CAN TAI CHI IMPROVE THE BALANCE CONTROL OF ELDERLY PERSONS WITH VISUAL IMPAIRMENT?

CHEN WEI ELLEN

M.Phil

The Hong Kong Polytechnic University

2011

THE HONG KONG POLYTECHNIC UNIVERSITY

DEPARTMENT OF REHABILITATION SCIENCES

CAN TAI CHI IMPROVE THE BALANCE CONTROL OF ELDERLY PERSONS WITH VISUAL IMPAIRMENT?

CHEN Wei Ellen

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Philosophy

January 2011

CERTIFICATE OF ORIGINALITY

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it produces no material previously published or written, nor material that has been accepted for the award of any other degree or diploma, except where due acknowledgement has been made in the text.

_______________ (Signed)

CHEN Wei Ellen (Name of student)

DEDICATION

I dedicate this work to my husband Michael CHEUNG, who has supported me throughout my master degree studies.

ABSTRACT

Introduction: Good balance is essential for controlling body movement, but it shows significant changes with age when vision is impaired. In addition, fear of falling increases with age and is associated with visual function. Regular exercise produces the same physiological and psychological benefits in the visually impaired as in others, but the visually impaired are usually less physically active, and therefore experience reduced physical functioning and well-being. Tai Chi has been suggested as a suitable form of exercise for those with visual impairment. Its benefits for balance control, muscle strength and preventing falls have been proven in studies with sighted elderly subjects.

This study examined whether or not balance control in the elderly differs with varying degrees of visual impairment and to what extent Tai Chi training might affect the balance control of elderly persons with visual impairment.

Methods: The investigation included a cross-sectional samples study comparing balance control between sighted, low vision, and blind subjects. A randomized clinical trial investigated the effect of Tai Chi on the balance control of elderly persons with visual impairment. The participants underwent the following assessments: 1) a passive knee joint repositioning test; 2) a sensory organization test (SOT); 3) muscle strength assessment; 4) a perturbed double-leg stance test (PDLST); 5) the standard five-times-sit-to-stand test (FTSTST); and 6) evaluation with the Falls Efficacy Scale – International (FES-I).

For the randomized clinical trial, 40 visually impaired elderly persons were randomly divided into a Tai Chi group and a control group. Both groups attended three, 1.5 hour training sessions per week for 16 weeks. Assessments were performed before and after the training.

Results: Compared with the low vision subjects, the sighted elderly achieved higher average peak torque-to-body weight ratios in concentric knee extension. In the SOT, the sighted elderly showed less body sway than the others in conditions where visual inputs could help them maintain standing balance. The sighted and low vision subjects showed less body sway during forward and backward translations of their support surface than the blind. The sighted elderly also reported less fear of falling than those with poor vision.

The Tai Chi trainees showed improvements in balance control after training. They had significant average improvements in knee proprioception, and in the SOT they achieved significant improvements in their visual and vestibular ratios compared to the control group. In the PDLST, the Tai Chi group swayed less than the control group during forward platform perturbations with the eyes closed.

Conclusions: Low vision and blind elderly persons have poorer balance control than the sighted elderly. Vision plays an important role for very old adults in controlling balance in challenging balance control circumstances.

Tai Chi can improve balance control in the visually impaired elderly. They had better knee proprioception and improved balance control when there was an increased reliance on the visual and vestibular systems during stance after 16 weeks of training.

ACKNOWLEDGEMENT

I would like to express my heartfelt thanks to my chief supervisor, Dr. William Tsang, Assistant Professor of the Department of Rehabilitation Sciences, The Hong Kong Polytechnic University. He diligently guided me throughout the whole process.

I would also like to deeply thank my co-supervisors, Dr. Amy Fu, Associate Professor of the Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, and Professor KM Chan, The Chinese University of Hong Kong, for their added insight into the study.

With their guidance, I learned how to complete research with an analytical and critical mind. It was such a fulfilling experience for me during these two years.

I would also like to express my deepest thanks my family, friends and teammates for their love and support throughout my whole study period.

I would also like to thank the following people:

- Mr. Chan Shing Chung and Mr. Man Cheung, technicians, Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, for their valuable skills and advice on the equipment and software programs required for my research study.
- Ken Cheung, Physiotherapist, The Hong Kong Society for the Blind, and Daisy Kwok, research assistant, The Hong Kong Polytechnic University, for their hard work and assistance throughout my study.
- The Hong Kong Society for the Blind, Tai Chi masters and their assistants, and all the participants.

This project was supported by a grant from the Hong Kong Polytechnic University

TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION

CHAPTER 2: METHODOLOGY

CHAPTER 3: BALANCE CONTROL IN VERY OLD ADULTS WITH AND WITHOUT VISUAL IMPAIRMENT

CHAPTER 4: THE EFFECTS OF TAI CHI ON THE BALANCE CONTROL OF ELDERLY PERSONS WITH VISUAL IMPAIRMENT

CHAPTER 5: SUMMARY AND CONCLUSION

LIST OF ABBREVIATIONS

ABC	:	Activities-specific Balance Confidence scale
ANOVA	:	analysis of variance
cm	:	centimeter
EMG	:	Electromyography
EQ	:	Equilibrium Quotients
FAC	:	Functional Ambulation Classification
FES	:	Fall Efficacy Scale
FES-I	:	Fall Efficacy Scale - International
FTSTST	:	Five times sit-to-stand test
Hz	:	Hertz
ICC	:	Intraclass correlation coefficient
METs	:	Metabolic equivalents
MMSE	:	Mini-Mental Status Examination
MMblind	:	Mini-Mental Status Examination for the visually impaired
P	:	Significance level
PDLST	:	Perturbed Double-leg Stance Test
SD	:	standard deviation
SOT	:	Sensory Organization Test

LIST OF TABLES

LIST OF FIGURES

APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Visual impairment

Impairment of vision can have a profound effect on how individuals live their life. Unfortunately, visual impairment is one of the conditions that affects the largest number of people worldwide (World Health Organization [WHO], 2008).

1.1.1 Prevalence of visual impairment

The World Health Organization (WHO) has estimated that in 2002 the number of people with visual impairment worldwide was more than 161 million. In China there were more than 34 million visually impaired people in 2004, with the prevalence of low vision and blindness estimated at 1.9% and 0.6%, respectively (Resnikoff et al., 2004). According to a survey by Hong Kong's Census and Statistics Department, in August 2001 there were about 73,900 people there who were visually impaired (Hong Kong Blind Union, 2001).

1.1.2 Definition of visual impairment

Visual impairment encompasses both low vision and blindness. According to revision 10 of the International Classification of Diseases (World Health Organization [WHO], 2007), low vision is defined as visual acuity of less than 6/18 but equal to or better than 3/60, or corresponding visual field loss of less than 20 degrees in the better eye with the best possible correction. Blindness is defined as visual acuity of less than 3/60, or corresponding visual field loss of less than 10 degrees, in the better eye with the best possible correction (WHO, 2007).

1.1.3 Aging and visual impairment

Visual impairment is well known to increase rapidly with age (Congdon et al., 2004; Dineen, Bourne, Ali, Huq, & Johnson, 2003; Klaver, Wolfs, Vingerling, Hofman, & de Jong, 1998; Watson, 2001). This trend is also apparent in Hong Kong. The Hong Kong Blind Union (2001) had stated that the prevalence of visual disability increased from 9.4% among people younger than 60 years to 75.6% among people aged over 60, and in 2002 a survey found that 41.3% of the Hong Kong population aged 60 years or older suffered from visual impairment (Michon, Lau, Chan, & Ellwein, 2002). As a result, it seems visual impairment is largely confined to those over 60 years old in Hong Kong.

1.2 Balance control

Balance control is an imperative skill for daily life which involves three major components: (1) sensory systems for accurate information regarding the body's position relative to the environment; (2) the brain's ability to process this information; and (3) the muscles and joints for coordinating the movements required to maintain balance. The somatosensory, visual, and vestibular systems are sensory systems which provide three sensory inputs important for maintaining balance.

1.2.1 Aging on balance control

Good balance is an essential skill in controlling body movement, but as one ages the ability to maintain balance control deteriorates. This decline in balance control with aging is theorized to be due to varying degrees of decline in the somatosensory, visual, and vestibular systems. Studies have found aging to be significantly associated with the functioning of the visual, vestibular and somatosensory systems (Baloh, Jacobson, & Socotch, 1993; Baloh, Ying, & Jacobson, 2003; Enrietto, Jacobson, & Baloh, 1999; Skinner, Barrack, & Cook, 1984). In a longitudinal study, Baloh and colleagues (2003) assessed the functioning of the somatosensory, visual, and vestibular systems of 59 healthy elderly subjects followed up at yearly clinical examinations for 8 to 10 years. They reported that visual acuity, auditory thresholds and Tinetti scores decreased on average by 0.01 logMAR units, 1.5 dB, and 0.5 units per year, respectively. In addition, vestibulo-ocular responses showed notable declines at 0.05 and 0.20 Hz and there was moderate loss of deep tendon reflexes and vibration sense over 10 years. These numbers indicate highly significant age-related deteriorations in visual, vestibular, auditory and somatosensory acuity in healthy older people.

Age-related decline in balance control has been well-documented (Laughton et al., 2003; Lord & Ward, 1994; Tsang, Wong, Fu, & Hui-Chan, 2004). In 1994, Lord and Ward conducted tests of the visual, vestibular, sensori-motor and balance functions of 550 women aged 20-99 years to detect whether there was an association between age and balance control. Postural sway, which indicates one's ability to control balance, was measured in four testing conditions: standing on a firm surface with the eyes open (condition A); standing on a firm surface with the eyes closed (condition B); standing on a compliant surface with the eyes open (condition C), and standing on a compliant surface with the eyes closed (condition D). They calculated postural sway in conditions B, C, and D relative to condition A, their postural sway baseline. They found that body sway in condition C relative to condition A increased slightly from the 20-39 year old group to the 70-74 year old group before drastically increasing in the 85+ year old group. In condition D, the sway relative to condition A increased steadily with age to over 4 times as much in the 85+ group. This study demonstrated the degree to which postural sway, particularly in conditions C and D, increased with age. In addition, the degree of postural sway had significant age-associated changes when vision and/or lower limb joint proprioception were blocked or reduced. A sensory organization test has been commonly used to test balance and measure postural sway while altering the subject's visual, vestibular and somatosensory inputs. Tsang and his colleagues (2004) compared the anteroposterior body sway amplitude between young university students and an active elderly group using a sensory organization test. The results showed that the older adults had greater anteroposterior body sway than the younger subjects in a reduced or conflicting sensory environment.

In order to maintain standing and walking balance, an individual needs adequate muscle strength in the lower limbs. However, muscle strength also declines with age, as many studies have confirmed (Al-Abdulwahab, 1999; Frontera, Hughes, Lutz, & Evans, 1991; Frontera et al., 2000). Sturnieks and colleagues (2008) reviewed the age-related changes in the motor system which can contribute to balance deficits. They reported that the decline in muscle strength accelerated after 60 years of age, declining approximately 50% by the age of 80 years. Another study by a group led by Larsson (1979) compared the isometric and dynamic strength of the quadriceps of 114 men aged 11 to 70 years and confirmed that the more elderly had significantly less strength than the younger participants. A cross-sectional study (Lindle et al., 1997) measured isokinetic maximal voluntary concentric and eccentric muscle strength in the dominant knee extensors of 346 men and 308 women between the ages of 20 to 93 and found both men and women experienced significant age-related declines in all of the variables tested.

