The efficacy of Tai Chi Chuan in physical rehabilitation: a literature review

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The Efficacy of Tai Chi Chuan in Physical Rehabilitation: A Review of the Literature

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The Efficacy of Tai Chi Chuan in Physical Rehabilitation: A Literature Review

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Introduction

The number of older adults is steadily increasing, and many older adults continue to remain active and care for themselves. However, differences exist in older adults' ability to perform activities of daily living. One of the challenges faced by people with advancing age is decreased postural stability and increased risks for falls. Recent studies suggest that impaired balance and decreased lower extremity strength, which are universal in the geriatric population, are important risk factors in the occurrence of falls in the geriatric population. Falls may result in head trauma, fractures, and even death. 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 the geriatric population than in younger populations (Wu et al., 2002). The potential trauma as a result of these falls is more costly than the introduction of preventive approaches, and one of these interventions is the use of Tai Chi Chuan. Regular practice of this form of exercise by the well and the impaired geriatric population produces important benefits, including a reduced risk of 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 have been inconsistent. There is a wide variation in the use of balance measures, subject population, type and duration of Tai Chi exercise, and type of study. Despite the increased number of studies in recent years relating Tai Chi to balance, strength, and fall prevention, results are scattered and inconsistent. The goal of this review is to address the following concerns: what factors effect falls in the geriatric
population, and what level of evidence exists supporting Tai Chi as an effective exercise for preventing falls and fall related factors. Can a Tai Chi training regimen be a significant intervention for preventing falls and fall related injuries in the geriatric population?

**Description of Tai Chi Chuan**

Tai Chi is a martial arts exercise consisting of systematic strength and conditioning exercises that are low velocity and low impact motions that demand precise joint movement, stability, and balance. Performing Tai Chi can include double stance weight-bearing or single stance weight-bearing maneuvers, which further require the pivoting of the whole body or the twisting of the trunk. In performing Tai Chi, which emphasizes positive control throughout dynamic movements, the roles of the muscles continually change between those of stabilizers and movers, weight-bearers and non-weight-bearers, and between contraction and relaxation. It has been suggested (Van Deusen, J., & Harlowe, D. 1987) that the practice of Tai Chi may increase the repertoire of motor programs stored in the brain, and therefore serve to train the various balance systems to promote greater steadiness. Tai Chi is a Chinese conditioning exercise, and recent studies substantiate its benefits in physiological responses to include cardiovascular, cardiopulmonary, strength, and balance characteristics (Van Deusen & Harlowe 1987, Lai et al. 1993, Lai et al. 1995, Lan et al. 1996, Schaller 1996, Wolfson et al. 1996, Jacobson et al. 1997, Lan et al. 1998, Yan J. H. 1998, Hain et al. 1999, Lan et al. 1999, Hong et al. 2000, Lan et al. 2000, J X Li et al. 2001, Wang et al. 2001).
Methods

The literature search process began with the collection of previously published research from Medline 1953-1965, 1966- Present, 1999- Present; Cinahl 1982-Present; and from internet resources: center for Tai Chi Chuan studies, archives of physical medicine and rehabilitation, and pub med. Four-hundred-twenty-seven articles (136 Tai Chi; 291 supporting) were found from 1947-2004, with all encompassing research topics such as the history of Tai Chi, technique of Tai chi, balance, strength, aerobic capacity, flexibility, fall related factors, and fall prevention. The article elimination process focused on primary Tai Chi research in the past ten years, focused research to participants greater than 55 years old in the experimental group and the control group either age matched or younger to the experimental group, and focused research subjects to strength and balance, resulting in 93 articles (34 Tai Chi; 59 supporting) from 1995-2004 that were evaluated. Supporting articles consisted of research topics involving trunk and lower extremity strength and balance reactions in relation to lower extremity pathology. The articles presented in this text were chosen by the depth and variation of the measures and variables researched, analyzed, and discussed throughout the respective publications.

