ABSTRACT

THE EFFICACY OF A 12-WEEK TAI CHI INTERVENTION FOR IMPROVING GAIT VELOCITY AND REDUCING FALL RISK IN COMMUNITY-DWELLING OLDER ADULTS: A PILOT STUDY

Purpose: Falls are a significant health concern for older adults in the United States due to their prevalence, mortality risk, and cost. Tai Chi has been commonly studied for its effect on improving function and reducing the incidence of falls in older adults. The purpose of this study was to determine the effect of a community-based Tai Chi class on fall risk.

Methods: Eight participants who were at risk for falls were recruited for this study. Subjects participated in a 50-minute, 1 time per week Tai Chi group exercise class for a duration of 12-weeks. The class was taught by a certified Tai Chi instructor and incorporated various movements to improve strength and balance. Objective measures included preferred and maximum gait velocity.

Results: Five participants completed the study and were available for follow-up. A one-tailed, paired t-test was used for within group repeated measures and revealed a significant improvement in maximum ($p=0.008$) but not preferred ($p=0.057$) gait velocity.

Conclusions: The overall effect of our study cannot be expanded to the general population due to the small sample size. Older adults who participated in the study were able to demonstrate a significant improvement in maximum gait velocity. Further research is needed to determine the true effect of Tai Chi on fall risk in community-dwelling older adults.

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THE EFFICACY OF A 12-WEEK TAI CHI INTERVENTION FOR IMPROVING GAIT VELOCITY AND REDUCING FALL RISK IN COMMUNITY-DWELLING OLDER ADULTS: A PILOT STUDY

by

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BACKGROUND

The risk of falling is of significant health concern for older adults due to their high prevalence and related risk for morbidity and mortality.[1,2] Normal physiologic changes experienced throughout the lifespan lead to impaired gait and balance that increase the number of falls experienced in the aging population.[3] Effective preventative strategies are needed for the older adult to reduce the incidence and burden of experiencing a fall.[4]

Approximately 30% of the population aged 65 years or older will experience a fall each year.[2,5] The incidence shows a direct increase with age, where half of those above the age of 80 will have a fall each year.[6-8] Of those who have experienced a fall, two-thirds will suffer a subsequent fall within the next 6 months.[2,7] In 2012, the most recent year for which data could be found, this accounted for over 3 million falls in the United States.[1] This number has risen, and is expected to keep rising in the aging population, with over 84 million Americans projected to be above the age of 65 by the year 2050.[1,9]

Experiencing a fall can result in both fatal or non-fatal injuries.[1,9-11] The Centers for Disease Control (CDC) has reported over 3 million non-fatal injuries caused by falls in the older adult population each year.[12] While the majority of falls lead to minor lesions, 20-30% can cause moderate to severe injuries.[10,12,13] Among the older adult population, falls are the most common cause of TBI and account for 46% of all fall related deaths.[7,14] While the rate of hip fracture following a fall is only 1%, 90% of hip fractures are due to a fall and 25% of elderly patients will die within 1 year of this injury.[10,11,15,16] The likelihood of death due to a fall increases with age.[1] In total, over 28,000 people greater than 65

years old died from a fall in 2015, making falls the fifth-leading cause of death in this age group.[1,7,9,17]

Surviving a fall can often times lead to a reduced quality of life in the older adult population. A history of previous or recurrent falls can cause a fear of falling and 40% of older adults with this fear will self-restrict their activities of daily living (ADL).[7] This reduction in activity results in a decline in physical function, social isolation, depression, and an increased risk of falling.[17]

The negative impacts of falls in the older population represent a great portion of health care spending in the United States, accounting for 6% of Medicare and 8% of Medicaid total spending in 2015.[1,4,9,18] The direct medical costs vary following fatal versus non-fatal falls and include expenditures related to hospitalization, emergency department visits, and outpatient appointments.[1] In 2015, fatal falls accounted for over $754 million while non-fatal falls totaled over $49.5 billion, a greater than $14.2 billion increase from just three years prior.[1,9] The costs associated with falls are expected to rise over the coming years due to the presence of an aging population.[4,19]

Physiological Changes Associated with Aging

Aging is an inevitable aspect of life and can be defined as a physiologic decline and an increased prevalence of disease or pathology.[3] Many theories have been proposed regarding the underlying mechanism of the aging process but no consensus has been reached.[19,20] It is well accepted that aging is the result of progressive changes at the cellular level throughout the body.[3,19] While all cells undergo these changes at a different rate, the result is a general progressions away from uniformity in structure and organization.[3] These microscopic changes manifest themselves differently at the organ-system, and organism levels.[3]

The changes of each individual body system manifest in different ways but can ultimately lead to an increased susceptibility to pathologic processes.[3,19,21] The combined changes of the various systems can lead to an overall decline in physical function in the aging adult which can eventually increase the likelihood of experiencing a fall. Of particular importance to fall risk are changes in the neuromuscular and neurosensory systems.[19]

Neurosensory

The neurosensory system is comprised of the nervous system and the 5 senses (hearing, taste, touch, vision, smell).[19] Each component of this system demonstrates change in the aging adult. Due to their role in maintaining balance, vision, somatosensation, proprioception, and the vestibular systems are of particular importance for fall risk in this population.[19]

Visual deficits in the older adult are characteristic of the changes that occur in the eye. The size of the pupil declines with age and there is an overall increased stiffness of the lens.[19] Poor ciliary muscle efficiency leads to impaired ability to change focus leading to slower reaction to light.[19] Impaired visual acuity has been correlated to an increased risk for falls in older adults.[15]