1.2.2 Balance control and falls

Falls are more common among the elderly and indeed are a serious threat to their health and safety. One in three people over the age of 65 experiences at least one fall each year (O'Loughlin, Robitaille, Boivin, & Suissa, 1993) and 10-15% of these falls are associated with serious injury (Sattin, 1992; Tinetti, Speechley, & Ginter, 1988), often a hip fracture. Research has linked poor balance control to increased risk of falling. After reviewing 12 large studies on the causes of falls in older persons, Rubenstein and Josephson (2002) summarized that balance-disorder related falls are the second most common type among community-dwelling and institutionalized populations, just after accident and environment-related falls, with an average of 17% calculated from the 3628 reported falls among the 12 studies. Chu's group (2005) found that among the Chinese older adults, the incidence of falls was 270 per 1000 person-years. They reported that the important independent predictors of falls or recurrent falls were a history of falls, age, lower limb muscle weakness, and impaired balance control.

1.2.3 Balance control of elderly persons with visual impairment

As reported earlier, balance control appears to diminish when visual input is altered or removed, so those with visual impairment would be expected to have poorer balance control than those with normal vision. A group led by Ray (2008) recruited 23 sighted subjects (aged 38.2±14.4 years) and 23 visually impaired subjects (aged 39.8±14.4 years) and used a sensory organization test to measure their postural stability. Poorer balance ability was reported in the individuals with vision loss. Lee and Scudds (2003) recruited 66 Chinese subjects in care and attention homes and categorized them into 3 groups: subjects with no visual impairment (aged 77.3±5.1 years), subjects with mild visual impairment (aged 80.0±6.9) and subjects with moderate visual impairment (aged 84.0±6.2). They illustrated that visual acuity affects balance control by comparing the visual acuity and functional balance ability of the 3 groups. People with vision loss may partially compensate by relying more on proprioceptive and/or vestibular cues for balance (Di Girolamo et al., 1999; Elliott et al., 1995), but joint proprioception and vestibular acuity also decline with age (Baloh et al., 2003; Skinner et al., 1984; Tsang & Hui-Chan, 2004). As a result, balance control in older people with visual impairment is poorer than among those with good vision.

Indeed, balance control is a major problem for older individuals with visual impairments (Lee & Scudds, 2003; Maeda, Nakamura, Otomo, Higuchi, & Motohashi, 1998), making visual impairment one of the risk factors for falling (Lundebjerg et al., 2001). Many studies have found that visual impairment increases the risk of falls and the risk of injuries from falls (e.g. Freeman, Munoz, Rubin, &

West, 2007; Harwood, 2001). Legood and colleagues (2002) reviewed the association between impaired vision and risks of falls and injuries and concluded that visually impaired people are at 1.7 times greater risk of falling, 1.9 times greater risk of recurrent falling, and 1.3-1.9 times greater risk of fractures from a fall than their counterparts with good vision.

1.2.4 Fear of falling among elderly persons with visual impairment

The prevalence of fear of falling increases with age (Arfken, Lach, Birge, & Miller, 1994; Friedman, Munoz, West, Rubin, & Fried, 2002; Scheffer, Schuurmans, van Dijk, van der Hooft, & de Rooij, 2008) and is associated with visual function (Fletcher & Hirdes, 2004). In the study led by Arfken, the prevalence of fear of falling in the oldest age group (81+ years) was 20% higher than in the youngest group (66-70 years). In addition, a systematic review conducted by Scheffer's group (2008) concluded that age was one of the major risk factors for developing a fear of falling. These findings are important because fear of falling independently predicts becoming a faller (Friedman et al. 2002). The presence of poor vision was revealed in the study to be associated with fear of falling. A cross-sectional study by Fletcher and Hirdes (2004) involving 2,300 seniors examined the factors associated with restriction of activity due to fear of falling. They found that the people who had severely impaired vision had a 3 times greater chance of restricting their activity due to fear of falling than those with normal (corrected) vision. In summary, elderly persons with visual impairment are more likely to fear falling than the sighted elderly, and with good reason.

1.3 Exercise for balance control

1.3.1 Effects of exercise on balance control in the elderly

Among the elderly, regular exercise is important to maintain the physical fitness they need for carrying out daily activities (Taylor-Piliae, 2003). Many investigators have put effort into designing and testing training programs which improve the balance control of the elderly. Interventions involving gait, balance and co-ordination training, functional exercise, muscle strengthening and other various exercise types can be effective in improving balance, as well as reducing falls and fall-related injuries (Barnett, Smith, Lord, Williams, & Baumand, 2003; Howe, Rochester, Jackson, Banks, & Blair, 2007; Judge, Lindsey, Underwood, & Winsemius, 1993; Lord & Ward, 1996). The group led by Barnett (2003) conducted a randomized and controlled trial with 163 people aged over 65 years who were identified as at risk of falling. The subjects participated for one year in a weekly group exercise program consisting of functional exercises, balance and co-ordination exercises, strength work and aerobic activity. They reported improvements in both static and dynamic stability, as there was decreased postural sway on the floor with the eyes open or closed in standing, and also better coordinated stability. The rate of falls in the intervention group was 40% lower than among the controls over the 12-month trial period. Bulat and colleagues (2007) found that an hour a week of functional balance training for 8 weeks in a small group setting showed improvements in the Berg Balance Scale scores, limits of stability and sensory interaction in balance of older adults identified as being at risk of falls. Judge's group (1993) found that a combination of resistance training, brisk walking, flexibility training and postural control exercises improved the single-leg stance balance of healthy older women.

1.3.2 Limitations of exercise on balance control in elderly persons with visual impairment

In fact, regular exercise and physical activity produces the same physiological and psychological benefits in individuals with visual impairment as it does in anyone else (Leverenz, 2009). However, older individuals who are visually impaired are usually less physically active than sighted old people (Crews & Campbell, 2001) and have less choice of exercises. They therefore, on average, have poorer physical functioning and well-being (Chia et al., 2004; Salive et al., 1994). Crews and Campbell (2001) applied the International Classification of Functioning, Disability, and Health (ICIDH-2) as a conceptual framework to summarize the health conditions, activity limitations, and restrictions on participation of visually impaired older people. With regard to activity limitations, people who reported vision problems were twice as likely as those with normal vision to have difficulty walking and getting into or out of a chair or bed. In addition, they were three times as likely to have difficulty getting outside and shopping for groceries. Limitation in these activities alone would likely restrict visually impaired elderly persons from participating in regular exercise.

Although many exercise protocols have been proven effective for maintaining balance control (which is attributed to improved physical functioning), there are still limitations for visually impaired older adults wishing to participate in exercise programs. The exercise should be safe, easy and convenient enough for such individuals. Tai Chi has been suggested as a suitable form of exercise for those with visual impairment (Miszko, Ramsey, & Blasch, 2004).

1.4 Tai Chi

1.4.1 Background

Tai Chi is a mind-body exercise that has been practiced for centuries in China for both psychological well-being and physical fitness by a wide range of people, especially the elderly. Over the past few decades, Tai Chi has gained wide-spread popularity and it is now practiced by many people all over the world and in a variety of settings. Tai Chi can be classified as moderate exercise, as individuals will not exceed 55% of their maximum oxygen intake and 60% of their maximum heart rate (Li, Hong, & Chan, 2001). It can be practiced conveniently because it needs neither much space nor equipment. The movements are slow, soft and fluid, which is ideal for older people.

Tai Chi movements require shifting body weight between the legs, double and single-leg stance, pivoting the whole body, and stepping backward. Doing it well demands precise joint movements, muscle coordination and good balance performance (Li et al., 2001). Studies have analyzed the kinetic characteristics of the Tai Chi movements. Leung and Tsang (2008) measured the maximum center of pressure displacements of subjects while performing standing Tai Chi forms. They found that the maximum center of pressure displacements in the anteroposterior and mediolateral directions ranged from 2.6% to 9.5% and 0.3% to 29.6% of the subject’s height, respectively. Wu and colleagues (2004) compared the kinematics of Tai Chi gait with normal gait and reported that Tai Chi gait has longer single-leg stance duration, larger ranges of motion of the knee and ankle joints and a larger lateral body shift. The higher demands required to perform Tai Chi gait might be expected to help improve balance, lower limb muscle strength and joint proprioception.

1.4.2 Effects of practicing Tai Chi for older adults

Numerous studies have proven that Tai Chi can benefit balance control and muscle strength, and even prevent falls in an elderly population (Hong, Li, & Robinson, 2000; Tsang & Hui-Chan, 2005; Wolf et al., 1996).

1.4.2.1 Joint proprioception

Good Tai Chi exercise requires precise joint movements, which are thought to improve joint proprioception in the lower limbs. Tsang and Hui-Chan (2003) found that elderly Tai Chi practitioners had significantly better knee joint proprioception than non-practitioners, regardless of how long they had been practicing (Fong & Ng, 2006). Xu and her colleagues (2004) provided further evidence by reporting that elderly long-term Tai Chi practitioners not only had better ankle and knee joint proprioception than sedentary controls, but also had better ankle joint kinesthesia compared to regular swimmers and runners.

1.4.2.2 Balance control

The benefits of practicing Tai Chi for balance control have been well documented by numerous cross-sectional and longitudinal studies. Tse and Bailey (1992) reported that Tai Chi practitioners performed better on tests of single-leg stance with the eyes open compared to non-practitioners. A group led by Wong (2001) found that elderly people who practiced Tai Chi regularly had better postural stability in challenging conditions (eyes closed on a sway-referenced platform, sway-referenced vision with a sway-referenced platform) than those who did not. Hong's group (2000) found that Tai Chi practitioners performed better on both legs than healthy but sedentary elderly controls in tests of single-leg stance with the eyes closed. These three cross-sectional studies indicate that Tai Chi practice can significantly improve balance with and without vision. In terms of postural control, another study found that elderly Tai Chi practitioners could demonstrate balance performance similar to those of young, healthy subjects under reduced or conflicting somatosensory, visual, and vestibular conditions (Tsang et al., 2004). In addition, several Tai Chi intervention studies on balance ability in an elderly population have been conducted. In particular, Tsang and Hui-Chan (2004) reported that elderly subjects showed less postural sway during a sensory organization test and better directional control of their leaning trajectory after only 4 weeks of intensive Tai Chi training. The participants in fact achieved balance similar to that of long-term (7.2 to 10.1 years) practitioners of Tai Chi.

1.4.2.3 Muscle strength

Tai Chi is performed in a semi-squatting posture which requires concentric, eccentric, and isometric contractions of the leg muscles. With this distinctive posture one would expect that Tai Chi may be an effective strengthening and endurance exercise for the muscles of the lower extremities (Wu, Liu, Hitt, & Millon, 2004). Lan and colleagues (1998) found that subjects who practiced the classical 108 forms of Yang Tai Chi for 12 months experienced an increase of 15%-20% in the concentric strength of their knee extensors and flexors. Tsang and Hui-Chan (2005) reported that experienced elderly Tai Chi practitioners showed higher peak torque-to-body weight ratios in concentric and eccentric isokinetic contractions of the knee extensors and flexors compared to matched non-practitioners. Specifically, they found that Tai Chi practitioners were 36% and 40% stronger in concentric knee extensor and flexor contraction, respectively. They also had 21% and 37.5% higher eccentric knee extensor and flexor muscle strength, respectively. In addition, Tai Chi practitioners had concentric hamstrings/quadriceps strength ratios similar to those of healthy control subjects, which indicated that Tai Chi may have the advantage of improving the muscle strength of both agonists and antagonists, avoiding muscle imbalance. These studies illustrate that Tai Chi training, which employs body weight shifting and changes of the postural height, can be effective in strengthening the lower limbs of the elderly.

