TC) Exercise to Balance

Author	Year	Number of Women	Group	Sample Size	Age	Health Status	TC Style	TC Duration weeks (times per week)	Balance-Related Measures	Result
Judge et al. ²⁵	1993	12	Training	12	All	Healthy	TC-like movement	24	Double stance	NS
Wolf et al. ²⁶	1996	9	Flexibility	9	62–75	Healthy	Yang, 10 form	15 (2)	SLS (EO)	*
		45	Balance	58	All >70	Faller 31%			12-minute walk	against TC*
		41	TC	51		Faller 42%			Fear of falling	favor TC*
Schaller ⁷	1996	45	Control	53		Faller 34% (all healthy)	TC Chih, 20 form	10 (1) + self 3/week	Rate of falls	favor TC*
		Unknown	TC	24	All >70	Healthy			IADLs	NS
Wolf et al. ²⁸	1997	19	Balance	24	All >70	Faller 25%	Yang, 10 form	15 (2)	SLS	EO only*
		22	TC	24		Faller 63%			Sit-to-reach	(not reported)
		19	Control	24		Faller 37%			MOS SF-36	(not reported)
Jacobson et al. ²⁹	1997	12	TC	12	All	Healthy	Yang, 108 form	12 (3)	Fear of falling	NS
		12	Control	12	20–45	Healthy			Center of balance	favor TC*
Kutner et al. ³⁰	1997	Unknown	TC	51	All >70	Healthy	Yang, 10 form	15 (1)	Lateral stability	*
		Balance	Balance	39		Healthy			Kinesthetic sense	60 ^o †
		Control	Control	40		Healthy			Exit interview	favor TC*
Forrest ³¹	1997	5	TC	8	36.5 (mean)	Healthy	Unknown	16	Foot COP (AP)	*
Shih ³²	1997	4	TC	11	20–43	Healthy	Yang, 24 form	16 (3)	EMG	*
		15	TC	17	68–92	Healthy			Unknown	8 (3)
Ross et al. ³³	1999	15	TC	17	68–92	Healthy	Unknown	8 (3)	Dynamic COP	*
Hain, et al. ³⁴	1999	17	TC	6	20–60	All with mild balance disorder	Combination of Yang, Wu, and Pa Kua	8 (1) + self daily	Sit-to-reach	NS
		7	TC	7	61–75	Healthy			SLS	NS
		9	TC	9	>75	Healthy			Tandem walk	NS
Hartman et al. ³⁵	2000	15	TC	19	69 (mean)	Osteoarthritis	Yang, 9 form	12 (2)	SOT	*
		13	Control	16	67 (mean)	Osteoarthritis			Romberg stance	*
		13	Control	16	67 (mean)	Osteoarthritis			Reach test	*
			TC	19	69 (mean)	Osteoarthritis	Yang, 9 form	12 (2)	MOS SF-36	*
			Control	16	67 (mean)	Osteoarthritis	Yang, 9 form	12 (2)	Rise from chair	NS
			Control	16	67 (mean)	Osteoarthritis	Yang, 9 form	12 (2)	SLS	NS
			Control	16	67 (mean)	Osteoarthritis	Yang, 9 form	12 (2)	50-foot walk	NS

*Statistically significant.
 †At 60° of medial rotation of the shoulder joint.
 SLS = single-leg stance; EO = eyes open; NS = not significant; IADL = instrumental activity of daily living; MOS SF-36 = Medical Outcomes Study Short Form; COP = center of pressure; AP = anterior-posterior; EMG = electromyography; SOT = sensory organization test.