Somatosensation, or touch sensation, relies on peripheral receptors in the skin and the peripheral nerve fibers to relay information to higher brain centers.[19] While a decline in this function has been identified in older adults, there is question regarding the cause. Since peripheral nerve receptors show only minimal change throughout the lifespan, changes in sensation are thought to be caused by changes in the skin experienced by this population.[19] Regardless of the cause, the somatosensory system is heavily relied on for the maintenance of upright stability, and deficits in this system can be a culprit in experiencing a fall.[22]

The vestibular system senses the bodies movement and orientation.[23] The system relies on the structures of the inner ear, the otoliths and semicircular canals, for proper function and maintenance of balance.[23] Degeneration of these structures in the aging adult can lead to balance impairments and risk of falls that are further increased when the visual and somatosensory systems have also experienced a decline in function.[19]

Proprioception is the individual's sense of joint position.[24] Receptors are present in muscles, tendons, and cartilage, and information is sent to the cerebral cortex for interpretation.[19] Degradation of these structures with age will lead to decreased position and movement sense. Thus, older adults will display impaired limb awareness that can affect their overall balance and safety during functional tasks.[19]

Neuromuscular

General changes in the neuromuscular system are seen after the age of 40 years old and can have an impact in the risk of falling.[19] These changes are caused by slowed nerve conduction and a reduction in overall muscle mass due to a reduction in the size and number of individual muscle fibers.[19,25] These combined changes lead to a 20-40% strength loss, slowed movements, impaired coordination, poor postural stability, and an inadequacy to respond to a changing environment.[19,26,27] Knee extensor strength is an important determinant of gait speed in older adults and has shown a direct correlation with functional ability in this population.[28] Moxley et al. found a moderate-high correlation between quadricep strength and preferred gait velocity (r=0.51), and Bohannon et al. performed a regression analysis that revealed non-dominant knee extensor strength as the best overall predictor of maximum gait speed in this population.[28]

Human Gait Characteristics

Gait is the primary means of locomotion in humans. Human ambulation is commonly studied under normal and pathologic circumstances. Having an understanding of gait in humans is useful in determining one's overall level of function and independence in daily life, and the assessment has commonly been deemed an additional "vital sign."[29]

Gait velocity is a commonly used metric of the gait cycle. Velocity is reported as the distance covered per unit of time, typically recorded in meters per second. Normative values for velocity have been commonly studied in the literature and speeds vary between men and women, and among different age groups.[30]

Age-related Gait Changes

The presence of gait changes in the aging adult population has been widely reported in the literature. Uncertainty exists regarding whether or not these changes are the result of physiologic changes, a fear of falling, or a combination of both. Regardless, changes in gait characteristics of older adults have been correlated with reduced balance and an increased risk of falling.[29]

Physiologic changes including decreased joint ROM, reduced muscle power, and postural changes are related to gait difficulties in the aging adult.[31] Changes in gait among older adults include decreased stride length and increased stride time variability.[6,32,33] While measures such as cadence, step width, and double limb stance time have not been shown to vary much throughout the aging process, the cadence-stride length relationship leads to a reduction in gait velocity.[31-33] Changes in this relationship and reduced velocity can be due to energy conservation needs in the older adult.[31]

Gait Velocity Relationship to Fall Risk

Various measures of gait serve as assessment tools to measure function in older adults. Gait velocity is a commonly used metric that has value in predicting falls and adverse events in this population.[29] Gait velocity is known to decline in the aging adult and is correlated to adverse events, hospitalizations, risk of falls, reduced functional independence, and an increased need for a caretaker.[29] Normative values have been reported in the literature for comfortable and maximum gait velocities and range between 1.41 (0.21) – 2.13 (0.42) m/s for men, and 1.31 (0.20) – 1.81 (0.32) m/s for women between the ages of 50-79 years old.[28] An improvement in gait speed by 0.05 m/s and 0.10 m/s is suggestive of small and substantial meaningful changes, respectively.[34]

Preventative Strategies

Fall prevention has been considered a public health mission and is commonplace in clinical and research settings.[4,35-37] A growing body of research supports that falls can be reduced by a combination of both clinical and community based interventions with a return on investment ranging between 36-64%.[4] Groups such as "Stopping Elderly Accidents, Deaths, and Injuries" (STEADI), The Prevention of Falls Network Europe (PROFANE), The American & British Geriatric Societies(AGS/BGS), and the United States Preventative Services Task Force (USPST) all focus on the prevention of falls in older adults through research on screening techniques and intervention recommendations.[4,35,37] Findings of these projects support the use of physical activity interventions that promote improvements in strength, balance, and stability for adequate fall reduction; and the USPST reports moderate benefit of exercise interventions for fall prevention with minimal risk of adverse events in this population.[4,35,37,38] Despite these findings, there is a disconnect between fall prevention research and

practice, as almost 75% of primary care physicians do not base their fall prevention interventions on clinical guidelines.[36]