1.4.2.4 Fear of falling

Researchers have found that Tai Chi exercise can reduce the fear of falling in older adults. A longitudinal study conducted by Wolf's group (1996) reported that subjects in the Tai Chi group had less fear of falling after 15 weeks of moderate Tai Chi intervention. Furthermore, the same group (Wolf, Barnhart, Ellison, & Coogler, 1997) found that the frequency of fear of falling in the Tai Chi group decreased 25% (from 56% to 31%) after 15 weeks of training, as opposed to a balance training group where there was no change and an education group where fear of falling increased. A group led by Sattin (2005) used the Activities-specific Balance Confidence scale (ABC) and the Fall Efficacy scale (FES) to determine whether an intense Tai Chi exercise program could reduce older adults' fear of falling compared to a wellness education program. The subjects practiced Tai Chi twice per week for durations starting from 60 minutes and progressing to 90 minutes, for 48 weeks. With subjects aged about 80 they found that Tai Chi led to a significant decrease in fear of falling compared to the wellness education program. Moreover, the Tai Chi group had a greater mean ABC score compared to the wellness education group throughout the intervention, and the difference was greatest at 12 months.

1.5 Previous research on Tai Chi for elderly persons with visual impairment

Although Tai Chi has been proved beneficial for elderly people, there have been very few studies on its benefits for people with visual impairment, and none with very old subjects. A study of Tai Chi training in Miszko's laboratory (2004) involved 8 subjects with visual impairment with an age range of 33-77 years. This small study did not find any significant improvement in balance control, perhaps because of the small sample size, the wide age range and the brevity of the Tai Chi training (16 sessions). Also, that study lacked a control group. That previous study did demonstrate, however, that Tai Chi can be performed safely by subjects with visual impairment.

CHAPTER 2

METHODOLOGY

2.1 Objectives of the present study

1. To explore whether balance control in subjects aged ≥ 70 years differs with varying degrees of visual impairment.
2. To investigate the effects of Tai Chi on balance control in elderly persons with visual impairment.
3. To demonstrate that such visually impaired elderly subjects can accept Tai Chi training.

2.2 Study design

This study involved both a cross-sectional sample study comparing balance control between elderly subjects with visual impairment and age-matched control subjects with normal (corrected) vision, complemented by a randomized, single-blinded, controlled clinical trial to investigate the effects of Tai Chi on balance control in elderly persons with visual impairment.

The outline of the intervention protocol and the randomization process are shown in Figure 2.1. The assessor was blinded to the subjects' intervention assignment.

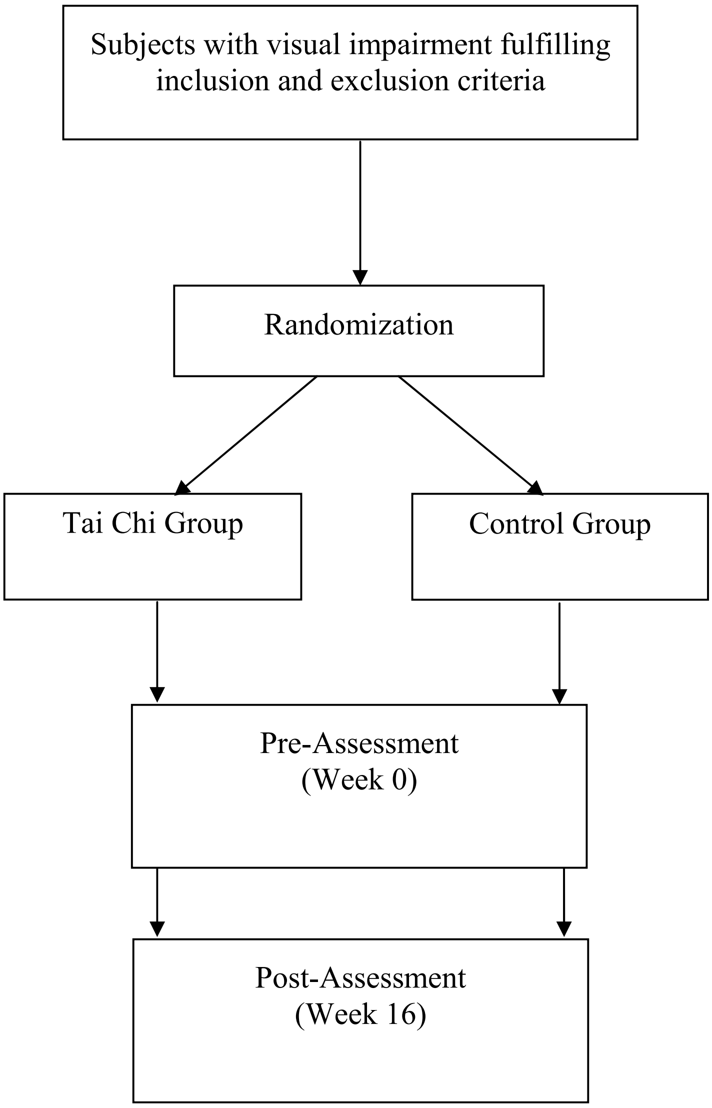

Figure 2.1 Flow chart of subjects recruitment and assessment

2.3 Subject Recruitment

The cross-sectional samples study involved 17 low vision subjects (1 male, 16 females; mean age = 82.9±5.4 years), and 16 blind subjects (1 male, 15 females; mean age = 82.2±8.1 years). They were recruited from residential care homes of the Hong Kong Society for the Blind. Fifteen sighted subjects (3 males, 12 females; mean age = 79.7±5.2 years) were recruited from the community. For the randomized clinical trial, 40 visually impaired elderly from residential care homes were randomly divided into Tai Chi (n=21; mean age = 85.5 ± 6.9 years) and control (n=19; mean age = 82.9 ± 7.5 years) groups. All of the subjects were recruited by convenience sampling. Participants were required to be older than 70 years, independent walkers, independent in their activities of daily living, and able to communicate and follow testing procedures. They were excluded if they had any vestibular problems, symptomatic cardiovascular disease at a moderate exertion level, poorly controlled blood pressure, a history of neurologic disease (e.g. Parkinson's disease), acute orthopedic problems that affected ambulation, or metastatic cancer. All of the subjects underwent 2 screening tests:

1. The Functional Ambulation Classification (FAC) was used to determine each subject's ambulation level (Holden, Gill, Maglipzzi, Nathan, & Piehl-Baker, 1984) (Appendix A). The FAC is a clinical gait assessment scale used to assess neurologically impaired people (Collen, Wade, & Bradshaw, 1990; Holden, Gill, & Maglipzzi, 1986) and is also recommended for geriatric populations (Martin & Cameron 1996). Subjects whose FAC categories were 3 or above, indicating

that they were physically independent in ambulation, were accepted for study (Kollen, Kwakkel, & Lindeman, 2006).

2. The visual acuity of the visually impaired subjects was recorded from recent medical records, and the visual acuity of the sighted subjects was checked using the Snellen eye chart. Low vision was defined as visual acuity of less than 6/18 but equal to or better than 3/60 in the better eye with the best possible correction. Blindness was defined as visual acuity of less than 3/60 in the better eye with the best possible correction. Normal vision was defined as visual acuity of better than 6/18 on the Snellen eye chart in the better eye with best possible correction (WHO, 2007).

Each subject also completed a physical activity questionnaire (Van Heuvelen, Kempen, Ormel, & Rispens, 1998) which categorized their daily activities according to the metabolic index units (METs) required as either light (<4 METs), moderate (4-5.5 METs), or heavy (>5.5 METs), reflecting energy expenditure (Tsang & Hui-Chan, 2003).

The project was approved by the Ethics Committee of The Hong Kong Polytechnic University. The procedures were fully explained to all subjects who met the criteria and informed consent in Chinese (Appendix B) or in English (Appendix C) was obtained from all eligible visually impaired subjects. Appendix D presents the consent form used with all eligible sighted subjects. Those who could not sign used their finger print as a signature.

2.4 Test Procedure

Sighted subjects who were recruited for the cross-sectional samples study underwent assessment once and with exactly the same assessment as the visually impaired participants. The results can thus be compared to the pre-intervention assessment results of the visually impaired subjects. Visually impaired subjects participating in the study were assessed pre- and post-intervention at the Hong Kong Polytechnic University. Assessments included a questionnaire on general health and physical activity (Appendix E), the version of the Mini-Mental Status Examination for the visually impaired (MMblind) (Appendix F) and sensori-motor and balance control measurements. The general health and physical activity questionnaire consisted of questions that addressed a subject's demographics (age, sex, weight, and height), physical status, and health status (medical diagnosis, medication, fall history, and mobility aids used). The Mini-Mental Status Examination (MMSE) is widely used as a screening instrument for dementia syndrome. The MMblind is the MMSE version for those with visual impairment, where all items requiring image processing are omitted. The content validity of the MMblind has been proven in a previous study (Reischies & Geiselmann, 1997). However, the reliability had not previously been tested with a very old population. In this study, the test-retest reliabilities of the MMSE and the MMblind were compared. The results showed that the reliability of the MMblind was higher than that of the MMSE, with intraclass correlation coefficients 0.67 and 0.49, respectively (please refer to the reliability section below). The sensori-motor and balance control assessment included a passive knee joint repositioning test, a muscle strength test, a sensory organization test, a perturbed double-leg stance test, the five times sit-to-stand test and assessment with the international version of the Falls Efficacy scale.

Stratified randomization by drawing lots was used to determine the assignment of subjects to the Tai Chi group or the control group. The stratified factors were age (65-74 years, 75-84 years, 85+ years), sex (female or male), and level of visual impairment (low vision or blindness).

2.5 The test re-test reliability of the Mini-Mental Status Examination version for the visually impaired

The diagnostic validity of the MMblind has been proven in a previous study with subjects aged from 70-103 years (Reischies & Geiselmann, 1997), but its reliability has not been established in a very old population. In this study the test-retest reliabilities of the MMSE and MMblind were compared. Five males and thirteen females (mean age: 80.1 ± SD 6.8 years) with visual impairment (subjects with low vision = 14; totally blind subjects = 4) were recruited to participate in the test-retest reliability study. The MMSE and MMblind were administered twice with one week in between. The ICC (3, 1) value for the MMSE was 0.49 (confidence interval (CI) 0.073-0.773) and for the MMblind ICC (3, 1) it was 0.67 (CI 0.319-0.864). These data showed the MMblind as having better reliability than the MMSE with very old visually impaired subjects. The MMblind was therefore used in this study for comparisons between the two groups.

2.6 Training Protocol

In the randomized clinical trial, training for each group was conducted at their respective centers. Both groups participated in a total of 48 sessions (3 sessions per week for 16 weeks) of activities with each session lasting for 1.5 hours. Their attendance was recorded.

The classes for both groups consisted of a 15 minute warm up, 1 hour of either Tai Chi or music percussion training, and 15 minutes of cooling down. The warm up and cool down sessions involved stretching of the upper and lower limbs.

Each Tai Chi class was led by a Tai Chi master and his assistants. The subjects in the Tai Chi group practiced a modified 8-formYang style Tai Chi (Figure 2.2). The forms included were selected to focus on joint sense, lower limb muscle strength and balance control while being suitable for older people with visual impairment. Each of the 8 forms derives from the basic forms of traditional Tai Chi. The features and physical functions of each form is shown in Table 2.1. A previous study (Lee, Jones, & Tsang, 2010) showed that these forms require relatively large displacements of the center of mass, which could help to provide training in balance control. The movements involved weight shifting and stepping in different directions. Verbal cuing and physical guidance were given to help the subjects understand the movements more easily.