Table 2. Summary of Cross-Sectional Studies Relating Tai Chi (TC) Exercise to Balance

Author	Year	Number of Women	Group	Sample Size	Age	Health Status	TC Style	TC Duration (years)	Balance-Related Measures	Result
Tse and Bailey ²²	1992	3	TC	9	65–84	Healthy	Unknown	1–20	SLS	*(EO only)
		3	Control	9	66–86			0	Heel-toe walk	*
Hong et al. ²³	2000	0	TC	28	All >65	Healthy	Yang, 108 form	>10	SLS (EC only)	*
		0	Control	30				0	Sit and reach	*
									Step test	*
Lin et al. ²⁴	2000	7	TC	14	66–74	Healthy	Unknown	2–35	Lateral WS	NS
		10	Control	14	66–76	(no fall history in past year)		0	AP WS	*
									Multi-dir. WS	NS
									Static balance	complicated condition*

*Statistically significant.

SLS = single-leg stance; EO = eyes open; EC = eyes closed; WS = weight shift; AP = anterior-posterior; NS = not significant.

Table 3. Summary of Other Type of Studies Relating Tai Chi (TC) Exercise to Balance

Author	Year/Type	Number of Women	Group	Sample Size	Age	Health Status	TC Style	TC Duration	Balance-Related Measures	Result
Koh ²¹	1982 single	Unknown		1	Unknown	Severe ankylosing spondylitis	Unknown	2.5 years, daily	Balance Limb coordination	*
Wolfson et al. ³⁶	1996 follow-up	12	Balance	28	All > 75	Faller 5	Unknown	24 weeks × 1 session/week	Loss of balance	NS
		10	Strength	28		Faller 9			Functional BOS	against TC*
		13	Balance + Strength	27		Faller 8			SLS	mixed
		11	Control	27		Faller 7			Gait velocity	mixed
			TC follow-up							

*Statistically significant.

BOS = base of support; SLS = single-leg stance; NS = not significant.

of Tai Chi on balance or falls. This review will also help identify directions for future research.

VARIATION IN OUTCOME MEASURES OF BALANCE OR FALLS

There is no one standard or common measure for an individual's postural stability or balance. Consequently, in Tai Chi studies relating to balance or falls, a variety of balance measures were used. They included self-report; functional measures such as double- or single-leg stance, walking, or abilities to perform activities of daily living (ADLs); laboratory-based balance measures such as platform stability tests; and direct measures of falls such as risk of fall occurrence and fear of falling. Each of these measures has a different sensitivity to balance. Thus, studies using different measures may report different results.

Self-Report

One of the earliest studies that documented the effect of Tai Chi on balance is a single-case study by Koh in 1982.²¹ The author suffered severe ankylosis spondylitis and started practicing Tai Chi as an alternative treatment. After two and half years of practice, the author noticed significant improvement in pain, weakness, and general malaise. Furthermore, the author noticed improvement in limb coordination and balance, among other aspects.

In a longitudinal study at the Atlanta Frailty and Injuries: Cooperative Studies of Intervention Techniques (FICSIT) site, Kutner et al. conducted an exit interview with three groups of older people who participated in Tai Chi, balance training, or no training for 15 weeks. All the groups had a 4-month follow-up.³⁰ In the interview, questions regarding perceived benefits on overall health were asked. Although no questions were asked about balance, it was noted in the report that 54% of the subjects in the Tai Chi group attributed their improved sense of confidence to improved balance. They felt "less likely to lose balance" when their balance was disturbed and felt "more secure in movement."

Functional Measures

Single-Leg Stance

The amount of time a person can maintain single-leg stance has been shown to correlate strongly with falls. Gehlson et al. compared older fallers and nonfallers and found that older people who did not sustain a fall over a 1-year period could maintain a single-leg stance for a longer time.³⁷ In addition, Brown et al. correlated single-leg stance time with number of falls in older people and found a very high correlation (correlation coefficient = 0.93).³⁸ Consequently, single-leg stance has been widely used in the Tai Chi-related studies (see Tables 1 through 3).

Six Tai Chi studies, two cross-sectional,^{22,23} three longitudinal,^{27,33,35} and one follow-up,³⁶ evaluated the effect of Tai Chi using single-leg stance measures. The overall findings suggest that participating in Tai Chi on a regular basis improves the ability to stand on one leg. However, it seems that the degree of the benefit depends on the practice frequency or duration and health status of the participating subjects.