Cardiovascular and Cardiopulmonary Characteristics

Aging is associated with a decline in aerobic capacity and vascular responsiveness to exercise. Decreased VO$_2$ max in the geriatric population can be attributed to decreased cardiac output and, to a lesser extent, arterio-venous oxygen differences (Wang J-S, Lan C, Wong M-K., 2001). The decrease in cardiac output and decreased arterio-venous oxygen difference, which appears to result from a less efficient redistribution of blood flow rather than a deficiency in oxygen extraction, is universal in the geriatric population.
While the decrease in cardiac output is secondary to the age associated decline in physiologic function, the change of blood flow is most likely caused by an alteration in the relation between local vasodilator and vasoconstrictor mechanisms. Endurance training could partially reverse the age-related decline in aerobic power secondary to decreased VO\textsubscript{2} max and decreased arterio-venous oxygen difference. From the perspective of oxygen transport, the increase of aerobic capacity after exercise training may be attributed to the increase of cardiac output and peripheral blood flow (Wang J-S, Lan C, Wong M-K., 2001).

Previous studies (Lai et al., 1993, Lai et al., 1995, Lan et al., 1996, Lan et al., 1998, Lan et al., 1999, Hong et al., 2000, Lan et al., 2001, Wang et al., 2001) have shown that physical conditioning and exercise training can enhance vascular responsiveness and increase the levels of plasma nitric oxide metabolite at rest and after exercise (nitric oxide is an endothelial-dependent vasodilator that has an important role in the regulation of vascular tone and contributes to vasodilatation response during exercise). Although nitric oxide has only a modest role in exercise hyperemia, active cutaneous vasodilatation requires functional nitric oxide bioactivity to achieve full expression (Wang et al., 2001).

During exercise, as core temperature rises, skin blood flow increases to facilitate the convective transfer of heat from core to skin. The decrease with aging in thermoregulatory response to heat stress can be life threatening to the elderly, due to the fact that skin components tend to diminish in size and number with age and the structural changes in cutaneous vasculature limit vasodilatation. However, exercise training can partially reverse the age-related decline of microcirculation through enhancement of nitric oxide release. Therefore, older individuals that participate in physical conditioning
and exercise training can show a greater increase in sweating and skin blood flow than older sedentary individuals (Wang J-S, Lan C, Wong M-K., 2001).

Studies conducted by Wang and colleagues have reported that Tai Chi benefited the aerobic capacity of older individuals, and long-term Tai Chi training can significantly increase their VO$_2$ max through increased vasodilator and vasoconstrictor mechanisms. A study conducted by Wang, Lan, and Wong (Wang J-S, Lan C, Wong M-K., 2001) compared cutaneous microcirculatory responsiveness to acute exercise in elderly Tai Chi practitioners and sedentary individuals, and measured the subjects' plasma nitric oxide metabolites to explore the potential enhancing effect of Tai Chi Chuan training on the release of nitric oxide.

The objective of this case-control study involving 10 elderly male Tai Chi practitioners (mean age, 69.9 ± 1.5 yr) and 10 sedentary men with matched age and body size (mean age, 67.0 ± 1.0yr) was to evaluate cutaneous microcirculatory function in geriatric Tai Chi practitioners. The Tai Chi group had practiced Tai Chi for 11.2 ± 3.4 years with an exercise frequency of 5.1 ± 1.8 times weekly. Each session included 20 minutes of warm-up, 24 minutes of Tai Chi practice, and 10 minutes of cool down. Skin blood flow, cutaneous vascular conductance, and skin temperature were measured at rest and during exercise testing, while plasma nitric oxide metabolite was analyzed before and immediately after exercise. A graded exercise test with blood-gas analysis was conducted on a bicycle ergonometer for each subject for a pre-training baseline measurement and for post-training improvements. The significant findings include:
i. That strenuous exercise increased the level of plasma nitrite plus nitrate in both groups, and levels of plasma nitrite plus nitrate correlated positively with skin blood flow, cutaneous vascular conductance, and skin temperature in both groups.

ii. The Tai Chi group had higher levels of plasma nitrite plus nitrate than the sedentary group at rest and immediately after exercise.