Form 1
Starting
(起式)

Form 2
Parting the wild horse's mane
(野馬分鬃)

Form 3
White crane spreads its wings
(白鶴亮翅)

Form 4
Brush knee, push
(摟膝拗步)

Form 5
Playing the lute
(手揮琵琶)

Form 6
Repulse monkey
(倒卷肱)

Form 7
Cross hands
(十字手)

Form 8
Close
(收式)

Figure 2.2 The modified 8-forms of Yang style Tai Chi

Table 2.1 The features and physical functions of the 8-forms

English Name	Features	Physical Function	Training focus
Starting	- Standing - Lowering of centre of mass	1. To prepare and relax whole body 2. To locate optimal knee flexion level for subsequent forms 3. Mind concentration	Muscle strength Proprioception
Parting the wild horse's mane	- Trunk rotation - Single-leg stance - Weight shift forward & backward	Single-leg stance balance	Muscle Strength Proprioception Balance (anterior-posterior)
White crane spreads its wings	- Weight shift backward - Body weight shifted to hind leg (L) - Arms hanging in the air	Single-leg stance balance	Muscle Strength Balance (anterior-posterior)
Brush knee, push	- Weight shift forward & backward - Trunk rotates forward	Anterior-posterior balance	Muscle Strength Balance (anterior-posterior)
Playing the Lute	- Sits on hind leg	Single-leg stance balance	Muscle Strength Balance (anterior-posterior)
Repulse monkey	- Hind leg remains bent - Trunk rotation - Weight shifted backwards	1. To sustain hind leg knee flexion longer 2. To walk backward	Lower limb muscle endurance Proprioception Prevent falls when stepping back
Cross hands	- Continuous weight shifting from left to right and back	1. To train knee joint sense 2. To cool down the body	Muscle strength Proprioception
Close	- Relax	Completion of all the forms	Relaxation

Subjects in the control group participated in a music therapy activity. The subjects were taught to play the Djembe, a percussion instrument used in ceremonial dances in West Africa. The subjects sat on armless chairs with drum placed between the legs. Before starting to play the Djembe, their hands rested comfortably flat on the head of the drum at a 90-degree angle to each other. They then struck the drum using both hands to make different tones.

Participants must attend at least 75% of the sessions (36 sessions) in order to take part in the post-intervention assessment.

2.7 Outcome measures and assessment protocols

Passive knee joint repositioning test

Knee proprioception was assessed using the passive knee joint repositioning test. Elderly persons prone to falls often have significantly reduced lower limb proprioception (Lord, Rogers, Howland, & Fitzpatrick, 1999). In this study the dominant leg was first determined by having the subject kick a ball. The subject then sat in the chair of a Cybex Norm dynamometer (Cybex International Inc., Ronkonkome, NY) with the hips fixed in 60° of flexion. The seat was adjusted so that the edge of the seat was 4-6 cm from the popliteal fossa of the knee to ensure that the subject's cutaneous sensation of pressure was minimized. To further minimize the influence of cutaneous input, an air splint at 20 mm Hg was applied to the tested ankle. The test leg was positioned to align the rotation axis of the dynamometer's knee adaptor with the subject's lateral femoral epicondyle. A malleable electrogoniometer (Penny and Giles Biometric Ltd., type XM180, Blackwood, UK) was then attached to the lateral aspect of the knee with the proximal attachment aligned with the femoral axis between the greater trochanter and lateral femoral epicondyle. The distal attachment was positioned in line with the fibular axis between the fibular head and the lateral malleolus. The subject was then blindfolded to begin the test.

For the test itself, the knee was passively extended at a constant angular velocity of approximately 3 degrees/second from the initial position of 30 degrees of knee flexion. After 3 degrees of extension, it was held for 3 seconds in the target position before being returned passively to the initial position. The subject was instructed to press a thumb switch when he or she perceived that the knee had regained the original position. However, a random interval of 3 to 8 seconds before extension was included to minimize the possibility of the subjects "counting" to estimate the return. A surface electrode (NeuroCom International Inc., Portland, USA) was used to detect electromyographic activity in the thenar eminence muscles (mainly the flexor pollicis brevis) of the subject's thumb to indicate the moment when the subject perceived that the knee had regained the target position. The EMG signals from the thumb muscles were monitored in real time to ensure that there was a quiet baseline before the subject pressed the thumb switch. The signals from the electrogoniometer, thumb switch, and EMG were stored (through an A/D card, DataQ Instruments Inc., type DI-720P, Akron, USA) for off-line analysis. Each subject completed 3 trials. The error with which the subject reproduced the initial position was calculated. The 3 absolute error values were averaged, and the average value, termed the *absolute angle error*, was used for comparing the groups. High test-retest reliability (0.9 with a CI of 0.64-0.97) has been demonstrated for this procedure in a previous study (Tsang & Hui-Chan, 2003).

Muscle strength:

Decreased muscle strength is an intrinsic cause of falls in older adults (Vandervoort, 2002). In this study, the Cybex Norm dynamometer was used to test the concentric isokinetic strength of the knee extensors and flexors of the subjects' dominant legs. Subjects sat on the dynamometer's chair with the hips kept at 70° of flexion. The dominant leg was secured to the dynamometer's knee adaptor with the rotation axis aligned with the lateral femoral epicondyle. The dynamometer set the starting position at 90 degrees of knee flexion and the endpoint at full knee extension. In addition, knee muscle strength was measured at an angular velocity of 30 degrees/second. Before practice trials and testing, the subjects performed a 5-minute warm-up, which consisted of stretching the quadriceps and hamstring muscles. Practice trials consisted of three sub-maximal repetitions of concentric contractions to ensure reliable data in the isokinetic muscle testing (Chan, Maffulli, Korkia, & Li, 1996). Five maximal contractions of the concentric knee extensors and flexors were recorded following a one minute resting period after the practice trials. The reliability has been established in a previous study with ICC ranging from 0.86 to 0.97 for these testing conditions (Tsang & Hui-Chan, 2005).

Sensory Organization Test

A Sensory organization test (SOT) was used to measure the subjects' ability to use somatosensory, visual, and vestibular information to control body sway when standing under reduced or conflicting sensory conditions (Figure 2.3). Deterioration in balance control under reduced or conflicting sensory conditions has been found to be related to falls in older subjects (Ho, Mak, & Hui-Chan, 1998). In this study, the subjects stood on a support platform (Smart EquiTest, NeuroCom International, Inc.) without shoes while wearing a security harness to prevent them from falling. They were instructed to stand quietly with their arms at their sides and eyes looking forward. During the SOT, the support platform and/or the visual field could be "sway referenced", so that one or both moved in the same direction and with the same magnitude as the subjects' anteroposterior sway. The subjects' task was to stand with as little sway as possible for 20 seconds under each of the following six sensory conditions. In conditions 1, 2, and 3 the subjects stood on a fixed platform with their eyes open, eyes closed, and looking at a sway-referenced visual field (which produces conflicting visual signals), respectively. In conditions 4, 5, and 6, the subjects stood on a sway-referenced platform (to minimize ankle somatosensory input) under the same three visual conditions. For each condition, three trials were performed. Body sway angles in the anteroposterior direction were estimated from the force data collected, and the three results were averaged for statistical comparison. The reliability of this procedure has been established in a previous study with ICC ranging from 0.72 to 0.93 for the six conditions (Tsang et al., 2004).

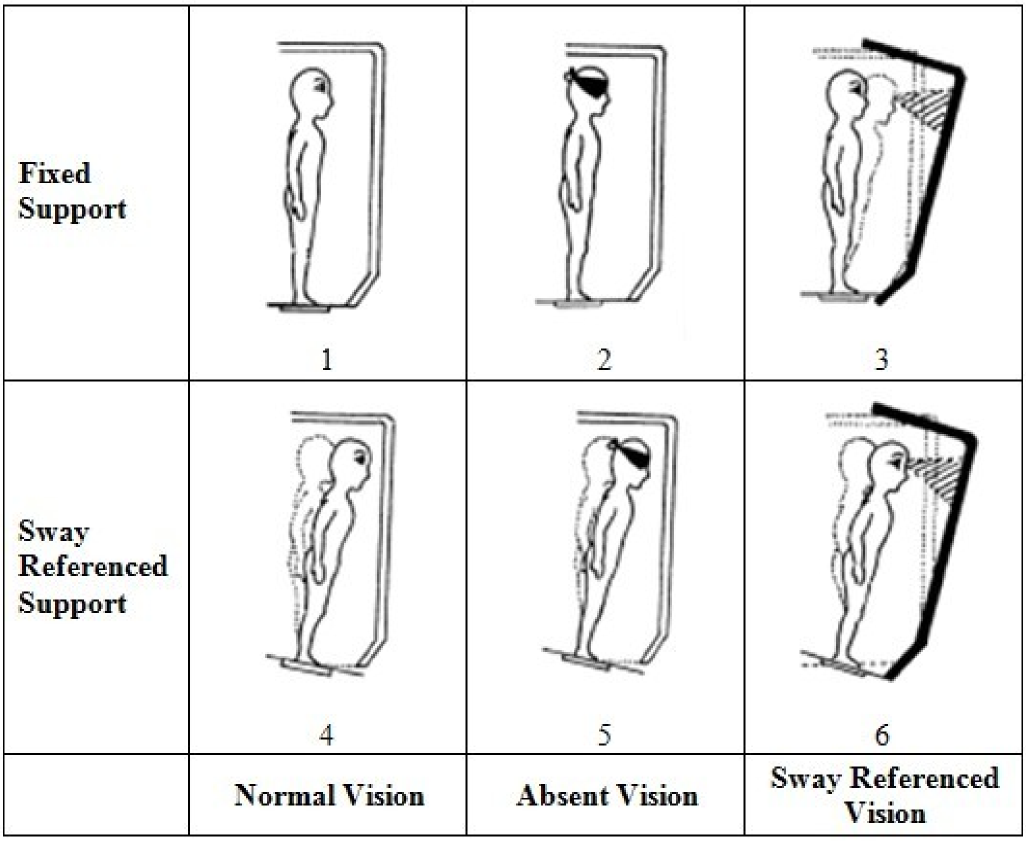

Figure 2.3 The 6 conditions of the sensory organization test.

Perturbed double-leg stance test

The perturbed double-leg stance test (PDLST) assessed the ability of the automatic motor system to quickly recover following an unexpected external disturbance (Figure 2.4). Subjects were asked to stand upright with arms by their sides. Large platform translations in the forward and backward directions, which were scaled to the subject's height, were applied randomly with the subject's eyes open and closed. The body sway was first recorded for 2 seconds before the platform translation. The average of the body sway angles during the 2 seconds served as the baseline. After the platform translation, the maximum body sway angle was estimated and the difference from the baseline value, termed the *perturbed body sway angle*, was calculated. Three trials were performed for each perturbation direction, and the average value was used for comparison. If any subject fell in response to the platform translation, an angle of 12.5 degrees, the theoretical anteroposterior sway stability limit, was assigned as the perturbed body sway angle for that test (NeuroCom, 2000). A “fall” was recorded if the subject touched the visual surround for support, or gained support by stepping forward, or was supported by the investigators.

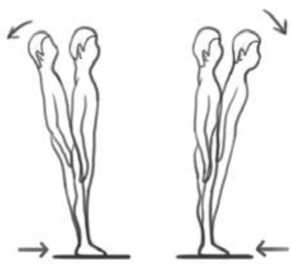

Figure 2.4 Perturbed double-leg stance test.