Both cross-sectional studies reported in favor of long-term Tai Chi practice for improving the ability to stand on one leg. However, there is a discrepancy regarding whether the improvement is with eyes open or eyes closed. In the earlier study by Tse et al.,²² the authors examined a group of long-term (1–20 years) Tai Chi practitioners and a group of age-matched nonpractitioners. All subjects were aged 65 and older. They measured the single-leg stance time with eyes open and closed. It was found that Tai Chi practitioners were able to stand significantly longer only with eyes open. It was reasoned that this is because maintenance of balance with vision excluded is not a usual life experience. However, this finding is challenged by a more recent cross-sectional study by Hong et al.,²³ which found a significant difference between Tai Chi practitioners and nonpractitioners in single-leg stance time with eyes closed. This discrepancy could be because the subjects in the study of Hong et al. had a minimum of 10 years of Tai Chi experience, whereas the subjects in Tse's study had a minimum of 1 year of Tai Chi experience.

This time dependency is also seen in the longitudinal studies. Schaller²⁷ compared a group of older people who participated in a 10-week Tai Chi practice (once a week in class and three times a week self practice) with another age-matched control group. The author measured single-leg stance time with eyes open and closed and found that Tai Chi participants improved more than 50%, whereas the control group decreased by 2%. This significant change was only with eyes open.

Alternatively, Ross et al. conducted a similar study, but with only 8 weeks of training (three times a week).³³ They found no significant improvement, although with a positive trend, in single-leg stance time. Similarly, Hartman et al.³⁵ found no significant changes after a 12-week training period (two times a week). The total number of practice sessions in these two studies is far less than that in Schaller's study (24 vs 40). Furthermore, the study by Hartman et al. used older people with osteoarthritis, whereas others all used healthy individuals. The physical condition and pain in the osteoarthritis population might have prevented them from performing better in the physical function tasks.

One additional piece of evidence to support the time dependency effect is based on a follow-up study by Wolfson et al.³⁶ In this study, healthy older people first participated in four different training programs designed for improving balance and strength for 3 months and then continued with a Tai Chi maintenance program for 24 weeks (once a week). At the end of the maintenance program, no significant change in single-leg stance time was found in three of four groups. For the group that had a significant change, a negative change was found.

In summary, single-leg stance time has shown improvement with Tai Chi practice only in some studies. The improvement is most evident with eyes open and after sufficient practice time (≥ 40 times). The single-leg stance time with eyes closed has shown significant improvement only with very long-term practice (at least 10 years).

Romberg Stance

Romberg stance has been used as a standard test for balance, especially for people with vestibular impairment. To

date, only one study, by Hain et al.,³⁴ has evaluated subjects' Romberg stance score before and after an 8-week (daily) Tai Chi exercise program. It was found that the Romberg score was significantly improved for subjects in the young (aged 20–60) and old-old (aged ≥ 75) groups, but not in the old group (aged 61–75). It is premature to generalize this result, because only a limited number of subjects was tested (see Table 1).

Walking

Walking velocity has been shown to decrease with age and to be associated with balance and falls.³⁹ Five Tai Chi studies, one cross-sectional,²² three longitudinal,^{26,33,35} and one follow-up,³⁶ evaluated walking-related parameters. These parameters included distance, time, velocity, and number of steps. These studies also included two walking styles: normal walking and tandem walking (stepping over a straight line).

Of these studies, the cross-sectional study by Tse et al.²² is the only one that showed a significant benefit of Tai Chi on walking. In this study, subjects were asked to perform a tandem walk with eyes open. The number of steps was recorded and reported. It was found that Tai Chi practitioners were able to walk significantly more steps than nonpractitioners, especially women.

Interestingly, no other study reported significant benefit, although some reported positive changes. Ross et al.³³ examined the change in tandem walk after an 8-week Tai Chi program. Subjects were asked to walk on a narrowly marked line for 60 seconds or 15 steps. The length of time the subject was walking on the line was measured and reported. Although this measure was found improved, it did not reach statistical significance.