iii. Tai Chi practitioners demonstrated higher skin blood flow, cutaneous vascular conductance, and skin temperature during exercise than did the sedentary subjects, and the results indicated that Tai Chi men had higher peripheral blood flow and heat dissipation during exercise.

iv. During the exercise test, the Tai Chi group had significantly higher skin blood flow than the sedentary group at the same percentage of VO\textsubscript{2} max, and also had higher cutaneous vascular conductance and skin temperature than the sedentary group at the same relative workload.

v. The resting HR, systolic and diastolic blood pressures, and MAP did not differ significantly between the Tai Chi and the sedentary group, although during peak exercise the Tai Chi group was 34% higher in VO\textsubscript{2} max than the control group.

vi. The Tai Chi group had higher peak oxygen pulse, work rate, and VE than the sedentary group.

vii. At the same relative percentage of VO\textsubscript{2} max, the Tai Chi group showed similar work rate, HR, and MAP. However, oxygen pulse was higher in the Tai Chi group than in the sedentary group for the same relative exercise intensity.

Lai et al. obtained similar findings during a two-year longitudinal study, which examined trends of cardio-pulmonary function among older Tai Chi practitioners and
sedentary subjects. Practitioners practiced Tai Chi five times a week, and each session included 20 minutes of warm up, 24 minutes of Tai Chi training, and 10 minutes of cool down. The VO$_2$ max in each subject was measured in the initial exercise test and two years later to determine the rate of decline of cardio-pulmonary function. In the Tai Chi group, there was a 2.8% decrease in VO$_2$ max in men and a 2.9% decrease in women. In contrast, the VO$_2$ max of the control group declined by 6.6% in men and 7.4% in women, showing that the regular practice of Tai Chi may delay the decline in cardio-respiratory function in older adults. (Lai et al., 1993, Lai et al., 1995, Lan et al., 1996, Lan et al., 1998, Lan et al., 1999, Hong et al., 2000, Lan et al., 2001, Wang et al., 2001)

Li, Hong, and Chan conducted a review of 31 controlled experimental studies and clinical trials designed to assess physiological responses during the performance of Tai Chi or to assess the impact of this exercise on general health and fitness. The main outcome measures of this review, which included a total of 2216 men and women, were metabolic rate, heart rate, blood pressure, ventilation, maximal oxygen uptake (VO$_2$ max), and falls. This review concluded that evidence provided by cross sectional and longitudinal studies suggests that Tai Chi exercise has beneficial effects on cardiovascular, cardiopulmonary, strength, and balance characteristics and the reduction of falls experienced by the elderly. This review found that the practicing of Tai Chi with lower center of gravity position techniques required significantly more energy than practicing Tai Chi with higher center of gravity position techniques. The conclusion reported Tai Chi is a moderate intensity exercise that is beneficial to cardiovascular, cardiopulmonary, strength, and balance characteristics; it improves muscle strength and reduces the risk of falls in the elderly. Thus, Tai Chi endurance training could partially

**Balance, Muscle Strength, and Posture Control**

Preventative care for the elderly has received increased attention because of the rapid increase in the elderly population and the high medical expenses associated with aging. Falls are a major cause of morbidity, hospitalization, and mortality among older people, and approximately 30% of those over 65 years of age sustain a fall, with about half having multiple events. About 10% to 15% of falls result in serious injuries and in soft tissue injuries. Many studies show that impaired balance and decreased lower extremity strength are important risk factors in the loss of physical functioning and the occurrence of falls in older adults (Wong AM, Lin Y-C, Chou S-W, Tang F-T, Wong P-Y 2001).

Recent studies have shown that supervised exercise for the elderly should emphasize aerobic, strength, flexibility, and balance training. However, vigorous high intensity, high impact exercises (these exercise techniques require advanced degrees of balance, eccentric/concentric muscle contractions, and muscular/aerobic endurance) are not suited for the majority of the geriatric population because of the significant decline in physical function associated with natural aging. Joint degeneration, impaired balance, decreased lower extremity strength, and decreased VO$_2$ max are universal in the geriatric population (Wong AM, Lin Y-C, Chou S-W, Tang F-T, Wong P-Y 2001). Therefore, dynamic coordination training regimens consisting of low velocity and low impact movements that
emphasize balance and lower extremity strength are preferred for the majority of older individuals.