Five times sit-to-stand test

Rising from a chair is an important task of daily living which many elderly people find challenging. The inability of rise, especially quickly, has been associated with an increased risk of falling (Tinetti et al., 1988). The five times sit-to-stand test (FTSTST) has previously been used to test functional leg muscle strength and balance control (Csuka & McCarty, 1985).

The time taken to complete 5 repetitions of the sit-to-stand maneuver from a chair was measured. The repetitions were performed from a hard chair without arm rests 43cm high and 47.5cm deep. A total of 5 trials were timed for each subject, with a 1 minute rest between trials as needed to prevent fatigue. The first 2 trials were considered practice trials for familiarization purposes. The average time of the last 3 trials was used for analysis. The standardized instructions given can be translated as follows. "On the count of 3, please stand up and sit down 5 times as quickly as possible. Place your hands in your lap and do not use them throughout the procedure. Lean your back against the chair's backrest at the end of every repetition." The time was recorded from when the subject's back left the backrest on the first repetition until their back touched the backrest after the last repetition (Mong, Teo, & Ng, 2010).

Fear of falling

The Falls Efficacy Scale – International (FES-I) (Appendix G) was used to determine the participants' fear of falling (Yardley et al., 2005). This 16-item instrument assesses the intensity of concern about falling when performing easy to more demanding physical and social activities. The FES-I was derived from the Falls Efficacy Scale (FES) (Tinetti, Richman, & Powell, 1990), which is one of the instruments most frequently used to assess for fear of falling with elderly populations. An advantage of the FES-I is that it covers a wider range of activities, both physical and social. It is a questionnaire consisting of sixteen items scored on a four point scale ranging from 'not at all concerned' to 'very concerned'. It includes all the questions from the original FES plus six items that assess walking on slippery, uneven or sloping surfaces, visiting friends or relatives, going to a social event, and walking in a crowded place. Participants were asked how concerned they were about falling while completing various tasks in varying situations. This test has been shown to have excellent internal and test-retest reliability (Yardley et al., 2005).

2.8 Statistical analysis

For the cross-sectional samples study, the groups' average ages, heights, weights, and MMSE results were compared using one-way analysis of variance (ANOVA). Post hoc analysis using Bonferroni's adjustment was conducted if a significant difference was found. A chi-squared test was applied for among-group comparison of genders. A Kruskal-Wallis test was used to compare the FAC and physical activity levels. If a significant difference was found, a Mann-Whitney test was conducted for between-group comparison. For among-group comparison of the FTSTST and FES-I results, one-way ANOVA was employed. Post hoc analysis using Bonferroni's adjustment was again conducted if a significant difference was found. Multivariate ANOVA was used initially to explore how performance on all the balance control and muscle strength tests differed among the 3 groups. If a statistically significant difference was found, univariate tests were used to analyze each component of these differences. Post hoc analysis using Bonferroni's adjustment was conducted if a significant difference was found in the univariate tests.

For the randomized clinical trial, the groups' average ages, heights, weights and MMblind results were compared using independent t-tests. A chi-squared test was applied for between-group comparison of gender, the level of visual impairment, and functional ambulation classification. To compare any changes in the outcome measures, percentage changes were calculated between the two groups after intervention. The passive knee joint repositioning test results were compared using independent t-tests. For the muscle strength, SOT and PDLST results, multivariate analysis of variance was used to determine the overall statistical significance of any differences. Univariate tests were used if a significant difference was found in the multivariate analyses of variance. The baseline outcome measures were compared by independent t-test. A significance level of 0.05 was chosen for all the statistical comparisons.

CHAPTER 3

BALANCE CONTROL IN VERY OLD ADULTS WITH AND WITHOUT VISUAL IMPAIRMENT

Publication

Chen EW, Fu SN, Chan KM and Tsang WWN. Balance control in very old adults with and without visual impairment. Age and Ageing (to be submitted)

3.1 Abstract

Background: Good balance is an important ability in controlling body movement, but it declines with age. In addition, balance control appears to diminish when visual input is restricted. Few studies have previously investigated balance control among visually impaired very old adults.

Objective: To explore whether the balance control of the very old differs with varying degrees of visual impairment.

Design: Cross-sectional study.

Setting: Community centers and residential care homes.

Subjects: Thirty-three visually impaired (17 = low vision; 16 = blind) and 15 sighted elderly aged ≥ 70 years participated in the study.

Methods: All participants were assessed in terms of: 1) concentric isokinetic strength of the knee extensors and flexors; 2) a sensory organization test to measure their ability to use somatosensory, visual, and vestibular information to control standing balance; 3) a perturbed double-leg stance test to assess the ability of the automatic motor system to quickly recover following an unexpected external disturbance; 4) the five times sit-to-stand test; 5) the international version of the falls efficacy scale to determine their fear of falling.

Results: Compared with low vision subjects, the sighted elderly achieved higher average peak torque-to-body weight ratios in concentric knee extension. The sighted elderly on average showed less body sway than the low vision and blind subjects in sensory conditions where they had visual inputs to help them maintain standing balance. The sighted and low vision subjects achieved smaller average body sway

angles during forward and backward platform translations compared to the blind subjects. The sighted elderly also reported less fear of falling than those with low vision.

Conclusions: Low vision and blind elderly persons have poorer balance control than the sighted elderly for both physiological and psychological reasons. Vision plays an important role for the very old in controlling their balance in challenging circumstances.

Key words: elderly, visual impairment, balance control, fear of falling

3.2 Introduction

Good balance is an essential skill in controlling body movement. However, as one ages the ability to maintain balance control deteriorates. This decline can be attributed to decline in the somatosensory, visual, and vestibular systems to varying degrees (Baloh et al., 1993; Baloh et al., 2003; Enrietto et al., 1999; Skinner et al., 1984). The incidence of visual impairment has also been shown to increase rapidly with age (Congdon et al., 2004; Klaver et al., 1998). In Hong Kong, the overall prevalence of visual disability is 9.4% among people younger than 60 years but 75.6% among people aged over 60 (Hong Kong Blind Union, 2001). It has been suggested that people with vision loss may partially compensate by relying more on proprioceptive and/or vestibular cues for balance (Di Girolamo et al., 1999; Elliott et al., 1995). However, with increasing age there is a decline in joint proprioception and vestibular acuity (Skinner et al., 1984; Tsang & Hui-Chan, 2004). In addition, the elderly experience age-related declines in the lower limb muscle strength

(Sturnieks et al., 2008) needed to maintain standing and walking balance. As a result, balance control is a major problem in older individuals with visual impairments (Lee & Scudds, 2003; Maeda et al., 1998). Furthermore, the prevalence of fear of falling also increases with age (Arfken et al., 1994), and it is associated with visual function (Fletcher & Hirdes, 2004), making visual impairment one of the risk factors for falling (Lundebjerg et al., 2001).

Previous studies have investigated the balance control of sighted elderly persons, but the balance performance of very old adults with visual impairment has been little studied. Whether or not balance control differs with varying degrees of visual impairment also remains to be answered.

3.3 Methods

3.3.1 Subjects and Study Design

Seventeen low vision subjects (1 male, 16 females; mean age = 82.9±5.4 years), and sixteen blind subjects (1 male, 15 females; mean age = 82.2±8.1 years) were recruited from residential care homes of the Hong Kong Society for the Blind. Fifteen sighted subjects (3 males, 12 females; mean age=79.7 ± 5.2 years) were recruited from the community. All the subjects were recruited by convenience sampling. All the subjects were independent walkers, independent in their activities of daily living, and able to communicate and follow the testing procedures. Candidates were excluded if they had any vestibular problems, symptomatic cardiovascular disease at a moderate exertion level, poorly controlled blood pressure, a history of neurologic disease (e.g. Parkinson's disease), acute orthopedic problems that affected ambulation, or metastatic cancer. All of the subjects underwent 2 screening tests.

1. Functional ambulation classification (FAC) (please refer to Appendix A) resulting in a classification of level 3 or above.

2. The visual acuity of the visually impaired subjects was recorded from their recent medical records, and the visual acuity of sighted subjects was checked using the Snellen eye chart. Low vision was defined as visual acuity of less than 6/18 but equal to or better than 3/60 in the better eye with the best possible correction. Blindness was defined as visual acuity of less than 3/60 in the better eye with the best possible correction. Normal vision was defined as visual acuity of better than 6/18 on the Snellen eye chart in the better eye with the best possible correction (WHO, 2007).

The results of Mini-Mental Status Examination (MMSE) and the modified physical activity questionnaire were used to compare among three groups. Scores of MMSE reflects the cognitive status (MF. Folstein, WE. Folstein, & McHugh, 1975). The modified physical activity questionnaire (Van Heuvelen et al., 1998) which categorized the subjects' daily activities using metabolic index units (METs) as either light (<4 METs), moderate (4-5.5 METs), or heavy (>5.5 METs), reflects energy expenditure (Tsang & Hui-Chan 2003).

The protocol was approved by the Ethics Committee of The Hong Kong Polytechnic University, and informed consent was obtained from all subjects. Those who could not sign used their fingerprint as a signature.

3.3.2 Test Procedures

All the participants underwent the following assessments.

3.3.2.1 Muscle strength

The concentric isokinetic strength of the knee extensors and flexors of each subject's dominant leg (the leg which they used for kicking a ball) were tested using a Cybex Norm dynamometer. Knee muscle strength was measured at an angular velocity of 30 degrees/second. Before starting, the subjects performed a 5-minute warm-up which included stretching the knee muscle groups. After 3 sub-maximal practice trials, five maximal concentric contractions of the knee extensors and flexors were recorded. The reliability of such testing has been established in a previous study with ICC ranging from 0.86 to 0.97 for these testing conditions (Tsang & Hui-Chan, 2005).

3.3.2.2 Sensory organization test

A sensory organization test (SOT) was used to measure the subjects' ability to use somatosensory, visual, and vestibular information to control body sway when standing under reduced or conflicting sensory conditions. The subjects' task was to stand on a force platform with as little sway as possible for 20 seconds under six sensory conditions (Figure 2.3): 1) standing on a fixed surface with the eyes open; 2) standing on a fixed surface with the eyes closed; 3) standing on a fixed surface with sway referenced vision, where the visual surround moves in the same direction and with the same amplitude as any postural sway; 4) standing with the eyes open on a sway referenced surface, where the support surface moves in the same direction and the same amplitude as any postural sway; 5) standing on a swayed referenced surface with the eyes closed; and 6) standing on a sway referenced surface with a sway referenced visual surround. For each condition, three trials were performed. Body sway angle in the anteroposterior direction was estimated from the force data collected, and the three results were averaged for statistical comparison. The reliability of this procedure has been established in a previous study with ICC ranging from 0.72 to 0.93 for the six conditions (Tsang et al., 2004).

3.3.2.3 Perturbed double-leg stance test

A perturbed double-leg stance test (PDLST) was used to assess the ability of the automatic motor system to quickly recover following an unexpected external disturbance. Subjects stood with the eyes open and closed on a platform which suddenly and randomly applied an anteroposterior body sway angle of 3.2 degrees, scaled to the subject's height, in the forward or backward direction (Figure 2.4). Body sway was first recorded for 2 seconds before the platform translation, and the average sway observed served as a baseline. After each platform translation, the maximum body sway angle was estimated and the difference from the baseline value, termed the *perturbed body sway angle*, was calculated. The perturbed body sway angles of three trials for each perturbation direction were averaged, and the averages were used to compare the three groups. A value of 12.5 degrees, the theoretical anteroposterior sway stability limit, was assigned as the perturbed body sway angle if any subject fell during the platform translation (NeuroCom, 2000). A “fall” was recorded if the subject touched the visual surround for support, or gained support by stepping forward, or required support by the investigators.