Physical Activity

The benefits of physical activity in older adults have been widely studied and reported in numerous publications.[39-43] Regular physical activity is important for promoting and maintaining health and wellness and is essential for healthy aging; it also assists in reducing the risk of falls premature mortality, functional limitations, and overall disability.[41,42] Exercise plays a role in reducing the risk of many chronic diseases such as cardiovascular disease, hypertension, type II diabetes mellitus, osteoporosis, and hypercholesterolemia among others.[41,42] Landi et al. reported that regular exercise can prevent and mitigate functional limitations and that older, active subjects were less likely to become disabled than their inactive counterparts.[40] A longitudinal study found that active patients getting 2 or more hours per week of physical activity were less likely to die than those with no- or low- physical activity levels (RR=0.51).[41] Boyle et al found that risk of death in adults who participated in 7 or more hours per week was 57% less than those who were not participating in any form of physical activity.[39]

The American College of Sports Medicine (ACSM), along with the American Heart Association (AHA) have published exercise recommendations for the purpose of improving and maintaining health in the aging adult.[42] The publication specifies the amount and type of physical activity necessary for health promotion and disease prevention, and is designed for older adults aged 65 and above, as well as those aged 50-64 years old with functional mobility deficits that limit participation in fitness and physical activity.[42] The recommendation includes aerobic exercise lasting 30 minutes, 5 times per week at a moderate intensity level,

or 20 minutes, 3 times per week at a vigorous intensity level.[42] Muscular strengthening and endurance exercise is recommended twice per week and should include 8 to 10 exercises with 10 to 15 repetitions each targeting the major muscle groups.[42] Flexibility exercises should be incorporated twice per week with the focus of maintaining or improving joint range of motion.[42] Balance exercise is recommended for those who are at risk of experiencing a fall in order to reduce the chance of injury involved. The exercises are geared towards maintaining or improving balance and should include activities that safely and effectively target the condition that is causative of the increased fall risk.[42] While the recommendation includes specific guidelines for each aspect of fitness, the ACSM and AHA suggest that the main goal is to reduce sedentary behavior and that exercise participation beyond those recommended will lead to greater fitness levels and thus greater benefits.[42]

The relationship between physical activity participation and fall risk has been largely studied in the literature. Exercise participation has been found to reduce the risk of falls, as well as the injuries and mortality rates associated.[42-44] Participation in physical activity has shown to reduce the risk of falls by 35-45% in various studies and reduce the overall probability of experiencing a fall compared to non-exercising control groups.[42,44] Additionally, physical activity participation results in fewer hospital admissions and 1/3 the cost of stay following a fall when compared to those who do not exercise.[44] While there is evidence to support the benefit of exercise on fall risk, research has been more focused on specific balance exercise as opposed to balance activities. This has led to difficulty with determining a specific frequency, duration, and configuration of balance activity prescription and further research is needed exploring the benefits of such.[42,43]

Tai Chi

Alternative forms of physical activity have been commonly studied for the reduction of fall risk among older adults, and one such intervention that has shown effectiveness is Tai Chi.[45-50] Tai Chi is a 400-year-old practice that originated in China and utilizes combinations of slow, purposeful, and gentle movements that promote relaxation and diaphragmatic breathing.[51,52] Tai Chi is practiced widely in numerous countries as a safe form of physical activity that can improve overall health and wellness.[53] Studies of Tai Chi among various populations have reported positive effects on memory, balance, flexibility, cardiac function, digestion, and overall quality of life.[54,55]

Relationship to Risk of Falls

The effectiveness of the various forms of Tai Chi on physical function and fall risk among older adults has been a common research topic. A recent systematic review and meta-analysis of 10 randomized controlled trials studied the effects of structured Tai Chi intervention on incidence of falls in community-dwelling older adults.[56] The authors concluded that Tai Chi is effective for preventing the risk of falls when compared to health education, various forms of exercise, or non-intervention (pooled estimated OR 0.70, 95% CI 0.59-0.84).[56] These results were upheld when sub-analyzing for the various styles of Tai Chi used as well as the length of the intervention.[56]

Other authors have reported the effectiveness of Tai Chi on fall risk in older adults using a variety of outcome measures including single limb stance time, fear of falling, functional gait measures with and without cognitive dual tasks, fall avoidance efficacy, proprioception, muscle strength, and flexibility.[45-50] The intervention has been compared to traditional physiotherapy programs, low-level stretching exercises, health and wellness education programs, and maintaining a

normal daily routine.[45-50] The effects of Tai Chi on gait velocity has been commonly studied as this measure has been correlated to fall risk in community-dwelling older adults.[29,45-50] Significant improvements in gait speed have been reported by various authors following intervention.[45-47]

Mechanism to Improve Gait Velocity

The underlying mechanisms leading to improvements in gait velocity following Tai Chi have not been extensively explored. However, improvements in neurologic and muscular function following the intervention have been reported and could explain the relationship to gait velocity.[28,57-60] A recent systematic review and meta-analysis supports the use of Tai Chi for improving lower limb proprioception in older adults.[59] Proprioceptive function of the lower extremity joints such as the ankle are crucial for precise control during gait and have an effect on gait and balance disorders.[60] Ko et al. reported that older adults with impaired balance had poorer ankle proprioception than their non-impaired counterparts, and this reduced ankle proprioception was associated with a slower gait speed.[60] The effects of Tai Chi on ankle proprioception could support the improvements in gait velocity among community-dwelling older adults.[59,60]

The effect of Tai Chi on lower extremity strength has been explored in the literature and it has been suggested that improvements in these measures can improve gait velocity and reduce the risk of falls in older adults.[57,58] Many of the movements incorporated in Tai Chi are similar to those in strengthening programs and include partial squats and lunges. Liu et al. performed a meta-analysis that explored the effects of Tai Chi on lower limb strength.[61] The results of the study revealed that both men and women demonstrated improvements in knee extensor strength following intervention compared to control groups.[61] These improvements

in gait velocity following Tai Chi intervention could be explained by the correlation between knee extensor strength and walking speed in this population.[28]

