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Impact of Tai Chi Chu'an Practice on Balance and Mobility in Older Adults: An Integrative Review of 20 Years of Research

Madeleine E. Hackney, PhD^{1,2,3}; Steven L. Wolf, PT, PhD, FAPTA, FAHA^{1,3,4}

ABSTRACT

Falls in older adults, which often result from decreased balance and mobility, are an important public health issue. The American College of Sports Medicine recommends multidimensional balance and mobility training to prevent falls. In the past 20 years, Tai Chi Chu'an (tai chi) has been found to be effective in improving balance, reducing falls and fear of falling for older adults. Efficient use of time devoted to exercise is critical; therefore, more research is needed into the underlying mechanisms of balance and mobility improvements in older adults as a result of tai chi practice, so that these interventions can be most targeted and efficient. The purpose of this integrative review is twofold. First, evidence is presented to show that balance and mobility have been improved by tai chi in older adults. Second, potential mechanisms of balance improvement from research conducted in longtime tai chi practitioners, and from clinical research conducted in older adults, are offered. A PubMed search with the terms "tai chi" and "balance" entered simultaneously was conducted. Articles were included if they were systematic reviews, pilot or clinical trials, related to both balance and tai chi, and/or specifically related to determining the mechanisms potentially underlying tai chi's effects. The systematic reviews and meta-analyses show that aspects of tai chi research findings remain equivocal. In spite of the inconclusiveness of these

review findings, many researchers have considered tai chi worthy of further investigation. Furthermore, practitioners in the clinic and those who deliver exercise in the community have evidently embraced tai chi as an appropriate exercise for older adults. This review, spanning 2 decades, suggests that tai chi has impacted the health and health behaviors of many older adults. Going forward, informing novel balance and mobility rehabilitation by uncovering mechanisms of tai chi's effects definitively may be the most important area of discovery in this field.

Key Words: exercise, falls, mechanisms, older adults, tai chi

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INTRODUCTION

One third of community-dwelling older persons fall annually.¹ Fully one fifth of fall incidents require medical attention, burdening a stretched-thin health care system.² The growth of the older adult population and the absence of effective fall prevention interventions are factors contributing to the fall-related economic burden. Reduction of fall risk is essential to reduce morbidity and mortality associated with aging.

Improvements in Balance and Mobility May Reduce the Risk of Falls in Older Adults

Problems with gait and balance are among the most common factors contributing to falls.³ Changes in joint range of motion, strength, sensory processing, and sensorimotor integration contribute to reduced balance stability and more cautious gait with increasing age, decreasing the ability to move adaptively in complex environments.⁴ Balance is essential for older adults to perform activities of daily living safely and remain independent within the community.⁵ Therefore, interventions designed to improve mobility and balance are necessary.

Habitual participation in physical activity, even begun late in life, improves postural control in older individuals.⁶ Research has led to specific recommendations for mobility training to improve balance.⁷⁻⁹ Exercise programs that (1) incorporate the practice of dynamic balance and (2) involve motor adaptation according to task and environmental demands¹⁰ can rehabilitate balance impairment.

¹Atlanta Veterans Affairs Rehabilitation Research and Development Center of Excellence for Visual and Neurocognitive Rehabilitation, Atlanta, Georgia.

²Birmingham-Atlanta VA Geriatric Research, Education and Clinical Center, Decatur, Georgia.

³Department of Medicine, Division of General Medicine and Geriatrics, Emory University School of Medicine, Atlanta, Georgia.

⁴Department of Rehabilitation, Emory University School of Medicine, Atlanta, Georgia.

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Address correspondence to: Madeleine E. Hackney, PhD, Division of General Medicine and Geriatrics, Emory University School of Medicine, Research Health Scientist, Rehab R&D Center (151R), Atlanta VA Medical Center, 1670 Clairmont Rd., Decatur, GA 30033 (mehackn@emory.edu, madeleine.hackney@gmail.com).