Using older people with osteoarthritis, Hartman et al.³⁵ compared the times of a Tai Chi and a control group to complete a 50-meter walk. After 12 weeks of training, it was found that the Tai Chi group had a trend of small to moderate increase, whereas the control group had a trend of moderate decrease. However, again, changes were not statistically significant.

In the follow-up study by Wolfson et al.,³⁶ the usual velocity to walk 8 meters was compared before and after a 24-week Tai Chi maintenance program. For subjects in three of four groups, the velocity was not significantly changed. The only significant improvement was found in subjects who underwent a combined balance and strengthening exercise program before the Tai Chi program. It was noted by the authors that this change might be due to the decrease in gait velocity in this group after the first phase of the program.

Wolf et al. reported the most negative results in their FICSIT study.²⁶ The authors measured the distance walked over a 12-minute period. It was found that subjects who participated in a 15-week Tai Chi program showed a trend of slight decrease, although not statistically significant, when compared with the baseline.

Overall, these study results suggest that walking-related measurements might not be sensitive enough to evaluate the effect of Tai Chi on balance. This is especially true if the time of practice is not sufficient and the walking condition is not challenging enough. For example, the above four studies that did not report significant changes had to-

tal Tai Chi practice time of 30 sessions or less, whereas the study by Tse et al. was a cross-sectional study with at least 1 year of practice. In addition, most of these studies used normal walking, rather than tandem walking, which is more difficult to perform.

Instrumental Activities of Daily Living

The ability to perform ADLs is related to balance and potential falls in older people.^{40,41} Only one study on Tai Chi has used this measure as an evaluation tool.²⁶ In particular, the authors used the instrumental activities of daily living (IADL) scale by Lawton and Brody.⁴² The study reported insignificant changes after participating in a 15-week Tai Chi program. However, it is premature to conclude that Tai Chi practice does not help improve ability to perform ADLs. This negative finding may be due to short or infrequent periods of practice or to the sensitivity of the IADL scale.

Medical Outcomes Study Short Form

The Medical Outcomes Study Short Form (MOS SF-36)⁴³ is a subjective assessment of functional limitation of ADLs. It is a reliable and well-validated generic health status measure.⁴⁴ Three longitudinal studies on Tai Chi used this measure.

Overall, the results from these studies are inconsistent. In the study by Hain et al., a group of subjects with self-perceived mild balance disorders participated in an 8-week daily Tai Chi practice.³⁴ At the end of the 8th week, the MOS SF-36 score for all subjects was significantly improved. However, after dividing the subjects into three age groups (young, old, and old-old), it was found that the improvement was most significant in the young and old groups (aged < 75).

In contrast, two earlier studies by Schaller and by Kutner et al. showed negative findings. In Schaller's study, a 10-week (once a week plus three times per week of self practice) Tai Chi program was provided to a group of healthy older people. Schaller mentioned that there was a lack of improvement on the MOS SF-36 subscales at the end of the program.²⁷ Similarly, in the study by Kutner et al.,³⁰ a 15-week (twice a week) Tai Chi program, a computerized balance training program, and no training was provided to healthy older people. The subjects assessed the MOS SF-36 questionnaire once before and once after the 15-week program and after 4 months. No statistically significant differences were found on the MOS SF-36 subscores among the three groups or over time.

The negative results found in these two earlier studies may be partly due to the short length or low frequency of Tai Chi practice. Compared with the study by Hain et al., these two studies had less practice (30 or 40 times vs 56 times). In addition, the negative results may be related to the type of subject population used. As indicated by both author groups, the MOS SF-36 scores for the subjects were relatively high, reflecting a generally healthy status. It might be difficult to detect improvements in those subjects already in good health. In contrast, the subjects in Hain's study had relatively moderate scores, thus leaving room for improvement.