Gaps in the Literature

Multiple studies support the use of Tai Chi for reducing risk of falls and improving functional gait measures in this population; however, there is controversy regarding the true effectiveness. Numerous authors have reported minimal or insignificant effects of Tai Chi for improving gait velocity in this population.[48-50] Inconsistencies regarding the true effect of Tai Chi on gait velocity are accompanied by methodological differences between studies in the measurement of gait velocity. Studies have used various distances, reporting units, and acceleration/deceleration distances that could alter the outcome of the measure and lead to difficulty when quantitatively analyzing the effects of multiple studies.[45-50]

Reports of maximum gait velocity has not been commonly used in determining improvements following Tai Chi intervention. Although the use of a maximal gait velocity has not been investigated as thoroughly as gait velocity at a preferred speed, the measure has shown importance in differentiating between fallers and non-fallers; and performs similarly to preferred gait velocity assessment at determining fall risk in older adults.[62,63]

Purpose & Hypothesis

Currently there is limited availability to community-based group exercise classes in the Central Valley region for community-dwelling older adults. Tai Chi is a low-impact, physical activity that has shown to have a positive effect on fall risk in older adults.[56] Therefore, Tai Chi is an exercise mode that can be offered in a group exercise class format at low cost for older adults. The purpose of this pilot

study was to determine the effects of a community-based group exercise Tai Chi class on gait velocity parameters for community-dwelling older adults with a history of falls or fall risk. It is hypothesized that there will be a statistically significant Improvement in gait velocity within community-dwelling older adults who participate in a 50-minute Tai Chi group exercise class, once per week for 12 weeks.

METHODS

Study Design

This pilot study was a study of convenience and utilized a within group, repeated measures design. The study was conducted from August through December of 2019. The design was a 12-week intervention with pre- and post-test measurements the week before, and the week following the intervention period. The study was approved by the Department of Physical Therapy institutional review board committee at California State University, Fresno.

Subjects

Participants were recruited with a sample of convenience from the greater Fresno and Clovis area through a combination of social media postings, a Medwatch television airing, and flyers at a local balance screening event. Subjects who were interested were contacted via phone or email for further details regarding the study. Eight participants (7 females, 1 male; mean ± SD age, 68.38 ± 10.07 years) volunteered to participate in this pilot study (Table 1). All participants were assigned to the intervention group consisting of 12 weeks of Tai Chi group training. The inclusion criteria in the study were community-dwelling men and women, aged 65 years of age or older; or those younger than 65 at risk for falls based on current functional status, previous history of falls, or near-falls. Participants must have been able to ambulate household distances with or without the use of an assistive device and be able to participate in a 50-minute exercise class 1 day per week for a duration of 12 weeks. Exclusion criteria included participants with any poorly controlled medical condition that would restrict exercise participation. Inclusion and exclusion criteria were assessed with an

intake form and brief history prior to participation. All subjects were asked to read and sign informed consent and intake forms before participating in the study.

Procedure

Initial testing and intervention took place at Community Regional Medical Center in Fresno, California. In order to best serve all investigators, class instructors, and participants, testing and intervention was scheduled one time per week on Saturday mornings. Initial testing began with all participants signing an informed consent followed by the completion of an intake form and brief history that inquired about age, gender, any known medical co-morbidities, history of falls or near falls, and any injuries resulting from such. Informed consent and full intake form can be seen in the Appendix. All participants were assigned an identification number and all of the collected data were kept with the primary investigator in the Department of Physical Therapy in a locked cabinet.

Graduate students from the Department of Physical Therapy served as co-investigators and completed Collaborative Institutional Training Initiative training courses in human subject research and information privacy security prior to data collection. Co-investigators were trained by the primary investigator in all measures and performed the assessments. Vital signs including heart rate, blood pressure, and oxygen saturation were measured for all participants prior to the beginning of any physical measures. Height and weight were assessed for each participant in order to calculate body mass index (BMI).

Gait velocity was measured with the use of the 10-meter walk test (10MWT). The instrument required an empty hallway greater than 10 meters distance, a stopwatch, and 4 cones. Participants were instructed to line up behind the first cone and, when they were ready, to begin walking through the marked

hallway. The participants were first instructed to walk at their normal, comfortable speed. Next, participants were asked to walk at their maximum speed that could be completed safely. The first and last 2 meters of the distance were subtracted from the total length and the time each participant took to traverse the middle 6 meters was recorded. The use of an assistive device was allowed but must be documented. Two trials were completed for each self-selected gait speed and velocity was calculated by dividing the distance, in meters, by the time, in seconds, that it took to cover the distance. The 2 trials were averaged to give a comfortable and maximum gait velocity for each participant.