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One form of balance and mobility exercise, which has gained considerable attention in the past 20 years, is Tai Chi Chu'an (tai chi), an ancient Chinese exercise form involving strong mental engagement and the practice of slow, sustained movements. Foci of tai chi training are vertical control of the trunk, step position and strategies, flexibility, whole body coordination, somatosensory awareness, and attention to internal as well as external coordinates in space. Tai chi involves bilateral, multidirectional movements, performed with flexed joints in a slow, smooth, and continuous rhythmical flow. Practitioners typically attend to accuracy of multijoint trajectories, and maintain a vertical head and trunk position during weight transfer and single limb support. They also maintain continuous balance of the center of mass (COM) while adopting multiple configurations of the base of support (BOS). Finally, practitioners try to achieve accurate positioning of the legs and feet as per the particular "form" (a series of movements) involved. Frequent and dedicated practice of these movement forms has led to enhanced dynamic stability and improved motor control in experienced tai chi practitioners.¹¹

Purpose and Methods of This Integrative Review

The purpose of this integrative review, a synthesis of the findings of selected studies, is twofold. First, evidence, which shows tai chi improves balance and mobility in older adults, is presented. Anchoring the past 20 years' findings, reviews of tai chi balance studies are included to offer periodic summaries, which are somewhat equivocal about tai chi's ability to reduce falls. However, the sheer number and variety of studies support tai chi's larger impact upon mobility/rehabilitation research, the clinic, and the community. Second, potential mechanisms of balance improvement from research conducted in longtime tai chi practitioners and from clinical research conducted in older adults are offered. This section of the article demonstrates how tai chi potentially impacts various aspects of function and the myriad of ways through which such understanding may improve mobility rehabilitation for older adults as well as those with other comorbidities. The article concludes with a presentation of negative studies and summarizing remarks, with respect to the value and impact of tai chi for physical therapy.

The following methods were used for this integrative review: a PubMed search was conducted using the terms "tai chi" and "balance", simultaneously, by the first author. Two hundred twenty-eight search entries resulted, and were reviewed for appropriateness and inclusion in the article. Abstracts concerning tai chi and balance-related systematic reviews and meta-analyses, randomized controlled trials (RCTs), and smaller pilot trials that concerned an older adult population, and/or specifically related to determining mechanisms of tai chi's effects, were included. One hundred forty-three search entries were deemed to be nonrelevant for the following reasons: too young participants, narrative reviews, peripheral mention/involvement of tai chi, concept/

perspective pieces, method articles, articles for which no abstract was available, and content targeting a specific diagnostic group.

To ensure that as many relevant articles were included as possible, a second search with the terms "tai chi" and "mobility" entered simultaneously was performed. Forty-three entries were brought up; however, all were either duplicates with the previous search or did not fulfill the inclusion criteria.

As early as in 1993, tai chi began to be evaluated for its ability to reduce frailty in older adults,¹² with results of a seminal study appearing in 1996,¹³ demonstrating that tai chi was effective in reducing fall incidence.² After this 1996 article, which has been cited more than 900 times and has received accolades,¹⁴ several articles have described the beneficial effects of tai chi on balance and mobility in older adults,¹⁵ which are discussed here.

EVIDENCE FROM CLINICAL RESEARCH IN OLDER ADULTS

Early studies examined the effects of tai chi in varying doses in community-dwelling older adults. These studies revealed the following: (1) tai chi was safe, enjoyable, and could improve balance,¹⁶ (2) when practiced just 1 time per week tai chi could enhance improvements gained from traditional strength and balance training,¹⁷ and (3) anxiety and pain perception improved.¹⁸ Mental as well as physical function enhancement was clear, given the added benefit of improved well-being and motivation to exercise.¹⁹ A larger RCT, the Atlanta Frailty and Injuries: Cooperative Studies on Intervention Techniques (FICSIT) demonstrated that tai chi delayed the onset of first or multiple falls in older individuals, while promoting confidence in movement.²⁰

Randomized controlled trials have since been conducted in several different countries, including Taiwan, Vietnam, Australia, New Zealand, Korea, China, Japan, and the United States, demonstrating the international impact of this novel field of research. Consistently, these RCTs have confirmed improvements in at least 1 and often several of the following outcomes: falls rates, falls efficacy and balance, quality of life, mental status, and cognition.²¹⁻²⁷ Smaller trials have continued to be conducted, which is indicative of the popularity of tai chi for investigation. These trials have demonstrated similar improvements in functional fitness, and balance using single leg stance, functional reach, and tests of muscle strength.^{28,29} In a community-based program outside stringent laboratory conditions, comparable benefits to flexibility and strength corroborated tai chi's effectiveness for community-dwelling older adults.³⁰ Because many tai chi balance studies were conducted throughout the late nineties and into the 21st century, it is helpful to consider the assessments of reviews, which have anchored findings of particular periods.