3.3.2.4 Five times sit-to-stand test

The five times sit-to-stand test (FTSTST) measures the time taken to complete 5 repetitions of standing from a chair. All sit-to-stand repetitions were performed from a hard chair 43 cm high and 47.5 cm deep without arm rests. Following standardized instructions, each subject completed 5 trials with 1 minute of rest between trials as needed to prevent fatigue. The first 2 trials were practice trials for familiarization purposes. The mean time of the last 3 trials was used for analysis. The time was recorded from when the subject’s back left the backrest on the first repetition and stopped when their back touched the backrest on the last repetition (Mong et al., 2010).

3.3.2.5 Fear of falling

The international version of the falls efficacy scale (FES-I) was used to assess the participants’ fear of falling (Yardley et al., 2005). The FES-I covers a wider range of activities, both physical and social. It is a questionnaire consisting of sixteen items scored on a four point scale ranging from ‘not at all concerned’ to ‘very concerned’ (Appendix F). Participants were asked how concerned they were about falling while completing various tasks in varying situations. This test has been shown to have excellent internal and test-retest reliability (Yardley et al., 2005).

3.3.3 Statistical Analysis

The groups' average ages, heights, and weights, and MMSE scores were compared using one-way analysis of variance (ANOVA). Post hoc analysis using Bonferroni's adjustment was conducted if a significant difference was found. A chi-square test was applied for among-group comparison of gender. A Kruskal-Wallis test was used to compare the FAC and physical activity level data. If a significant difference was found, a Mann-Whitney test was conducted for between-group comparison. For among-group comparison of the FTSTST times and FES-I results, one-way ANOVA was employed. Post hoc analysis using Bonferroni's adjustment was again conducted if a significant difference was found. Multivariate ANOVA was used initially to explore how performance on all the balance control and muscle strength tests differed among the 3 subject groups. If a statistically significant difference was found, univariate tests were used to analyze each component of these tests. Post hoc analysis using Bonferroni's adjustment was conducted if a significant difference was found in the univariate tests. A significance level of 0.05 was chosen for the statistical comparisons.

3.4 Results

3.4.1 Subjects

There were 17 low vision subjects, 16 blinded subjects, and 15 sighted subjects who completed all of the assessments. Table 3.1 summarizes the demographic results and shows that there were no significant differences in average age, gender, or weight among the three groups. One-way ANOVA showed an overall significant difference in both height and MMSE results ($p < 0.05$). Subsequently, a post-hoc test was conducted which showed that the sighted elderly were on average taller than those with low vision. The MMSE scores of the sighted elderly were higher than those of the other two groups with visual impairment. The Kruskal-Wallis test showed an overall significant difference in average FAC and physical activity levels among the three groups ($p < 0.05$). The post-hoc test showed that the sighted elderly had significantly better average FAC scores than the blind subjects, and higher average physical activity levels than both of the other two groups with visual impairment.

Table 3.1 Demographic characteristics of the three groups

Characteristics	**Sighted subjects (n=15)**	**Low vision subjects (n=17)**	**Blind subjects (n=16)**	***p***
Age (years)	79.7 ± 5.2	82.9 ± 5.4	82.2 ± 8.1	0.342
Gender (male/female)	3 /12	1 /16	1 /15	0.342
Height (cm)	153.5 ± 7.3**	145.2 ± 6.0	147.9 ± 6.7	0.004*
Weight (kg)	56.2 ± 10.1	52.4 ± 10.6	52.5 ± 8.0	0.471
MMSE score	26.0 ± 2.5†	21.2 ± 4.3	20.3 ± 3.2	0.000*
FAC	5 (5, 5)‡	5 (3, 5)	4 (3, 4)	0.003*
Physical activity levels				0.001*
Light < 4 METs	n = 9‡	n = 17	n = 16	
Moderate 4-4.5 METs	n = 6	n = 0	n = 0	
Heavy > 5.5 METs	n = 0	n = 0	n = 0	

NOTE. Values are mean ± SD, except the values for FAC were the median and (25^{th}, 75^{th} percentiles) are shown.
Abbreviations: MMSE, Mini-Mental Status Examination; FAC, Functional ambulation classification; MET, metabolic equivalent.
* Denotes a difference significant at the $p < 0.05$ level using one-way ANOVA or a Kruskal-Wallis test.
** Denotes a difference significant at the $p < 0.05$ level between sighted subjects and low vision subjects by means of post hoc analysis using Bonferroni's adjustment.
† Denotes a difference significant at the $p < 0.05$ level between the sighted subjects on the one hand, and the two groups of subjects with visual impairment, by means of post hoc analysis using Bonferroni's adjustment.
‡ Denotes a difference significant at the $p < 0.05$ level between sighted subjects and subjects with visual impairment by means of post hoc analysis using a Mann-Whitney test.

3.4.2 Muscle strength

Multivariate ANOVA of the knee strength results indicated an overall statistically significant difference among the three groups (p = 0.025). The univariate tests showed statistically significant differences in the average concentric knee extensor peak torque-to-body-weight ratios (p = 0.015). Compared to the low vision subjects (0.5±0.2%), the sighted elderly achieved higher concentric knee extensor peak torque-to-body-weight ratios (0.8±0.4%; $p = 0.024$). The torques of the blind subjects (0.7±0.3%) were not, on average, significantly different from those of the low vision subjects ($p = 0.06$) or the sighted subjects ($p = 1.000$).

3.4.3 Sensory Organization Test

The multivariate ANOVA of the SOT results showed an overall significant difference among the three groups ($p < 0.001$; Figure 3.1). The univariate tests indicated differences among the groups in the conditions one ($p = 0.018$) and four ($p < 0.001$). In condition one, sighted subjects had significantly higher equilibrium quotients (mean = 93.9±1.9%) than the blind subjects (mean = 91.5±2.5%; $p = 0.022$). In condition four, the sighted subjects equilibrium quotients (mean = 63.1±24.5%) were significantly higher than those of the low vision (mean = 24.6±25.7%) and blind subjects (17.1±22.7%) (both $p < 0.001$).

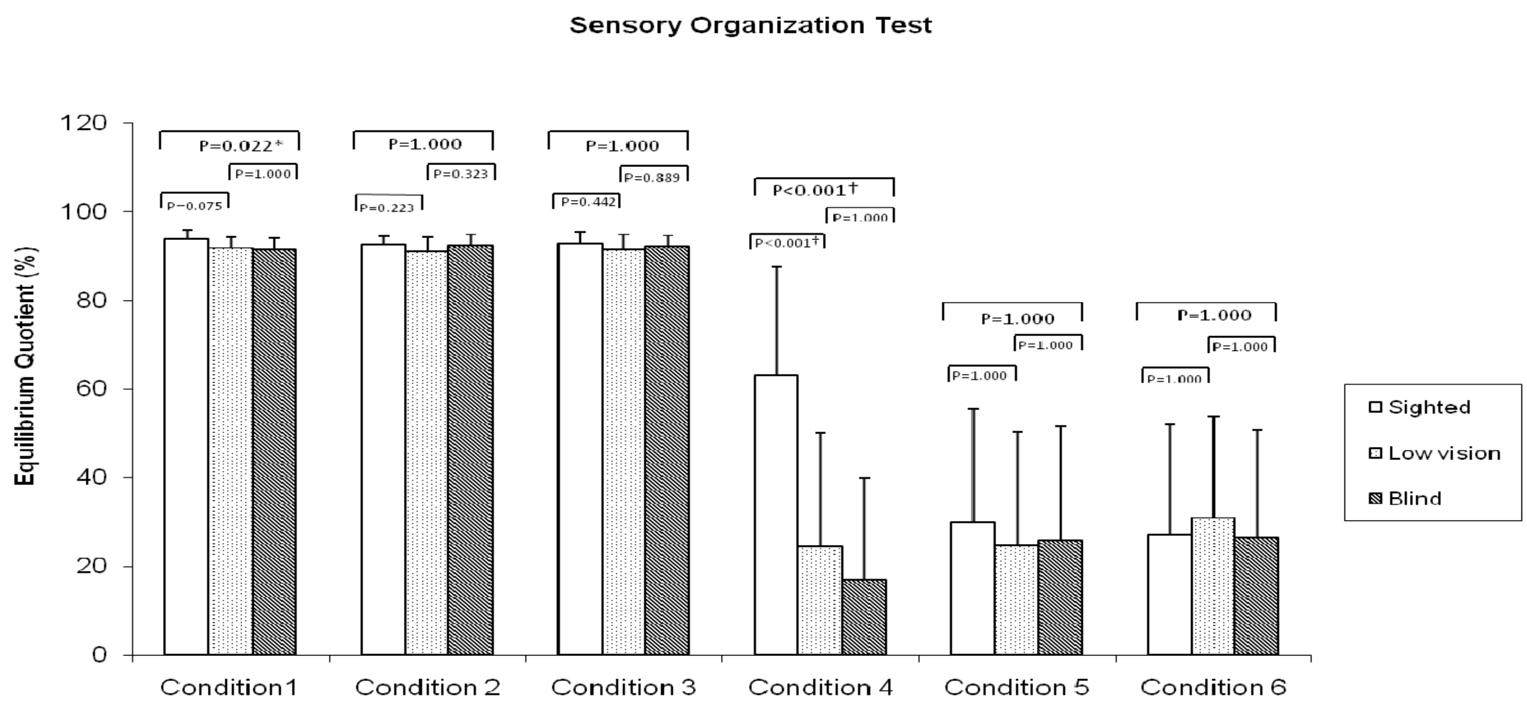

Figure 3.1 Average equilibrium quotients on the SOT among sighted subjects, subjects with low vision and blind subjects.
† Denotes difference significant at the $p < 0.001$ ($*p < 0.05$) confidence level

3.4.4 Perturbed double-leg stance test

The multivariate ANOVA of the PDLST results indicated an overall statistically significant difference among the three groups (p = 0.047; Figure 3.2). The univariate tests showed that sighted subjects and the low vision subjects achieved less body sway during the forward (means = 4.0±0.6° and 4.4±1.7°, respectively) and backward (means = 4.1±1.0° and 4.6±1.7°, respectively) platform translations with the eyes open compared to the blind subjects (means = 7.1±3.5°and 7.1±3.9°).