The contribution of vision to balance control has been well documented. Proper integration of the information from somatosensory, vestibular, and visual receptors is necessary to generate appropriate balance responses. However, with aging, there is a decrease in visual acuity, restriction of the visual field, and decreased depth perception. As a result, an older person’s use of visual information for balance control could be diminished, thus increasing the reliance on the somatosensory and vestibular system.

The practice of Tai Chi requires constant shifting between double-stance and single-stance, a requirement that constantly challenges the somatosensory and vestibular system to maintain the subject’s center of mass within the base of support. These controlled and dynamic movements may stimulate the somatosensory and vestibular systems, and repeated stimulation over time may facilitate balance control. Tai Chi movements and vestibular rehabilitation are similar in the manner that each regimen begins with simple and stable postures/movements and then gradually progress to more difficult movements by decreasing the base of support, changing the head or arm position, manipulating sensory cues, and moving from static to dynamic activities.

The objective of a cross-sectional study, conducted by Tsang (Tsang et al., 2004), was to evaluate the long-term effects of Tai Chi practice on balance control when elderly Tai Chi practitioners, as compared with the young and elderly non-Tai Chi practicing subjects, stood under reduced or conflicting somatosensory, visual, and vestibular conditions.
The subjects of this study included twenty Tai Chi practitioners (10 men, 10 women; mean age 70.7±5.1y, practicing Tai Chi 3 hours a week for more than 1 year, mean Tai Chi experience, 7.2 y), 20 elderly non-Tai Chi practitioners (8 men, 12 women; mean age 67.8±4.5y, no experience with Tai Chi), and 20 young university students. Exclusion criteria were the presence of symptomatic cardiovascular diseases at a moderate exertion level, poorly controlled hypertension or symptomatic orthostatic hypotension, a stroke diagnosis, Parkinson’s disease, peripheral neuropathy of the lower extremities, crippling arthritis, and a history of falls in the past 12 months.

The sensory organization test (studies conducted by Ho 1997, Wallmann 2001, Girardi 2001 have shown that the sensory organization test can differentiate between elderly fallers from non-fallers) was conducted to assess the balance control of the elderly subjects under different somatosensory, visual, and vestibular conditions. Subjects stood without shoes on the support platform, while wearing a security harness to prevent falls. They were instructed to stand quietly with their arms at their sides with their eyes looking forward. During the sensory organization test, subjects were exposed to 6 combinations of visual and support surface conditions. Each subject underwent 3 consecutive trials for each of the 6 conditions, and the amplitude of antero-posterior body sway was measured using computerized dynamic posturography. The significant findings include:

I. The Tai Chi practitioners had significantly better balance control than the non-Tai Chi subjects.

II. The non-Tai Chi practitioners exhibited more sway and attained statistically significantly lower sensory organization test scores than did the young subjects.
III. There were no significant differences in any of the 6 sensory combinations when the Tai Chi practitioners were compared with those of the young non-Tai Chi subjects.

IV. The elderly Tai Chi practitioners achieved the same level of balance performance as the young healthy subjects.

These results agree with previous findings (Schaller 1996, Wolfson et al., 1996, Jacobson et al., Hain et al., 1999, Hong et al., 2000, Wong et al., 2001, Wayne et al., 2004) that older subjects sway significantly more than young subjects when sensory inputs are reduced and/or distorted. However, the results of this study suggest that practicing Tai Chi improves the control of stance under reduced or conflicting sensory conditions in an elderly population, and that practicing Tai Chi has enabled the elderly subjects to achieve performance in balance control similar to that of the young control subjects. Elderly Tai Chi practitioners showed better balance performance under reduced sensory inputs than non-Tai Chi practitioners who were similar in age and gender. An important finding is that practicing Tai Chi for 7 years enabled the elderly subjects to achieve a level of balance performance comparable to that of young healthy subjects under this experimental design.