Reviews of Tai Chi's Effects on Balance in Older Adults

In a 2002 review, Wu³¹ covered the first 10 years of tai chi research, including the benefits upon one leg stance time after longtime practice, fall risk, and fear of falling. However, Wu³¹ asserted that research investigating the response on postural platforms—measuring the use of visual, vestibular, and somatosensory systems—was inconclusive and inconsistent among studies. His criticisms included extensive variation in the postural stability and balance measures used, differing doses, and styles of tai chi between studies. Furthermore, benefits were age dependent; that is, young subjects (younger than 45 years) seemed to benefit more than older subjects, and 40 or more sessions seemed necessary to affect balance. Examining the studies collectively, definitive conclusions were challenging to make at that time, because studies were not standardized in terms of measurements, treatment dosage, participant age, or style of tai chi.

Three reviews were published in 2004, and had mixed findings. Wang et al³² concluded that tai chi had physiological/psychological benefits, and could promote balance control and flexibility in older adults with chronic conditions. However, the authors also concluded that limitations existed in most studies and stressed the need for studies investigating the theoretical bases for the benefits of tai chi.³² A systematic Cochrane review, including 7 studies, found limited evidence that tai chi was effective in reducing falls in individuals older than 50 years.³³ A third, more positive review including 24 studies found generally supportive evidence that tai chi had beneficial effects on balance and postural impairments associated with aging. The authors further concluded that there was sufficient evidence that tai chi could reduce fall risk, or impact factors associated with postural control, supported by improved performance of activities of daily living, reduced fear of falling, and enhanced well-being.³⁴ Regardless of the conclusions, all 3 reviews supported more research into tai chi's effects and mechanisms and echoed the criticisms of Wu³¹ regarding consistency of measures and equivalency of dosages and teaching forms.

Recent review of current literature indicated support of improved balance³⁵ and reduced fear of falling.³⁶ Findings from a meta-analysis have allowed the authors to assert that tai chi is beneficial for increasing balance confidence in older adults (in this case, those older than 60 years or more).¹⁵ Lee and Ernst concluded in a recent review has found that tai chi is effective for fall prevention and improving psychological health for older people but not for certain comorbidities.³⁷ Therefore, given the currently available systematic reviews and meta-analyses of the data, quantitative findings remain quite inconclusive about tai chi's ability to prevent falls, citing research methodology as a primary reason for this uncertainty.³⁸ Thus, it follows that current recommendations corroborate that of Wu,

from 2002: further subgroup analyses to examine the effects in people with different physical characteristics,³⁵ using more consistent balance outcome measures across studies, extending postintervention follow-ups, and examining different styles of tai chi more closely.³⁹

Reviews may find aspects of tai chi research findings equivocal; however, in practice, the research and clinical communities have evidently embraced tai chi's beneficial effects on balance in older adults. This perspective is exemplified in that tai chi has begun to be used as the “standard of care,” against which novel experimental interventions are compared. For example, tai chi was recently employed as the control for a video balance board program, which was found to be as effective as tai chi in improving performance on dynamic posturography.⁴⁰ Tai chi has also been used as a control for a swimming intervention.⁴¹ This trend may continue throughout the early 21st century.

Frail Older Adults

After positive effects of tai chi in community-dwelling older adults were revealed, investigators began recruiting individuals with greater impairment, beginning with transitionally frail and frail older adults, for whom tai chi led to significantly reduced fear of falling.⁴² Similar gains to those in stronger older adults were seen in 49 frail older adults (older than 60 years), who after participating in an intensive 8-week tai chi group, improved in one leg stance and trunk flexion, and had a reduced fear of falling in comparison to an age-matched control group, who continued their usual exercise routines.⁴³

Older adults in long-term care facilities could also benefit from tai chi exercise. Single leg balance and forward trunk flexion improvements were noted in a long-term care facility in Japan.⁴⁴ Grip strength and lower body flexibility improved after participation in a simplified version of tai chi, adapted for the needs of frail older individuals in long-term care.⁴⁵ In older residents of a residential care facility, Sun-style tai chi improved knee and ankle flexor/extensor muscle strength and flexibility and helped participants feel more confidence in fall avoidance mobility than age-matched controls.⁴⁶ Another, less positive, study showed that declines in functional balance were only attenuated, and falls rates were not significantly reduced.⁴⁷ However, an RCT comparing tai chi to conventional physical therapy (n = 152) showed evidence that tai chi was the more effective of the 2 therapies in protecting against falls in older adults in long-term care.⁴⁸