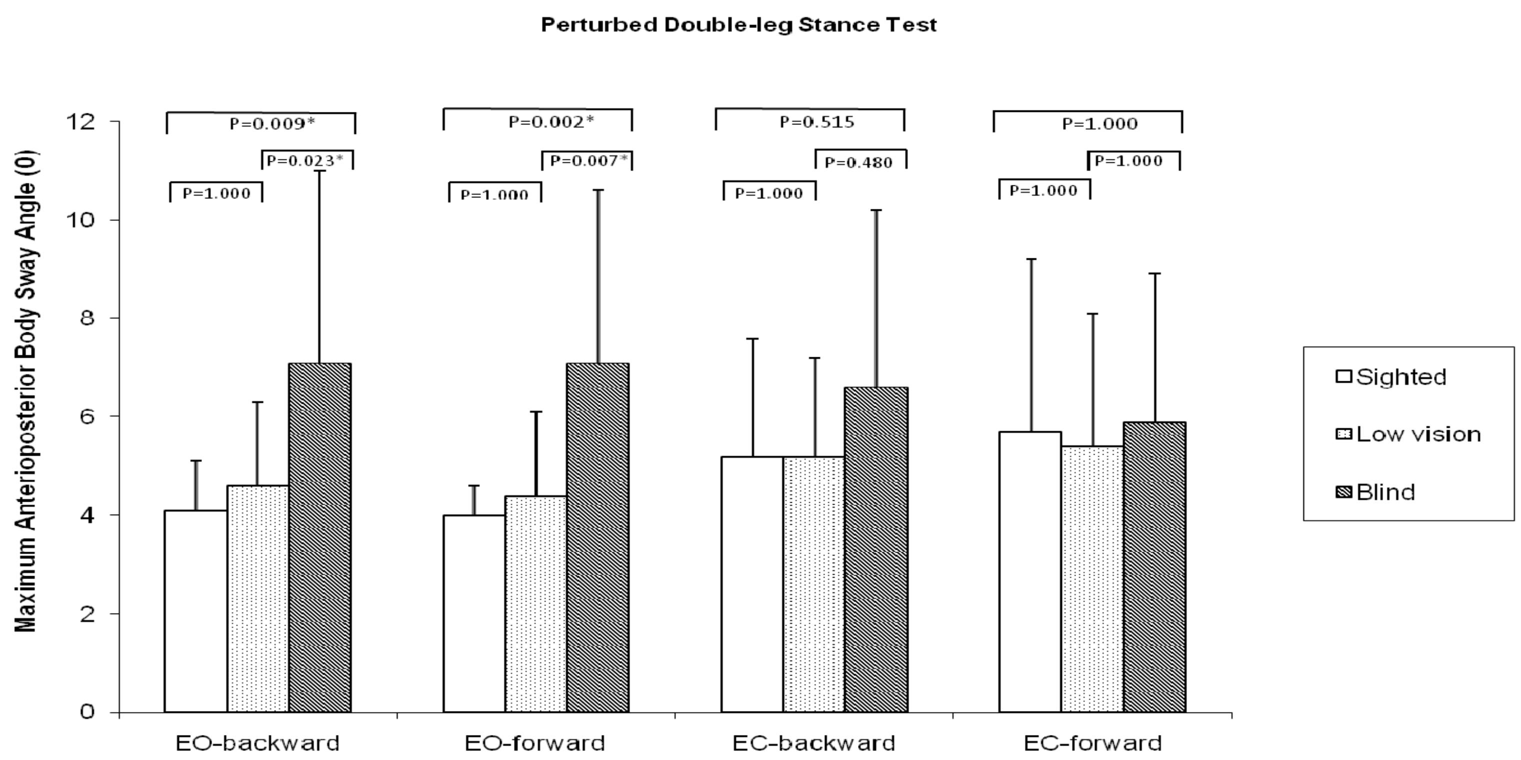

Figure 3.2 Results of the perturbed double-leg stance test among sighted subjects, subjects with low vision and blind subjects.
Abbreviations: EO, eyes open; EC, eyes closed.
* Denotes a difference significant at the p <0.05 level

3.4.5 Five times sit-to-stand test

The three groups showed no significant differences in their average performance on the FTSTST ($p = 0.185$). The sighted subjects had an average time of 15.3±3.3 seconds, the subjects with low vision had a time of 18.8±8.4 seconds, while the blind subjects had a time of 15.1±5.5 seconds.

3.4.6 Fear of falling

One-way ANOVA indicated that the sighted subjects reported significantly less fear of falling than the low vision subjects (average scores of 28.8±8.1 and 40.8±14.3, respectively; $p = 0.017$). The blind group (34.6±11.1) showed no significant difference from the low vision group ($p = 0.407$) and the sighted groups ($p = 0.499$).

3.5 Discussion

As might be expected, the sighted elderly attained better functional ambulation categories and scored higher in their physical activity levels than the visually impaired. A study by Crew and Campbell (2001) has previously reported that elderly people aged 70 and older with visual impairment often encounter activity limitations. This makes them less physically active and leads to reduced physical functioning. The findings of this study provide further evidence of greater decline in physical activity levels and functional ambulation in those with visual impairment. This amplifies the importance of finding a form of exercise that is suitable for this population to help improve physical functioning.

Also, these very old adults with visual impairment performed less well in certain balance control maneuvers and showed less knee extensor muscle strength than the sighted controls similar in age and gender distribution. The data confirm that vision plays an important role in controlling balance, especially in challenging circumstances. When standing on a firm surface during the SOT, all three groups achieved high equilibrium quotient scores (> 90%; Figure 3.1) regardless of the visual conditions. This suggests that visual impairment may not influence significantly the postural sway of the elderly in unchallenging conditions. Indeed, a study by Fitzpatrick and McCloskey (1994) has shown that proprioception in the lower limbs is the most important sensory input for controlling postural sway in unchallenging conditions. However, when standing on a sway-referenced surface and allowed visual input, the sighted elderly attained significantly higher equilibrium scores (condition 4 of the SOT). In this condition the subjects had to rely on visual inputs to maintain their balance, as the somatosensory inputs were misleading. This is in line with the results reported by Lord and Menz (2000), who concluded that visual impairment is strongly associated with increased sway when standing on a compliant surface. Poor performance in condition 4 of the SOT is an alarming sign and could account for the greater incidence of falls among those with visual impairment (Wallmanee, 2001). On the other hand, when visual input was distorted or taken away, the sighted elderly had no better balance performance than the visually impaired groups. In condition 5 subjects had to rely on vestibular inputs as there was no visual input allowed. The results confirm the importance of visual information from the environment as source of feedback for balance control (Stones

& Kozma, 1987). Outdoor surfaces are often compliant, which, according to the results of this study, should increase the body sway of older adults with visual impairment. Such unsteadiness in posture may explain the decreased physical activity of this group.

The SOT has been conducted with younger subjects (mean age 51.6 years) in a study by Chen, Fu, & Tsang (2010). The average equilibrium quotient (EQ) score of our sighted subjects in condition 4 was 12.7% lower than that of that younger group and that of our subjects with visual impairment was lower by 56%. This indicates that the balance abilities of visually impaired individuals decrease more than those of sighted individuals as they age. The dramatic difference in balance ability highlights the need for visually impaired persons to work at improving their balance control capability.

In the PDLST, the blind elderly swayed significantly more after being perturbed either forward or backward than the sighted and low vision subjects when their eyes were open (Figure 3.2). When there was no visual input allowed during the perturbation, no significant difference among the three groups was observed. These findings are consistent with the "two-mode" theory of vision (Held, 1970). According to this theory, visual information reaches an individual in ambient and focal modes. Ambient vision is responsible for orientation and locomotion, while focal vision is responsible for object recognition and identification. This theory further asserts that controlling postural sway relies heavily on the ambient visual mode. Based on this theory, our sighted and low vision elderly apparently made use of their ambient vision to react to an external perturbation, while the blind could not.

In performing daily activities one has to react to unstable support surfaces, such as when stepping onto a moving escalator or walking in the aisle of a moving bus or train. Increased postural sway under perturbation may hinder subjects with visual impairment in such activities and discourage them from going outdoors.

A group led by Whitney has reported that the time on the FTSTST with optimal sensitivity and specificity for identifying a balance dysfunction in people older than 60 years is 14.2 seconds (Whitney et al., 2005). The mean times observed in this study were 15.3 seconds for the sighted subjects, 18.8 seconds for the low vision subjects, and 15.1 seconds for the blind subjects, all of whom were around 80 years old. This would indicate that all our subjects probably had some degree of balance dysfunction.

The results show that the low vision elderly have a greater fear of falling than their sighted counterparts. The blind, however, showed no significantly different fear of falling than the sighted elderly. These blind subjects lived in residential care homes, and most of them did not need to carry out the activities asked about in the FES-I. For the items that they did not encounter, the subjects were asked to imagine the situation and consider how much they would be concerned about falling. They might, therefore, have over-estimated their abilities and thus reported levels of fear similar to those of the sighted subjects.

Certain limitations of this study protocol restrict the generalisation of these results. The sample size was small, and most of the blind subjects were well taken care of in residential care homes and did not often encounter many of the situations asked of in the FES-I. Although each subject's visual acuity was verified, other aspects of vision degrade with aging, such as contrast sensitivity, central processing of visual input and visual perception, were not tested and may make important contributions to balance in the elderly.

The study has shown, however, that elderly persons with low vision have poorer balance control than the sighted elderly for both physiological and psychological reasons. These results confirm that vision plays an important role for old older adults in controlling balance in the more challenging circumstances encountered in daily living.

CHAPTER 4

THE EFFECTS OF TAI CHI ON THE BALANCE CONTROL OF ELDERLY PERSONS WITH VISUAL IMPAIRMENT

Publication

Chen EW, Fu SN, Chan KM and Tsang WWN. The effects of Tai Chi on the balance control of elderly persons with visual impairment. Age and Ageing (to be submitted)

4.1 Abstract

Background: Balance control is a major problem for older individuals with poor vision. Regular exercise produces the same positive physiological and psychological benefits for such individuals as for persons without a disability. There are limitations, however, for visually impaired elderly persons wishing to participate in exercise programs. The benefits of Tai Chi for balance control, muscle strength, and preventing falls have been demonstrated with sighted elderly subjects. This study was designed to extend those findings to elderly persons with visual impairment.

Objective: To investigate the effects of Tai Chi on the balance control of elderly persons with visual impairment.

Design: Randomized clinical trial

Setting: Residential care homes

Subjects: Forty visually impaired persons aged 70 or over

Methods: The participants were randomly divided into Tai Chi and control groups and assessed pre- and post-intervention using 4 tests: 1) passive knee joint repositioning to test knee proprioception; 2) concentric isokinetic strength of the knee extensors and flexors; 3) a sensory organization test to quantify an individual's ability to maintain balance in a variety of complex sensory conditions; 4) a perturbed double-leg stance test measured the ability of the automatic motor system to rapidly recover after a sudden external disturbance.

Results: After intervention, the Tai Chi participants showed improvements in balance control. They also had significant improvements in knee proprioception and in their visual and vestibular ratios compared to the control group.

Conclusions: Practicing Tai Chi can improve the balance control of visually impaired elderly persons.

Key words: elderly, visual impairment, balance control, joint proprioception

4.2 Introduction

Visual impairment is the disability that affects the largest number of people worldwide (WHO, 2008). It has long been known to increase rapidly with age (Congdon et al., 2004; Klaver et al., 1998). In Hong Kong, 9.4% of people less than 60 years old have a visual impairment, but this number rises to 75.6% in those over 60 years old (Hong Kong Blind Union, 2001). It has been shown that people with poor vision have poorer ability to control their balance (Ray et al., 2008), and it has been suggested that they compensate by relying more on proprioceptive and/or vestibular cues for balance (Di Girolamo et al., 1999; Elliott et al., 1995). However, joint proprioception and vestibular acuity also decreases with age (Baloh et al., 2003; Skinner et al., 1984; Tsang & Hui-Chan, 2004). Balance control is thus a major problem for older individuals with visual impairments (Lee & Scudds, 2003; Maeda et al., 1998).