It has been extensively researched and proven that muscle atrophy, thus relating to a decrease in strength, is a physiologic response associated with aging (Lan et al., 2000, Li et al., 2001, Wu et al., 2002). In particular, type II fiber distribution and size are more affected than type I fibers by aging (Lan et al., 2000, Li et al., 2001, Wu et al., 2002). When biopsies taken from the vastus lateralis muscle in a group of sedentary geriatric subjects was compared with those from a group of younger subjects, the geriatric subjects
had twice as many type I muscle fibers as the young subjects, suggesting that geriatric individuals have fewer type II fibers than younger individuals. The age-related changes in type II fiber size and distribution in skeletal muscles are related to the decline in muscle power output, eccentric force, and level of physical function in the geriatric population. It may be that the age-related changes, which are decreased with proper exercise, in type II fiber size and distribution are also related to decreased postural stability (due to the muscle fiber contraction speed directly influenced by the myosin ATPase located at the cellular level) and increased incidence of falls in the geriatric population. Eccentric muscle force not only decreases with age but also is closely related to the atrophy of type II muscle fibers and to overall physical performance (Tsang et al., 2004).

In a cross-sectional study examining strength (concentric, eccentric) and muscular endurance of the lower extremities, Wu et al. (2002) compared isokinetic strength of leg muscles and foot center of pressure as a measure of sway between 20 long-term Tai Chi practitioners and 19 non-Tai Chi subjects. The subjects (age >55 yr) in the Tai Chi group had practiced Tai Chi on a regular basis at least 1 hour per day, 3 days a week, for a minimum of 3 years. The subjects (age >55 yr) in the control group had no previous Tai Chi experience, however, all of subjects were physically active in a regular exercise routine.

The center of pressure displacement in both antero-posterior and medio-lateral directions was first collected during quiet stance in order to attain postural stability measurements. Subjects were asked to stand on a biomechanical force plate with heels 10cm apart and toes 10° out with eyes either open or closed. When the eyes were open,
subjects were asked to look at a target in front of them. For each visual condition, subjects were instructed to stand as stable as possible for 30 seconds. A total of 5 trials were repeated for each visual condition, with at least a 1-minute break between each trial.

Each subject was then tested for isokinetic muscle strength in 2 muscle groups: knee extensors (quadriceps) and knee flexors (hamstrings) of the right limb. The measure of strength was peak torque as indicated by an isokinetic force dynamometer. Each subject was first stabilized in a testing seat by means of straps at the chest, waist, thigh, and the ankle. During testing, 3 continuous repetitions of concentric or eccentric strength were taken at each speed through the full range of motion. The concentric strength was measured at 60°/s, and eccentric strength at 60° and 120°/s. To minimize the effects of muscle fatigue, the sequence of measurements was randomized, and the subjects were given at least a 2-minute rest period between tests or as much time they needed. The significant findings of this study include:

I. Subjects with long-term Tai Chi practice had increased knee extensor strength and decreased foot center of pressure excursions during quiet stance than people without Tai Chi practice.

II. The results suggest that the increased eccentric strength of the knee extensors is associated with a reduction in the foot center of pressure displacement in both antero-posterior and medio-lateral directions.

III. Increased eccentric knee extensor strength results in reduced center of pressure displacement during quiet stance.

The results of this study suggest that subjects that had practiced Tai Chi on a regular basis at least 1 hour per day, 3 days a week, for a minimum of 3 years demonstrated
increased concentric and eccentric strength of the lower extremities and reduced foot center of pressure displacement during quiet stance, thus confirming a positive correlation concentric and eccentric strength of the lower extremities. The findings of this study support the hypothesis that the maintenance of concentric and eccentric strength of postural muscles in the lower extremities, which is beneficial for maintaining good postural stability, is helped through the long-term practice of Tai Chi.

A before and after study, conducted by Lan (Lan et al.2000) evaluated the training effect of a Tai Chi training program on knee extensor strength and endurance in forty one elderly individuals. Subject exclusion criteria included angina pectoris, history of myocardial infarction or stroke, chronic obstructive pulmonary disease, uncontrolled diabetes and hypertension, osteoarthritis of hip or knee, neuromuscular disease, and other major diseases. All subjects were community dwelling and led a normal lifestyle, capable of daily activities without limitations. In addition, subjects had not engaged in any strength training program or regular aerobic exercises (exceeding two times weekly) for at least 1 year.