New Frontiers in Tai Chi Research for Special Populations

Early studies of tai chi in older adults have had a major impact on interventional research among many populations facing aging-related disease (ie, stroke, Parkinson's disease, osteopenia, rheumatoid disease, and vestibular impairments among others). Similar to findings for older adults, tai chi

seems promising as a feasible complementary therapeutic option for exercise for individuals with greater functional limitations. The fact that tai chi's efficacy has been investigated for such diverse groups of individuals demonstrates tai chi's impact on science, on clinical recommendations, and on community-based exercise options for older individuals with impairments as well as for healthier older adults. Some of the newest areas of study include the investigation of tai chi's effect on pregnant women,⁴⁹ cancer survivors,⁵⁰ end-stage renal disease,⁵¹ schizophrenia,⁵² older adults with heart disease risk factors,⁵³ and older adults with low vision.⁵⁴ From the findings of these studies, mechanisms and methods by which to finesse tai chi regimens for particular populations with specific symptomatology will be revealed. Understanding these mechanisms will allow researchers and clinicians to develop and hone treatments, which will best rehabilitate and/or maintain function in older adults. Such mechanistic inquiry has already begun in longtime tai chi practitioners and in older adults who participated for the first time in tai chi of various durations.

Mechanisms of Balance Improvement: Learning from Expert Tai Chi Practitioners

Evidence regarding tai chi kinematics and kinetics among individuals who have spent many years engaged in tai chi practice may shed light on mechanisms behind postural control improvements noted in older adults. Static and dynamic balance, proprioception, neuromuscular function and strength of older, long-term tai chi practitioners may be enhanced compared with age-matched controls. These beneficial effects were determined through clinical tests of static balance, computerized posturography, and electromyography (EMG), among other methods.

Gait employed during tai chi differs from normative gait in key ways

An early study demonstrated that biomechanical characteristics of tai chi gait could be quantified.⁵⁵ The kinematics and the EMG of lower limb muscles of tai chi gait and normal gait were measured with motion analysis and force plates. General characteristics of tai chi gait in comparison to normative gait were longer single limb stance time, larger ankle and knee flexion, hip flexion and abduction, larger lateral body shift, and involvement of ankle dorsiflexor, knee extensor/hip flexor, and hip abductor muscles.

Plantar pressure distribution may impact dynamic balance during locomotion dramatically. Therefore, plantar pressure distribution during stance phase of the gait cycle during single limb support, while performing tai chi, was examined in 16 experienced tai chi practitioners in comparison to normal walking. The duration spent on single limb support during tai chi was less, and the loading of the first metatarsal head and great toe was noted to be significantly greater than in other regions of the foot, in

comparison to normal walking. Furthermore, in tai chi, the center of pressure (COP) was more medial and lateral than during normative walking.⁵⁶ These characteristics may be associated with an improved ability to balance on a single limb because increased contact in multiple directions of the plantar area of the foot may lead to enhanced somatosensory information.

Tai chi training may be gentle on the body, which is especially important for older, less fit populations. A study of plantar pressure during a tai chi partnered, contact exercise—called “push-hands” in which 2 individuals stand in double support with flexed knees, and alternately exert forces, and yield resistance toward each other through the upper limbs—demonstrated that tai chi practitioners' toes sustained the greatest plantar force. Furthermore, the maximum vertical ground reaction force never exceeded 88% of body weight. In short, the push-hands exercises generate lower vertical forces than those induced by walking, bouncing, and jumping.⁵⁷ Lower vertical forces indicate that tai chi training creates the generation of lesser impulses on the lower limbs, trunk, and joints.

Enhanced function as a result of tai chi practice

Tai chi practice may favorably affect the ability to respond to reduced or conflicting sensory situations. Tsang et al⁵⁸ demonstrated that older tai chi practitioners (mean experience, 7.2 ± 7 years) exhibited equivalent balance control as young subjects when standing under reduced and conflicting somatosensory, visual, and vestibular conditions.^{58,59} Even after vigorous stimulation of the horizontal semicircular canals (whole head/body rotation at 80 degrees for 1 minute), older tai chi practitioners had better anteroposterior standing balance control than age-matched older controls, which may represent enhanced ability to respond appropriately to vestibular information.⁶⁰ Computerized posturography of 31 older tai chi practitioners, who had practiced tai chi 5 times per week for 4 years or more, revealed significantly better balance in sway-referenced support (inducing somatosensory conflict) than age-matched controls.⁶¹