In summary, there is modest evidence to support that Tai Chi practice helps improve general health and physical

functioning as assessed by the MOS SF-36, but the improvement is significant only with sufficient amount of practice and in those subjects who may have some functional limitations.

Laboratory-Based Balance Measures

Postural Platform Measures

Postural platforms have been commonly used to assess postural stability. They usually consist of one or two biomechanical force plates. With subjects standing on them, the footplate contact force is measured. This can then be used to compute various variables such as displacement of center of pressure, center of gravity, body sway, and functional base of support. Five studies, one cross-sectional,²⁴ three longitudinal,^{28,32,34} and one follow-up,³⁶ evaluated the effectiveness of Tai Chi on balance using these measures.

The testing conditions used for the postural platform measurement in these studies are similar to those of the sensory organization test by Nashner.⁴⁵ Briefly, they included quiet stance with or without eyes open, with or without change in the visual field, and with or without change in supporting base position or a combination of these.

Overall, the study findings are not consistent. In the study by Hain et al., the effect of an 8-week (daily) Tai Chi exercise was evaluated in three age groups of healthy adults (<60, 61–75, and ≥ 76 years). The authors reported the composite score only. Nevertheless, the results indicated a significant improvement in the younger and the older groups after the 8-week training, but not in the 61- to 75-year age group.

Lin et al.²⁴ conducted a cross-sectional study that included subjects between the ages of 66 and 74. In this study, the results from the postural platform testing were reported by testing conditions. It was found that, although there were no significant differences between Tai Chi practitioners (2–35 years of experience) and nonpractitioners in four out of six test conditions (quiet stance with and without eyes open, sway-referenced vision with fixed support, and sway-referenced support with eyes open), the Tai Chi group did significantly better in the two most difficult sensory organization conditions (sway-referenced support with eyes closed and sway-referenced vision and support).

Shih³² measured the velocity of center of pressure during static and dynamic stance and compared this between pre- and post-Tai Chi exercise (16 weeks, three times a week). Subjects were healthy young adults (aged 20–43). It was found that the center of pressure velocity was not significantly changed after the exercise program during quiet stance condition but was significantly reduced during the dynamic stance condition. Similarly, Forrest⁴⁶ measured the center of pressure displacement while standing on an unstable support surface that was disturbed by a self-dropping load. The author compared the results before and after 16-weeks of Tai Chi training of a group of healthy young subjects. It was found that the center of pressure displacements in anterior/posterior and lateral directions were significantly reduced after the Tai Chi training.

One study that showed negative results is by Wolfson et al.³⁶ After a 6-month weekly Tai Chi maintenance pro-

gram, all subjects (aged ≥ 75) were reevaluated using the sensory organization test.⁴⁵ Only two parameters, loss of balance and static base of support, were reported. It was found, in all subjects, that the loss of balance was not significantly changed, but the base of support was significantly reduced, indicating a decreased postural stability.

Another study by Wolf et al.²⁸ also showed negative results. In this study, the authors examined the center of pressure displacement in the medial-lateral and anterior-posterior directions and the total dispersion during stance with and without vision and with and without toes-up tilt of the supporting base. After a 15-week (twice a week) Tai Chi program, no significant differences were found, compared with pretraining, in any of the parameters or in any testing conditions for those subjects who participated in Tai Chi training.

An examination of the above studies seems to suggest that the discrepancies may be due to time of practice and complexity of testing. For the two studies that showed negative results,^{28,36} the exercise frequency (<30 sessions) is far less than that in other studies (≥ 50 sessions).^{24,32,34} In addition, even with sufficient amount of practice, the testing conditions that present more-challenging environments (such as dynamic vs static and disturbance of two sensory systems vs only one) seem more likely to show significant changes.