Forty-one subjects (15 men and 17 women) aged 61.1 ± 9.8 years participated in a 6-month Tai Chi training program every day for the duration of the study. Each session consisted of 20 minutes of warm-up, 24 minutes of structured Tai Chi training, and 10 minutes of cool-down exercises. Tai Chi was practiced in a semi-squat position and integrated movements involving multiple joints in a rotational pattern were performed. In this position, the height of posture could be easily adjusted to control the weight bearing on lower extremities. All subjects used a high-squat posture because it was suitable for beginners or elderly individuals.
The pre-training and post-training measurements were taken, using a Cybex 6000 isokinetic dynamometer, for the peak torque of dominant and non-dominant knee extensors at speeds of 60°, 180°, and 240°/sec concentrically and eccentrically, muscular endurance of the knee extensor tested at the speed of 180°/sec. Following a warm-up phase, the subject sat with 90° of hip flexion and was stabilized at the chest, waist, and thigh with a strap, and a shin strap was secured to the lower leg above the malleoli. Each test consisted of three concentric and eccentric exercises for knee extensor at 60°, 180°, and 240°/sec in sequence. Subjects were instructed to extend the knee as far as possible to produce a maximum contraction, and to maintain maximal contraction during the eccentric phase. Each set of exercise consisted of five maximal extension cycles. All subjects were allowed a 2-minute rest period between tests on the same joint, as well as a 5-minute rest period between tests on each side, and the three most identical curves among the five trials were used for analysis. Examinations were performed before training and 6 months after training to measure the changes of concentric and eccentric muscle strength. The significant findings include:

i. After 6 months, Tai Chi training was effective for enhancing quadriceps strength and subjects showed strength increases ranging from 13.5% to 21.8% during concentric contractions

ii. After 6 months, Tai Chi Chuan training was effective for enhancing quadriceps strength and subjects showed strength increases ranging from 15.1% to 23.8% in eccentric contractions

iii. After 6 months, Tai Chi Chuan training was effective for enhancing knee extensor endurance by 9.6% to 18.8%
Muscular strength is important for daily activities. However, maximal muscular strength gradually declines after 50 years of age, and it declines at an increased rate in the lower body than in the upper body. Declines of lower body strength are a superior problem than declines of upper body strength due to the increased risk of falling. In addition, strength during concentric contractions declines to a greater extent than strength during eccentric contractions. Therefore, strength training that emphasizes the lower body eccentric strength is important in an exercise program for the elderly. Studies involving knee extensor training programs (Wolfson et al. 1996, Jacobson et al. 1997, Wolf et al. 1997, Li et al. 2001, Wu et al. 2002, Christou et al. 2003, Tsang et al. 2004) have reported a 3% to 21% increase in isokinetic strength. In low-to-moderate resistance training programs, 3 to 10 months of training has reportedly increased isokinetic strength by 3% to 9%. In high-resistance training programs, a greater improvement of 10% to 18% in strength has been reported. The results of these studies concluded that Tai Chi training will increase concentric and eccentric strength and endurance of lower extremity musculature, decreasing the center of pressure excursions, and thus possibly reducing the probability of falls.
Conclusion

Evidence accumulated from previous cross-sectional and longitudinal studies indicate that Tai Chi can significantly increase lower extremity extensor strength, decrease foot COP excursions, and improved posture control during dynamic motion, which can contribute to the prevention of falls. Therefore, a Tai Chi training regimen consisting of low velocity and low impact exercises emphasizing balance and lower extremity strength should be among the recommended exercise programs for the geriatric population. The significant clinical relevance of this literature review is that the strength and balance achievements from the practice of Tai Chi fundamentals can be a practical, functional, and effective method to increase strength and balance across diverse patient diagnoses and co-morbidities.
References


34) http://www.chentaiji.com/research/