Tai chi may improve overall sensorimotor control of balance in older adults.⁵⁹ During perturbed limb stance, long-term older tai chi practitioners ($n = 24$; age, 69 ± 5 years) had less body sway and greater balance confidence than age-matched controls.^{59,62} Tai chi practitioners demonstrated quicker reaction time in initiating voluntary weight shifting than controls, greater limits of stability and smoother control of the trajectory when leaning their COM to their maximal limit of stability,^{59,63} a finding that has been replicated in other tai chi practitioners.⁶⁴

Enhanced proprioception is offered as a potential mechanism underlying restored/improved balance control in older adults, because of increased sensation in the movement in ankles and other joints, which likely provides more accurate spatial position information.

Older tai chi practitioners demonstrated enhanced knee proprioceptive activity relative to age-matched controls in passive knee repositioning.^{59,63} In a related finding, better proprioception in the ankle and knee joints was noted in 21 older adult tai chi practitioners in comparison with swimmers, runners, and controls.⁶⁵ Furthermore, long-term tai chi practitioners showed, in conjunction with superior knee proprioception, enhanced balance on a tilt board in comparison with groups with little to no tai chi experience.⁶⁶

Those who practice tai chi have also outperformed age-matched controls on more complex and challenging mobility tasks. For example, 24 tai chi practitioners (mean age, 69 years) had better ability to perform a single leg jump and more stability in landing on a single limb. This ability was highly correlated with limits of stability measures of movement velocity, endpoint, and maximum excursions.⁶⁴ Furthermore, less postural sway was observed in the tai chi group than in control groups under eyes open, eyes closed, while eyes were both open, and eyes closed while the head was turning left and right, indicating that there were positive effects of long-term practice of tai chi on balance under challenging conditions.⁶⁷ Fifteen experienced tai chi practitioners (age range, 23-66 years) demonstrated a wider BOS in recovery after stepping over an obstacle, and made substantial anticipatory adjustments before crossing the obstacle.⁶⁸ Such ability to adapt and respond appropriately to challenging environmental situations may be developed and practiced from the discipline of tai chi.

Heart rate variability (HRV) likely affects postural control as well, because HRV is considered to reflect the activity of the autonomic nervous system, noted to decline through aging. However, physical activity can improve autonomic function.⁶⁹ Thus, tai chi practitioners have also been examined for state spectral HRV and changes in HRV measures, compared with controls. The short-term effect of tai chi enhanced vagal modulation, decreasing sympathetic modulation, HRV, and systolic and diastolic blood pressure in older adults.⁷⁰ A related RCT has found that this effect may also translate into improved cardiovascular variables, in that body mass index, systolic blood pressure, and resting heart rate decreased in older adults who incorporated tai chi into their routine on a long-term (48 weeks), habitual basis.⁷¹ Although not extensively researched, this finding, if pursued further, could reveal important aspects of function underlying enhanced postural control, given that postural position alone has great effects upon HRV.⁷²

In summary, extended tai chi practice may enhance the accuracy of joint positioning and encourage smooth transfer of weight, with coordination of the neck, trunk, and upper and lower limbs, which may facilitate the enhanced postural control noted in these older tai chi practitioners. Practicing tai chi may also improve sensorimotor responses, particularly in challenging situations. Furthermore, tai chi

may challenge older adults' balance and muscles more than exercises using more normative gait: enhanced knee flexor and extensor muscle strength in older tai chi practitioners has been observed in comparison with age-matched controls.^{59,62} Furthermore, older adults who practiced tai chi had larger knee and hip flexion, longer duration and higher magnitude of the EMG recordings from tibialis anterior, rectus femoris, and tensor fascia latae muscles, and longer coactivation of many leg muscle pairs.⁷³ Habitual practice of tai chi postures and the careful weight transitions may transfer into performing functional activities in daily life. While performing tai chi, it is notable that movement from pattern to pattern is slow, but changes of direction are frequent and quick. In theory, these aspects of tai chi posture and movement, when practiced, may encourage balance-enhancing strategies in daily life, seen in older tai chi practitioners as well as older participants in the clinical studies discussed earlier.