The 10 MWT is a commonly used assessment tool in the rehabilitation setting and its use has been studied across multiple populations.[34,64-67] The measure has shown excellent interrater reliability (ICC=0.980) as well as excellent test-retest reliability for both preferred (r=0.75-0.90) and maximum (ICC=0.91-0.93) gait speeds.[64,66,67] Perera et al. reported a standard error of measurement of 0.06 m/s and responsiveness of 0.05 m/s and 0.10 m/s representing a small and substantial meaningful change in geriatric populations, respectively.[34] Van Swearingon et al. found that a speed of less than 0.55 m/s is predictive of recurrent risk of falls in community-dwelling, frail older adults.[65]

Intervention

Study participants underwent 12 weeks of structured tai chi intervention designed by Dr. Paul Lam's Tai Chi for Health Institute (TCHI).[68] The class was taught by an instructor who was certified in Tai Chi by TCHI and took place once per week on Saturday mornings and began 1 week following initial testing. Each class was 50 minutes long and included a brief warm-up and cool down period that was consistent for each intervention. The protocol was broken into 2 phases,

including series of basic and advanced movements. A new movement was added each week until all 12 of the Tai Chi movements of this form were taught. After a new move was introduced each day, the class practiced previous moves learned during prior sessions and incorporated all of the moves with fluidity. The intervention included both static and dynamic movements that incorporated varying degrees of single limb stance, weight shifting, squatting, and alternating upper and lower extremity arm movements. The Appendix illustrates each of the Tai Chi movements included in this form.

All participants were encouraged to practice the tai chi moves throughout the week as often as they could tolerate. Participants were also encouraged to continue with their normal daily lifestyle such as exercise routines, ADLs, and other community programs; however, they were asked to not begin any new participation in other exercise classes until after the post-test measurements were taken.

Statistical Analysis

Statistical analysis was completed using Microsoft Excel version 16.24 and SPSS version 26.00. Pre- and post-test data were analyzed by calculating the mean and standard deviation of the data sets for each outcome measure. Data collections took place 1 week before the start, and 1 week following the cessation of the 12-week intervention. A one-tailed, paired t-test was used for within group comparisons between pre- and post with $p<.05$ representing a statistically significant improvement following the intervention.

RESULTS

A total of 8 participants signed up to participate in this study (7 females, 1 male; 68.38 ± 10.07 years) (Table 1). Three participants withdrew from the study due to various reasons: medical diagnosis, transportation issues, difficulty level of the class. Five participants (4 females, 1 male; mean ± SD age, 61.4 ± 3.58 years) completed the 12-week Tai Chi intervention and were available for post-test assessment (Table 2). The remaining participants had a group attendance rate of 83.33% throughout the intervention (Table 3).

Preferred Gait Velocity

Prior to the intervention period, the group averaged 1.395 ± 0.098 m/s (mean ± SD) for preferred gait velocity in the 10MWT. Post-test measurements revealed an improvement in this measure to 1.499 ± 0.101 m/s. A one-tailed, paired t-test found that this improvement was not significant (p=0.057) (Table 4).

Maximum Gait Velocity

Prior to the intervention period, the group averaged 1.778 ± 0.025 m/s (mean ± SD) for maximum gait velocity in the 10MWT. Post-test measurements revealed an improvement in this measure to 1.951 ± 0.080 m/s. A one-tailed, paired t-test found that this was a significant improvement from baseline (p=0.008) (Table 5).

Individual Performance

Following the intervention period, all participants demonstrated some improvement in gait velocity under at least one condition. Participant 4 was the only subject that demonstrated a reduced preferred gait velocity following the

intervention. All participants demonstrated an improvement in maximum gait velocity at the end of the 12-week period.

Participant 1 attended 11 out of 12 (91.67%) of the group classes. This subject demonstrated a 0.235 s improvement for preferred gait velocity from baseline. For maximum gait velocity, this subject improved by 0.320 s following the intervention.

Participant 3 attended 8 out of 12 (66.67%) of the group classes. This subject demonstrated a 0.204 s improvement for preferred gait velocity from baseline. For maximum gait velocity, this subject improved by 0.080 s following the intervention.

Participant 4 attended 11 out of 12 (91.67%) of the group classes. This subject demonstrated a 0.039 s reduction in preferred gait velocity from baseline. For maximum gait velocity, this subject improved by 0.180 s following the intervention.

Participant 5 attended 11 out of 12 (91.67%) of the group classes. This subject demonstrated a 0.038 s improvement for preferred gait velocity from baseline. For maximum gait velocity, this subject improved by 0.091 s following the intervention.

Participant 9 attended 11 out of 12 (75%) of the group classes. This subject demonstrated a 0.080 s improvement for preferred gait velocity from baseline. For maximum gait velocity, this subject improved by 0.189 s following the intervention.

DISCUSSION

The primary purpose of this study was to determine the effect of a community-based, group Tai Chi intervention on fall risk as determined by preferred and maximum gait velocity in community-dwelling older adults. The hypothesis was partially accepted for a statistically significant change in maximum gait velocity following 12 weeks of Tai Chi intervention.

Preferred Gait Velocity

Preferred gait velocity changes were not statistically significant for this pilot study; however, there was a positive trend across the group for an improvement in this measure ($p=0.057$). Four out of the 5 participants demonstrated improvements in preferred gait speed following the intervention, and of those, 1 participant's improvements surpassed the cut-off for a small meaningful change, and 2 participants demonstrated a substantial meaningful change.[34]

Maximum Gait Velocity

Maximum gait velocity was significant ($p=0.008$) following the intervention. Each participant demonstrated improvement for a small meaningful change. Each participant was able to demonstrate an individual improvement in scores from baseline to 12-week follow-up. Three participants demonstrated a substantial meaningful change.[34]

Additional Literature

The findings of this pilot study regarding gait velocity parallel the inconsistencies among what other authors have reported following Tai Chi intervention. Manor et al. compared the effects of 12 weeks of Tai Chi

intervention versus education on age-related topics such as balance and nutrition for effect on gait velocity under both normal and cognitive conditions.[47] The authors found that Tai Chi can lead to a significant improvement in gait velocity under both conditions.[47] Similarly, Choi et al. concluded that a 12-week Tai Chi intervention led to a significantly improved 6-meter walk time when compared to controls who maintained their normal, daily routine ($p<0.001$).[45] When compared to a program of low-load stretching, Li et al reported that Tai Chi training was able to demonstrate a positive effect on all physical performance measures including a significant improvement in 50-foot walk test time after a 6-month follow up period ($p<0.001$).[46] Despite these positive findings, there continues to be inconsistency regarding the true effect of Tai Chi due to conflicting findings.