Lateral Stability

Jacobson et al.²⁹ compared the lateral stability of two healthy older groups who participated in a 12-week Tai Chi program or no exercise program. Subjects were asked to stand on a laterally tilting board and to keep the board horizontal for 1 minute. The instability (i.e., the time that the subject was unable to keep the board within 10° of horizontal) was recorded and reported. The authors reported significant differences between the two groups after the training. However, the authors did not provide detailed numerical data and did not mention whether the differences were positive or negative.

Direct Measures of Falls

To date, there is only one study that examined directly the effect of Tai Chi exercise on actual reduction of falls. A longitudinal study by Wolf et al.,²⁶ as part of the Atlanta FICSIT study, examined the rate of fall occurrence in three groups of older subjects: those who participated in a 15-week Tai Chi programs, a 15-week computerized balance training program, and no training (or control). All subjects were independent and ambulatory, but 42% of the subjects in the Tai Chi group and 31% to 34% of the subjects in the other groups had fallen in the previous year. In this study, the actual number of falls was recorded in each group over a period of 164 to 171 days. Fifty-six, 76, and 77 falls were reported in the Tai Chi, balance training, and control groups, respectively. Using the Anderson et al. extension of the Cox proportional hazards model,⁴⁷ the risk ratio for falls was calculated. It was found that those who participated in Tai Chi had a reduction of 48% in the risk of falls, whereas others did not have a significant reduction in the risk of falls.

Fear of falling is an indicator of low perceived self-efficacy at avoiding falls during essential, nonhazardous

ADLs.⁴⁸ To date, two studies have reported the effect of Tai Chi exercise on fear of falling. In the same FICSIT study at the Atlantic site, Wolf et al.²⁶ found that the change in the fear of falling scores after 15 weeks of Tai Chi exercise was significantly different from that of the control group, suggesting a reduction in fear of falling for the Tai Chi participants. Later, in a similar study by Wolf et al.,²⁸ it was reported that the frequency of fear of falling in the Tai Chi group was reduced from 56% to 31% (with a *P*-value of .08) after 15 weeks of exercise, whereas it was unchanged in the balance training group and increased in the control group.

Overall, based on the existing studies, it seems that practicing Tai Chi, for as short a time as 15 weeks, has a positive effect on reduction of risk and fear of falling.

EFFECT OF AGE

Degradation of balance is proven to correlate with increasing age. Therefore, it is critical to evaluate the effectiveness of Tai Chi against a matched control group. All of the studies reviewed in the paper noted the ages of the participants, and most of the studies included age-matched control group(s) (see Tables 1 through 3).

Although the effectiveness of Tai Chi on balance has been evaluated primarily within the older population, aged 61 and older, a few studies used younger subjects, aged 20 to 45.^{29,31,32} These studies all have positive findings. For example, Jacobson et al.²⁹ examined, among others, lateral body stability and kinesthetic sense at the shoulder joint. After 12 weeks of training, subjects in the Tai Chi group showed a significantly higher accuracy in kinesthetic sense at 60° glenohumeral rotation than the control group and a significant improvement in lateral stability compared with the control group. Shih³² measured the static and dynamic body sway velocity and found that the dynamic sway velocity became significantly lower after 16 weeks of Tai Chi training. Forest³¹ measured the anticipatory postural adjustment during various voluntary tasks and found that, after 16 weeks of Tai Chi practice, subjects showed counterintuitive reductions in the activity of several postural muscles but with decreased displacement of center of pressure under the feet (indicating an improved postural stability). Overall, these studies suggested that Tai Chi practice benefits postural stability even in younger subjects.

People at various ages may respond differently to the same exercise protocol. How do people at different age ranges respond to Tai Chi exercises? One study by Hain et al.³⁴ compared subjects in three age ranges: 20 to 60, 61 to 75, and 76 and older. The results seem to suggest an age dependency on the outcome effects. By the posturography score and Romberg stance score, for example, those subjects in the 61 to 75 age range showed less (or statistically insignificant) improvement, whereas subjects in the younger and older groups showed more (or significant) improvements. However, by the MOS score, the oldest subjects showed no significant improvement compared with younger subjects, who all showed significant improvement. Nevertheless, the same Tai Chi exercise protocol seems to benefit the youngest subject group the most. This may be due to the age-related declines in older people in their ability to respond to exercise and in other physical health aspects

such as weaker muscle strength and slower reaction time. This suggests that maybe Tai Chi exercise for older subjects should be different (such as of increased duration or frequency) than for younger subjects if a similar amount of benefit is desired.