Mechanistic Studies in Tai Chi: Hypothesis Testing

Movement studies

To elucidate mechanisms of recovered and/or enhanced postural control function, investigators have examined the kinematics, kinetics, EMG, Hoffmann (H-) reflexes, and functional mobility of participants who practiced tai chi, either de novo or long term. Those with exposure to tai chi practice may have smoother coordination of gait initiation,⁷⁴ better forward momentum generation because of greater plantar flexor power and lessened hip power,⁷⁵ improved use of vestibular input and the ability to adopt wider stances,⁷⁶ more accurate proprioception,⁶⁵ smoother coordination of the COP during stance,⁷⁷ and faster muscle contraction latencies.⁶⁶

Hass et al⁷⁴ hypothesized that the sometimes-noted reduction of falls in individuals who have participated in tai chi resulted from exercise-induced adaptation in the postural control systems. To test this hypothesis, Hass and colleagues studied the COP trajectory of gait initiation, which may represent the response of the central nervous system during postural adjustments. Gait initiation is challenging for the motor system because of the transition from a static stable condition with a large BOS to a dynamic unstable posture in locomotion with a small BOS. Compromised ability to generate sufficient momentum during gait initiation may cause older adults to fall. However, Hass and colleagues⁷⁴ showed that tai chi improved the generation of forward momentum in older adults who participated in 48 weeks of tai chi, by increasing the posterior displacement of the COP during heel strike and improved coordination during gait initiation, as exhibited by a smoother COP trace.

Plantar flexor power, which contributes to forward propulsion in gait, may be decreased in older adults who instead compensate with hip power.⁷⁸ Thus, the question

was asked whether tai chi would decrease hip mechanical energy expenditure (MEE) and increase ankle plantar flexor MEE. Improvements were noted on spatiotemporal measures, MEE and kinematics, in older adults who underwent vestibular rehabilitation or tai chi. The tai chi group's improvement demonstrates potentially reorganized lower extremity neuromuscular patterns, which promoted faster gait and reduced excessive hip compensation. These 2 motor outcomes may indicate a restoration to normative gait.⁷⁵

A salient effect upon neuromuscular activation in the supporting leg during dynamic stance may elucidate tai chi's mechanism for the sometimes-noted improved outcomes after slips and/or trips in older adults. Intensive tai chi (1.5 hours per day, 5 days per week for 3 weeks) resulted in reduced tibialis anterior response time and cocontraction of the antagonist muscle in response to perturbation. These improvements were corroborated with clinical balance measures.⁷⁹ In this same group, to investigate mechanisms controlling stepping strategies of the swing leg, kinematics, COP, and COM responses were measured. Importantly, the COM anteroposterior path increased after tai chi, suggesting improved ability to tolerate unsteadiness,⁸⁰ another mechanism by which tai chi may enhance balance in older adults.

Other studies investigating neuromuscular mechanism have concerned the H-reflex, the summation of afferent neural inputs converging on a target alpha motor neuron pool during a given motor task. The H-reflex can be investigated for change as a result of intervention to investigate spinal plasticity in relation to motor learning. Adaptations noted in the H-reflex could be attributed to neural mechanism at the spinal cord, which is likely related to supraspinal influence. After 12 weeks of tai chi training in 20 older adults, the H-reflex modulation of the soleus was upregulated in 4 sensory tasks (eyes open, eyes closed, eyes open unstable surface, and eyes closed unstable surface), though curiously, performance on balance tasks did not improve.⁸¹ The investigators concluded that facilitating the soleus H-reflex could be a result of functional adaptation increasing postural reflexes for postural control.

Cognitive components

Substantial data provide evidence of an important cognitive component related to postural control, gait, and fall incidence.^{82,83} Thus, it is unsurprising that recently cognitive effects in conjunction with training in tai chi have been explored. Tai chi may have a beneficial effect on cognition in older adults,⁸⁴ which can be maintained for 12 months.⁸⁵ Mobility needed in cognitive dual-tasking may also be enhanced by tai chi practice. When asked to step as fast as possible in forward and backward directions, with a cognitive dual-task, 10 older (older than 55 years or more) tai chi practitioners had shorter preparation and foot contact time and wider backward step width than

age-matched controls. Therefore, tai chi practitioners may be better prepared in situations of postural recovery from potential falls, even during mental distraction, than those who have not practiced tai chi.⁸⁶ In contrast, an investigation into tai chi's effect on the ability to allocate attention to balance under dual-task conditions revealed that tai chi did not support this benefit in 15 older adults, naive to tai chi, who practiced 30 hours over 12 weeks.⁸⁷ Hence, tai chi practice over several years may be necessary for enhancing the ability to divide attention during motor tasks.