Wolf et al. studied the effects of Tai Chi training versus a wellness education program among older adults. While both groups demonstrated a significant improvement from baseline ($p<0.001$), the Tai Chi group led to significantly greater improvements at 4-month ($p=0.017$) and 8-month follow-up ($p=0.020$).[49] There was no statistically significant difference between the 2 groups at 1-year follow-up ($p=0.19$).[49] Similarly, Tousignant et al. found no between-group differences in gait velocity when studying the effects of a 15-week Tai Chi intervention versus normal physical therapy ($p=0.663$).[48] Zhang et al. had a similar outcome when comparing 8 weeks of Tai Chi to controls who were asked to maintain their normal, daily routine. The trial found no significant differences in the time to walk 10 meters ($p=0.404$).[50]

It is important to understand some of the methodological differences of the aforementioned studies which could lead to the inconsistency between findings. The previous studies vary in the specific style of Tai Chi that is used, different control group interventions, the dosage (hours per week and duration of weeks),

the length of follow-up, the sample size, and age of participants.[45-50] Even more interesting is the lack of consistency in measuring gait speed as each study uses different distances for the measure; and the way the score is reported also varies, either distance per time, or the raw time to travel the pre-determined distance. Since gait velocity has been commonly used in the study of Tai Chi's effects on fall risk, it would be beneficial to utilize standardized procedures.

A recent publication in the *Journal of Geriatric Physical Therapy* proposed a standardized protocol for measuring gait velocity in older adults who are at risk for falls and other adverse events.[69] The study included a qualitative synthesis of 50 randomized controlled trials, cross-sectional studies, and longitudinal studies that measured gait speed over a distance of ≤ 15 meters.[69] The individual studies varied in distance covered, starting point, and the pace utilized. The study proposed that gait speed assessment in older adults should be conducted at a normal walking pace from a standing start over a distance of 9 meters. The first and last 2.5 meters are untimed and used for acceleration and deceleration only. The time taken for the subject to travel the middle 4 meters are recorded with a handheld stopwatch, and the fastest of 2 trials is recorded as meters per second.[69]

This protocol varies slightly from the one utilized in the present study. Our participants traveled over a distance of 10 meters, with the time recorded over the middle 6 meters. The acceleration and deceleration phase utilized totaled only 2 meters each. While this is mostly of concern for frail older adults, Macfarlane et al. reported that utilizing insufficient acceleration and deceleration distances can lead to measurement error and limit the possibility of identifying a significant change in measures, especially when the changes are small.[69,70] This could explain the lack of statistical significance for preferred gait velocity measured in the present study.

In order to determine the effect that the *JGPT* recommendation for assessing gait velocity could have on our current study, a separate analysis was performed. Although we were unable to change the length of the walkway, the timed distance, or the acceleration distance, we could follow their recommendations by only taking each individual's best score out of their 2 attempts.[69] From these new individual scores, we calculated means and standard deviations of the entire group for preferred and maximum gait velocity. Comparisons of group values between pre- and post-test data were completed using a one-tailed, paired t-test. The group was able to demonstrate a statistically significant change for both preferred ($p=0.047$) and maximum ($p=0.016$) gait velocity.

These findings demonstrate how a difference in the procedure for measuring gait velocity can affect findings of statistical significance. This is important to understand considering that previous studies regarding the effects of Tai Chi on gait velocity have each used a different protocol for assessing gait velocity.[45-50] Future research could benefit from the use of a standardized protocol such as those proposed by the *JGPT*.

Although the previous protocols do not include the use of maximum gait velocity, the measure has been found to demonstrate an important association with fall status[63] and proved beneficial in the present study in detecting significance following intervention. Middleton et al. performed a systematic review of community-dwelling older adults to determine the ability of self-selected and maximum walking speed to predict fall risk.[62] The authors concluded that both of the metrics were significantly associated with fall status ($p<0.001$) and that the 2 measures performed similarly in being able to discriminate between fallers and non-fallers.[62] A later publication by the same authors reported that a combination

of self-selected and maximum gait velocity might offer a more detailed picture of fall risk than either measure alone as maximum walking speed offers better insight about a participants capabilities in the community.[63] This is likely due to the need to increase walking speed in response to environmental demands, an important aspect of functional mobility and safety.[63] Furthermore, maximum gait velocity declines more steeply with advancing age than does preferred gait velocity[64], and this could support the findings of our current study which were able to detect significant changes in maximum, but not preferred gait velocity, following the intervention in our sample comprised of a population slightly younger (61.4 ± 3.58 years old) than a traditional community-dwelling older adult demographic.