EFFECT OF GENDER

The ability to maintain balance and to prevent falls is different between women and men. Studies have shown that women have worse balance than men and that their balance is less likely to improve with exercise interventions.⁴⁹ One of the reasons for this difference could be that men are stronger and have more practice with risk taking.²²

Is there a difference between men and women in their responses to Tai Chi exercises? Most Tai Chi studies did not examine gender difference in the results. In fact, in most of these studies, women subjects were dominant (as high as 92%), except for the one study by Hong et al.,²³ which used all male subjects.

Tse et al. conducted one study that compared across gender.²² In this study, the authors included three women and six men in each of the two groups (long-term Tai Chi practitioner and nonpractitioner) and measured single-leg stance time and tandem walking time. It was found that practitioners of both genders were able to walk or stand on one leg with eyes open significantly longer than nonpractitioners. There was no significant difference in single-leg stance with eyes closed between women practitioners and nonpractitioners, but there were significant differences between men in these groups. This somewhat demonstrated that the effect of Tai Chi on balance could be gender dependent. It should be noted that this study used a very limited number of subjects, especially female subjects. Generalization of these results should be done with caution.

EFFECT OF HEALTH STATUS

It has been shown that people with decreased physical function or general health are more likely to have poor balance and increased risks of falls and fall-related injuries.^{40,41,50,51} Does Tai Chi exercise benefit this at-risk population more than the otherwise not-at-risk population?

Currently available studies are limited in addressing this question. Most of the studies used “healthy” subjects. The word “healthy” is defined as having satisfactory health with no major health problems such as cardiopulmonary, neurological, musculoskeletal, and other chronic diseases that would affect mobility. Subjects in all of the studies were community-dwelling, ambulatory individuals.

Having a history of falls in the past has been identified as one of the risk factors for future falls. Two groups of Tai Chi studies used this as an inclusion/exclusion criterion. In the study by Lin et al.,²⁴ subjects were excluded if they had fallen in the past 12 months. In contrast, in the Atlanta FICSIT studies,^{26,28} subjects were not excluded if they had fallen in the past year. It turned out that 25% to 63% of the subjects had previous falls. Unfortunately, a direct comparison between the groups in these three studies on the benefit of Tai Chi on balance is not appropriate, because the first is a cross-sectional study and the others are longitudinal.

Only one of the studies used subjects who had had a mild balance disorder for 3 months.³⁴ However, the disorder

der was only self-perceived, and no further information was provided about how the balance disorder was defined and how valid the self-perception was. Nevertheless, comparing the results from this study with the ones that used healthy subjects of similar age range (such as in the study by Schaller,²⁷ Ross et al.,³³ and Hartman et al.³⁵), it seems that people with mild balance problems would be more likely to show significant improvement in balance measures after participating in Tai Chi exercise.

VARIATION IN TAI CHI EXERCISE

Tai Chi is practiced in many styles, such as Yang, Wu, or Tai Chi Chih. Each style has its own emphasis and movements. Based on subjective observations, it has been speculated that the style of Tai Chi may affect selected balance outcomes. For example, Yang style demands constant knee flexion, wide stance width, and a steady slow speed. The shifting of body weight during deep wide stance demands strength and flexibility of lower leg muscles. Therefore, Yang style may be a good exercise for strengthening leg muscles. Alternatively, Wu style has higher stances, narrower stance width, and a slower pace. Because the stance is less stable than in Yang style, Wu style may be a better exercise for improving balance. In contrast, Tai Chi Chih has shallow stances with no complete transfer of body weight.⁵² Therefore, it may require less balance and strength than the other styles.