The role of psychosocial aspects in effective rehabilitation is also a timely area for discovery. In comparison with conventional physiotherapy offered in a geriatric hospital day program, analyses demonstrated that tai chi had positive effects on fall prevention (observed 1 year after the interventional period) because of increased general self-efficacy, rather than from improved balance, gait, and fear of falling.⁸⁸ Likely more studies related to such constructs will reveal the impact on facets of psychological and mental health as a result of tai chi participation.

NEGATIVE STUDIES

This review has presented evidence, which supports tai chi's benefits on motor aspects of function, with salient exceptions^{47,81,87} and has cited reviews, which summarized important limitations to findings.^{31-33,38} In addition, several RCTs found differential effects of tai chi treatment.

In a large, controlled study, older participants with impaired balance improved more from 10 weeks of combined balance and step training consisting of fast and dynamic exercises ($n = 106$) than from tai chi ($n = 106$).⁸⁹ This negative finding illustrates the concept that faster and varied speeds of movement, perhaps a shortcoming in tai chi, could be important factors in acquiring better balance on a single limb. An RCT undertaken in Hong Kong included 180 participants aged 65 to 74 years who participated in tai chi, resistance exercise or untreated control. The results of this RCT showed no differences in balance, flexibility, or the number of falls between the 3 groups.⁹⁰ This study, which had high compliance, demonstrated only modest beneficial effects of tai chi on musculoskeletal health. Older individuals ($n = 269$) either participated in 1 hour 2 times per week for 13 weeks of tai chi or received usual care. The primary outcome, which was the number of falls over 12 months, was not different from control, and there were no significant intervention effects on the secondary outcome measures. The authors concluded that tai chi may not be effective in community-dwelling older people with high risk of falling.⁹¹ This finding speaks to intensity and the need for tailoring of any rehabilitative exercise program toward the population of interest.

Although these studies were conducted according to rigorous standards, extenuating factors may have led to dissension from other studies, which have demonstrated

tai chi's positive effect on balance and fall incidence. These factors could include tai chi instructional methods, motivation to exercise, and status of participants, among many others. As mentioned earlier, these same factors are also responsible for the inability of meta-analyses to draw firm conclusions about tai chi's effectiveness in reducing fall rates (and related adverse motor outcomes) in older adults, a problem that is not applicable to tai chi exclusively, but to rehabilitation research in general.

CONCLUSIONS

This review of studies spanning 2 decades supports the idea that tai chi has had substantial impact on health and health behaviors of many older adults. The promising early studies have spurred research into healthful effects of tai chi for other populations facing aging-related diseases, which have included Parkinson's disease and stroke, among others.

Multimodal interventions such as tai chi involving gait, balance, coordination, functional exercises, and muscle strengthening seem to have the greatest impact on balance in older adults. Furthermore, tai chi not only may be effective in improving balance but may also prove economical because tai chi group classes are generally inexpensive to administer.^{92,93} However, in spite of abundant evidence for physical benefits and cost containment when administering tai chi to improve balance and mobility in older adults, and although a surprisingly low level of participation will exert beneficial effects, exercise participation remains overwhelmingly poor in older adults. A study involving more than 5000 participants recently demonstrated that only 1 in 8 older adults engaged in strength or balance-challenging activities.⁹⁴ Adherence to an exercise regimen is critical, and research to encourage and facilitate participation by older adults must continue. Meeting in small, close-knit groups, less frequently and for shorter periods, may enhance adherence for older adults.⁹⁵ Therefore, effective interventions must be targeted and efficient to ensure that senior adults at risk for falls participate.

Rehabilitation to restore and/or improve mobility in older adults must be efficient as well as effective. Thus, identifying aspects of tai chi, which are most responsible for benefits, will be important for adherence to exercise, and for honing foundational principles of physical therapy targeting balance and mobility. Although mechanistic studies have begun to distinguish fundamental aspects of tai chi posture, gait, mechanics, and motor control contributing to benefits of the eastern art form, considerably more research is necessary. Going forward, uncovering mechanisms in definitive fashion may be the most important area of discovery in this field. The knowledge and principles gained will impact not only tai chi disciplines but also physical therapy for older adults, in general. Tai chi is a healthy exercise that targets postural control, which is an essential aspect of function for maintained independence. Improving

adherence and retention rates through creative means in a growing older adult population may be our biggest challenge.

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