The use of functional outcomes such as gait velocity to determine fall risk are commonly used, but these measures could be complimented with the use of long-term design that studies the overall incidence of falls experienced by participants. A recent systematic review and meta-analysis analyzed 10 randomized controlled trials comparing Tai Chi to health education, exercise, or nonintervention for community-dwelling older adults; the primary outcome used was incidence of falls.[56] The authors concluded that Tai Chi was effective for preventing risk of falls in older adults (pooled estimated OR 0.70, 95% CI 0.59 to 0.84).[56] These findings held up when sub analyzing the length of the intervention and the Tai Chi style used.[56]

Tai Chi encompasses a number of principles that can be seen in traditional balance training prescribed in physical therapy, including changes in base of support, incorporation of single leg stance, static and dynamic weight shifting, and alternating upper and lower extremity movements. Although the mechanism behind why Tai Chi practice can be effective in reducing fall risk in older adults is inconclusive, one theory that has been recently been tested is the effect on lower

extremity proprioception following intervention.[59] Proprioception can be defined as the ability to sense the bodies position and movement in spacing through the use of mechanoreceptors in the muscles, joints, and ligaments.[59] The age-related decline of this function can lead to balance issues and increased fall risk in older adults.[71,72]

Numerous studies have analyzed the relationship between Tai Chi practice and proprioceptive function in this population; a recent systematic review and meta-analysis by Zou et al. compared measures such as time to detect passive joint movement, joint position reproduction tests, and the X-sens 3-dimensional positional measuring system in adults aged 55 years and older following Tai Chi intervention.[59] Statistical analysis revealed a significant large effect size in dominant/right knee measures (SMD-0.82, $p<0.001$) as well as a moderate effect size for non-dominant/left knee measures (SMD=-0.71, $p<0.001$), ankle dorsiflexion (SMD=-0.75, $p<0.001$), and plantarflexion (SMD=-0.55, $p=0.002$) in the Tai Chi group compared to controls.[59]

The effects of Tai Chi exercise on lower extremity strength have been studied in the literature and improvements in knee extensor strength could serve as an additional mechanism explaining trends in gait speeds.[28,57,58,73] Lan et al. studied the effects of a 6-month Tai Chi intervention on knee extensor strength in community-dwelling adults aged 60 years and older. The study found a significant increase in both dominant, and non-dominant, knee extension peak torque both eccentrically and concentrically.[57] A systematic review by Qi et al. studied the combined effects of Tai Chi and resistance training in older adults and report a significant increase in knee extensor strength in this population ($p<0.001$).[58] The combined improvements in proprioception and knee extensor strength suggest

valid mechanisms of Tai Chi for reducing risk of falls and improving gait velocity in older adults similar to the results in this study.

Limitations

While interpreting these results, it is important to understand the limitations involved in this study. The current design was a small, experimental pilot study. The pilot study had a small sample size. In addition, there was no control group for comparison, no blinding of the participants or assessors, and no long-term follow-up.

The study had a small sample size (n=5) which limited comparison of descriptive variables such as: gender, age, risk for falls. This small sample is ineffective at representing the entire population that is at risk for falls due to their age, gender, and pre-test data of functional outcome measures and therefore poses a threat to external validity. With this small sample size, the data was skewed significantly by one participant when analyzing the preferred gait velocity changes.

The mean age for the intervention group was affected by the drop-out rate. The mean age changed by 7 years (see Tables 1 & 2) and it dropped the mean below 65 years old. Community-dwelling older adults are typically defined as 65 years of age or older, and while risk of falls is not inherent to this age group alone, we would have liked to have captured a population closer to this age. The 3 participants who withdrew from the study had the lowest baseline scores for gait velocity under both conditions and therefore could have offered better insight to this studies hypothesis had they finished the intervention and been available for post-test data collection.

While all participants were asked to practice the Tai Chi movements in between sessions, logging of individual practice time was not measured. Additionally, participants were allowed to continue with their normal physical activity routine. Since each participant had a different activity level, this could have had an effect on the results in the study.

Finally, graduate students collected date for this pilot study. Intra-rater reliability was not established and could have weakened the data collection results. However, the students were trained by the primary investigator for all data collection procedures and were consistent in performing the same pre- and post-test outcome measures.

Clinical Relevance

The results of this pilot study as well as previous studies suggest that Tai Chi can have an effect in improving function and reducing the risk of falls in older adults.[45,47-50,59] This offers clinicians the benefit of advising patients who are at risk for falls about other programs that can serve as an adjunct to traditional balance training experienced in Physical Therapy. Additionally, the movements used in Tai Chi can be incorporated into Physical Therapy treatment.

The high cost associated with experiencing a fall has led to a significant financial burden in the United States.[1,4,9,18] Physical therapy interventions can be beneficial for improving balance and stability in older adults that are at risk for falls. Maintenance of physical activity throughout the aging process can be effective in reducing falls.[42-44] A growing body of research has shown that falls can be reduced by a combination of both clinical and community-based interventions with a return on investment ranging between 36-64%.[4] Group

interventions such as Tai Chi can serve as a cost-effective alternative or addition to traditional balance training programs.

Future Direction

Despite the inconsistency of findings in the literature regarding the effects of Tai Chi, the practice remains a popular intervention for improving function and reducing the risk of falls in older adults.[45-50,56,59] Clinicians could benefit from further research regarding Tai Chi in order to better serve and inform their patients who are at risk for falls. The results of this pilot study could be more accurately explored in future research. Future studies could benefit from a larger sample size, equal representation across gender, adults over age 65, and a control group.[45-49]

Future research projects could consider expanding the study to encompass resistance training as offered across evidence in the peer-reviewed literature. Another consideration would be long-term follow-ups of participants to assess lasting effects of the intervention and fall risk, including gait velocity considerations or change with a re-assessment at a later period of time such as 3-months or 6-months post-intervention.