Unfortunately, in Tai Chi studies relating to falls or balance, the most popular style used is the Yang style.^{23,26,28–30,32,35} Others either did not mention the specific type of Tai Chi style used^{21,22,24,46,53} or used others, such as Tai Chi Chih,²⁷ a combined style,³⁴ or “Tai Chi-like movements.”²⁵ Because of the inconsistencies between these studies (in terms of the measurement and the length of exercise), a conclusion cannot be made regarding whether the style of Tai Chi would affect improvement in balance.

Tai Chi is also practiced in different lengths (or forms). For example, Yang style has at least three lengths that are commonly practiced: the traditional form that includes 108 movements, the simplified form with 24 movements (or Beijing form), or the simplified basic form with nine or 10 movements. The traditional Wu style has 100 movements, but most people practice shorter forms of 24 to 36 movements. Tai Chi Chih has one form of 20 movements. Usually, experienced practitioners practice a long form, such as traditional Yang or Wu style, and beginners practice short forms, such as simplified Yang or Wu style or Tai Chi Chih.

Of the seven studies that used the Yang style, two used the long form,^{23,29} one used the simplified form,³² and four used the simplified basic form.^{26,28,30,35} A comparison of these studies seems to suggest that longer forms affected selected balance measures more significantly than shorter forms, although the shortest form did significantly reduce fall risks and fear of falling. It should be noted that the studies that used longer forms^{29,32} involved younger subjects and more practice sessions than the other studies.

EFFECT OF DURATION OF TAI CHI EXERCISE

The mastery of Tai Chi practice takes time. Farrell et al. believe that it takes at least a year of three times a week of

practice to “learn” Tai Chi,⁵⁴ but many of the longitudinal studies were short, ranging from 8 to 16 weeks. During those weeks, subjects practiced Tai Chi between once and three times per week in a class setting. Two studies required additional home practice time, ranging from three times per week²⁷ to daily.³⁴ From the earlier analyses, it is clear that the number of practice sessions makes a difference in the effectiveness of Tai Chi on certain balance measures. In general, although it seems that 40 or more practice sessions is a good number to start showing significant improvements in most of the balance measures, it is important to point out that Wolf et al. showed a significant reduction in the risk of falls after only 30 sessions.²⁶

COMPARISON WITH OTHER INTERVENTIONS

Most of the studies on the effect of Tai Chi on balance used a control group. A few study reports based on the Atlanta FICSIT study used a third group with a particular type of balance training intervention.^{18,26,28,30} In 1995, Province performed a meta-analysis of FICSIT studies on interventions aimed at preventing falls in older people.²⁰ This meta-analysis included seven sites and an array of intervention exercises (such as endurance, resistance, flexibility, balance, and combinations of these). Only the Atlanta site had Tai Chi as one of the interventions. The results indicated that Tai Chi has the lowest incidence ratio (IR), with a significant decrease in the risk of falling (IR = 0.63, $P = .01$) of all treatments. One other treatment that showed a significant decrease in fall risks is the individualized treatment (IR = 0.79, $P = .03$), which included a combination of resistance, balance, and flexibility exercises. For other treatments, nonsignificant changes in fall risks were found.

CONCLUSIONS AND IMPLICATIONS FOR FUTURE RESEARCH

Currently, the existing literature provides only scattered evidence to support the positive effect of Tai Chi on postural balance and fall prevention. Because of wide variations in the use of subject population, type, and duration of Tai Chi exercise and choice of balance measures between the limited number of studies, the reports on the outcomes are inconsistent, leaving many questions unanswered. It is suggested that future studies focus on testing subjects who have balance disorders or who are at risk for falls, comparing subjects of various age spans, identifying the optimal duration or frequency of Tai Chi programs, and searching for the optimal style or movements for balance and fall prevention. In addition, studies should choose consistent and sensitive balance tests. In particular, a direct measure of the number of falls should be included, because improving balance may not directly relate to a reduction in falls.

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