Finally, the careful selection and implementation of outcome measures could prove beneficial in further answering our research question. While physical measures such as gait velocity adequately capture change in functional status, standardized protocols such as those describe by Mehmet et al. would improve statistical comparison between the works of multiple authors.[69] The use of measures for proprioception could further explore the mechanism behind why Tai Chi might have an effect on fall risk[59]; and collecting data for the overall incidence of fall following intervention would be beneficial in describing the true effect on fall risk reduction.[56]

Conclusions

Our study had a small sample size therefore the overall effect cannot be expanded to the general population. Maximum gait velocity for adults over the age of 60 who participated in the 12-week Tai Chi intervention demonstrated improvement. Continued research is necessary to determine if Tai Chi can contribute to change in gait speed and fall risk in community dwelling older adults.

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TABLES

Table 1. Initial Participant Demographics

Demographic	Age	Gender (F/M)	BMI
1	65	F	20.40
2	84	F	25.94
3	59	F	19.75
4	61	F	24.40
5	65	M	29.77
6	82	F	17.91
7	74	F	27.08
8	57	F	33.47
Total	68.4 ± 10.07	7/1	

Table 2. Participant Demographics (Follow-up)

Demographic	1	3	4	5	8	Total
Age	65	59	61	65	57	61.4 ± 3.58
Gender (F/M)	F	F	F	M	F	4/1
BMI	20.4	19.8	24.4	29.8	33.5	25.6 ± 5.96
Falls in Past 6 Months	Yes	No	No	No	No	1/5
Near-fall in Past 6 Months	Yes	No	Yes	No	Yes	3/5

Table 3. Group Attendance Throughout Intervention

Participant	Sessions Attended	Percentage
1	11/12	91.67
3	8/12	66.67
4	11/12	91.67
5	11/12	91.67
8	9/12	75
Total Average	10/12	83.33

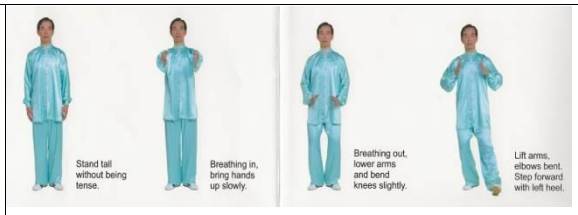
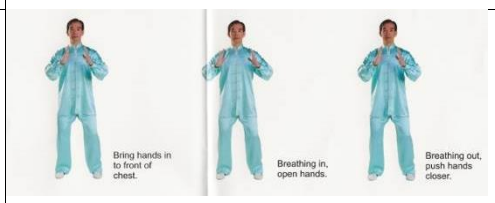
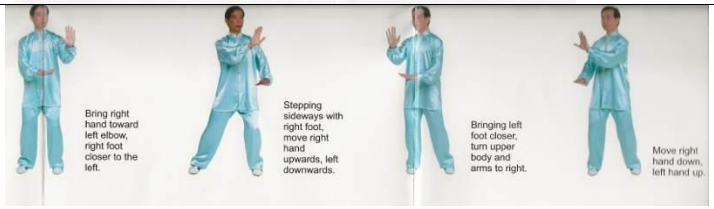
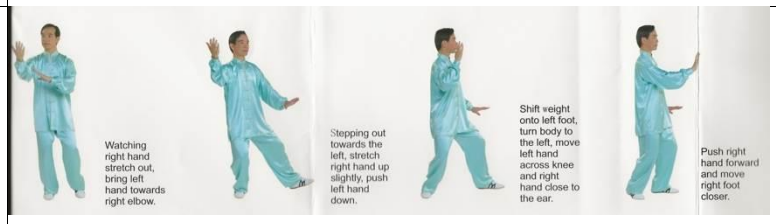
Table 4. Average Preferred Gait Velocity (m/s) of 2 Trials

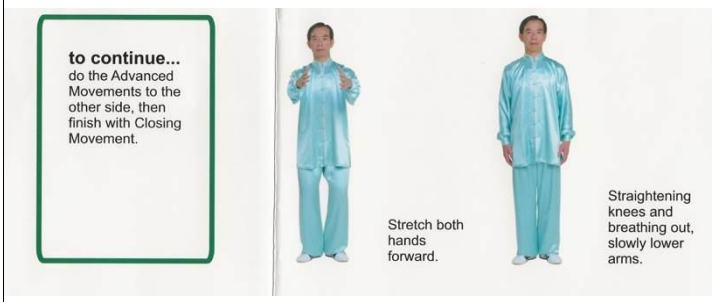
Participant	Pre-Test	Post-Test
1	1.37	1.60
3	1.29	1.49
4	1.41	1.37
5	1.55	1.59
8	1.36	1.44
Mean ± SD	1.40 ± 0.10	1.50 ± 0.10

Table 5. Average Maximum Gait Velocity (m/s) of 2 Trials

Participant	Pre-Test	Post-Test
1	1.76	2.08
3	1.81	1.89
4	1.75	1.93
5	1.79	1.88
8	1.78	1.97
Mean ± SD	1.77 ± 0.03	1.95 ± 0.08

APPENDIX: TAI CHI MOVEMENTS

Commencement	
Open and Close	
Single Whip	
Waving Hands	
Brush Knee	
Playing the Lute	

Parry and Punch	
Block and Close	
Push the Mountain	
Closing	

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March 18, 2020

Date