Regular exercise is important for the elderly to maintain their physical fitness (Taylor-Piliae, 2003). In fact, regular exercise among individuals with visual impairment produces positive physiological and psychological benefits similar to those accruing to individuals without a disability (Leverenz, 2009). However, older individuals who are visually impaired are less physically active than the sighted elderly (Crews & Campbell, 2001), leading to reduced physical functioning and well-being (Chia et al., 2004; Salive et al., 1994). Of course, any exercise should be safe, easy and convenient enough for such individuals. Tai Chi has been suggested as a suitable form of exercise for those with visual impairment (Miszko et al., 2004). It is a mind-body exercise which has been practiced for centuries in China to promote health and physical fitness, particularly among the elderly. A number of studies with sighted elderly subjects have proven that Tai Chi can benefit their balance control and muscle strength, and decrease the incidence of falls (Hong et al., 2000; Tsang & Hui-Chan, 2005; Wolf et al., 1996). The present study was designed to investigate the effects of Tai Chi on the balance control of elderly subjects with visual impairment.

4.3 Methods

4.3.1 Subjects and Study Design

This was a randomized, single-blind, controlled clinical trial. Forty visually impaired elderly persons recruited from residential care homes were randomly divided into either a Tai Chi group (n=21; mean age = 85.5±6.9 years) or a control group (n=19; mean age = 82.9±7.5 years). The subjects were recruited by convenience sampling. Stratified randomization was used, and the stratified factors were age (65-74 years, 75-84 years, 85+ years), sex (female or male), and the level of visual impairment (low vision or blind). All the participants were independent in walking and the activities of daily living, able to communicate and follow testing procedures, and had no previous Tai Chi experience. Candidates were excluded if they had any vestibular problems, symptomatic cardiovascular disease at a moderate exertion level, poorly controlled blood pressure, a history of neurologic disease like Parkinson's disease, acute orthopedic problems that affected ambulation, or metastatic cancer. All the subjects underwent 2 screening tests:

1. Functional ambulation classification (FAC) (please refer to Appendix A) on which they received a grade of 3 or better (Holden et al., 1984).

2. The subjects' visual acuity was recorded from their recent medical records. Low vision was defined as visual acuity of less than 6/18 but equal to or better than 3/60 in the better eye with the best possible correction. Blindness is defined as visual acuity of less than 3/60 in the better eye with the best possible correction (WHO, 2007).

In addition, they were required to complete the Mini-Mental Status Examination for the visually impaired (MMblind) and a physical activity questionnaire. MMblind (Reischies & Geiselmann, 1997) was used to record subjects' cognitive status. The modified physical activity questionnaire (Van Heuvelen et al., 1998) categorizes the subjects' daily activities into 3 different physical activity levels according to the metabolic index units (METs), namely light (<4 METs), moderate (4-5.5 METs), and heavy (>5.5 METs) reflecting the energy expenditure (Tsang & Hui-Chan, 2003). Assessment sessions were arranged pre- and post-intervention.

The study protocol was approved by the Ethics Committee of The Hong Kong Polytechnic University, and informed consent was obtained from all subjects. Those who could not sign used their fingerprint as a signature. The outline of the trial and the randomization process are shown in Figure 4.1.

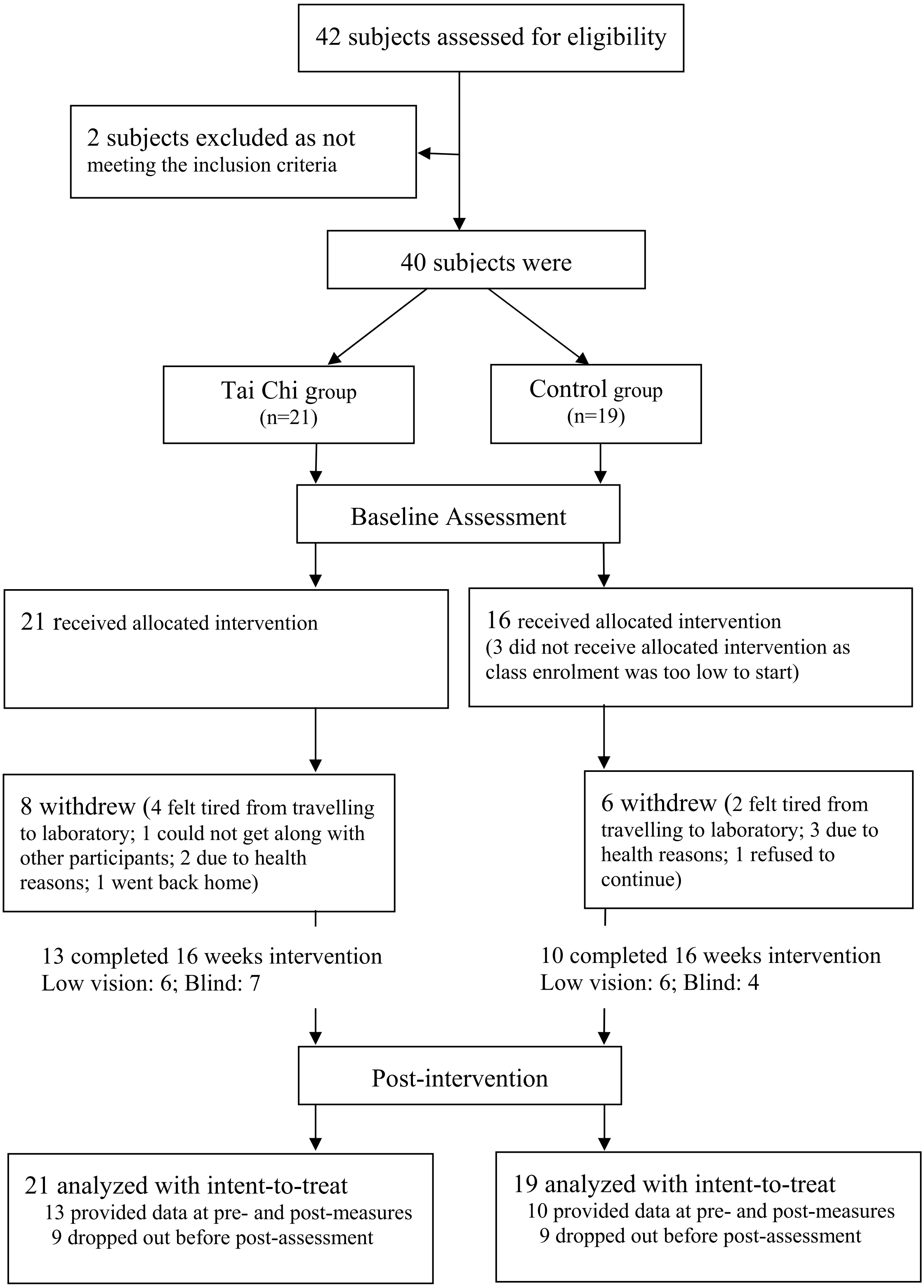

Figure 4.1: Flow chart of subjects recruited in the Tai Chi and control groups

4.3.2 Training protocol

Training for each group was conducted at their respective centers. Both groups participated in 1.5 hours sessions, three times per week for 16 weeks. Their attendance was recorded. Each session consisted of 15 minutes of warm up, 1 hour of either Tai Chi or music percussion training, and 15 minutes of cool down. The warm up and cool down components involved stretching of the upper and lower limbs.

Subjects in the Tai Chi group were taught by an experienced Tai Chi master and his assistants how to perform a modified 8-form Yang style Tai Chi routine (refer to Figure 2.2). The style retained the traditional Tai Chi forms and emphasized multi-directional weight shifting, head and trunk rotation, and awareness of body alignment. Verbal cuing and physical guidance were given to help the participants in practicing the movements more easily. Subjects in the control group participated in a music percussion activity which involved mostly sitting. The subjects were taught how to play the Djembe, a percussion instrument.

4.3.3 Test Procedures

4.3.3.1 Passive knee joint repositioning test

A passive knee joint repositioning test was used to test knee proprioception. The dominant leg, determined by kicking a ball, was tested using a Cybex Norm dynamometer (Cybex International Inc., Ronkonkoma NY). An air splint at an air pressure of 20 mm Hg was applied to the tested ankle to minimize cutaneous input.

A malleable electrogoniometer (Penny and Giles Biometric Ltd., type XM180, Blackwood, UK) was attached to the lateral aspect of the knee to measure the angle. The subject was blindfolded to begin the test. The knee was passively extended at a constant angular velocity of approximately 3 degrees/second from the initial position of 30 degrees of knee flexion. After 3 degrees of extension, it was held for 3 seconds in the target position before being returned passively to the initial position. The subject was instructed to press a thumb switch when he or she perceived that the knee had regained the previous target position. However, a random interval of 3 to 8 seconds before extension was included to minimize the possibility of subjects "counting" to return the knee to the target position. A surface electrode (NeuroCom International Inc., Portland OR) was used to detect electromyographic activity in the thenar eminence muscles to indicate the moment they perceived the knee had regained the target position. Each subject completed 3 trials. The average of the 3 absolute error values, termed the absolute angle error, was used to compare the groups. High test-retest reliability (0.9 with a confidence interval of 0.64-0.97) has been demonstrated for this procedure in a previous study (Tsang & Hui-Chan, 2003).

4.3.3.2 Muscle strength

The Cybex Norm dynamometer was also used to test the concentric isokinetic strength of the knee extensors and flexors of the dominant leg. These were measured at an angular velocity of 30 degrees/second. Prior to testing, the subject's leg dominance was verified by having them kick a ball, and they were then required to complete a 5-minute routine stretching the knee muscle groups. Each subject first completed 3 sub-maximal practice trials. After the practice trials, five test trials with the subject using maximum force were recorded with the concentric knee extensors and flexors. The ICC for this test have been established in a previous study to range from 0.86 to 0.97 (Tsang & Hui-Chan, 2005).

4.3.3.3 Sensory organization test

A sensory organization test (SOT) was used to quantify an individual's ability to maintain balance in a variety of complex sensory conditions. Subjects were required to stand on a force platform with as little sway as possible for 20 seconds under six sensory conditions. Three trials were performed for each condition. The force data collected was used to estimate the body sways angles in the anteroposterior direction. The three trials for each condition were averaged for statistical comparison. The reliability of this procedure has been established in a previous study with ICC ranging from 0.72 to 0.93 for the six conditions (Tsang et al., 2004).

4.3.3.4 Perturbed double-leg stance test

The perturbed double-leg stance test (PDLST) measured the ability of the automatic motor system to rapidly recover after a sudden external disturbance. Subjects stood on a platform that translated in the forward and backward directions. These movements were dependent on the subject's height and were applied in random with the subject's eyes open and closed. The average body sway angle was recorded for 2 seconds before the platform movement to establish a baseline. After the platform perturbation, the perturbed body sway angle was calculated as the difference between the maximum body sway angle and the baseline value. The two groups were compared using the average perturbed body sway angle of three trials, both forward and backward. If any subject fell during the platform movement, a value of 12.5 degrees—the theoretical anteroposterior sway stability limit—was recorded. A "fall" was given if the subject touched the visual surround for support, or gained support by stepping forward or backward, or required support from the investigators.

4.3.4 Statistical Analysis

The groups' average ages, heights, weights and MMblind scores were compared using independent t-tests. A chi-squared test was applied for between-group comparison of gender, the level of visual impairment, and FAC. To compare any changes in the outcome measures, percentage changes were calculated between the two groups after intervention. Intention to treat with last observation carried forward design was employed for the missing data. Since there was a comparatively large drop-out subjects in the two groups, an on-protocol analysis was also conducted (Portney & Watkins 2009). The passive knee joint repositioning test results were compared using an independent t-test. For the muscle strength, SOT and PDLST results, multivariate analysis of variance was used to determine the significance of the observed differences. Univariate tests were used if a significant difference was found in the multivariate analyses of variance. The baseline outcome measures were compared by independent t-test. A significance level of 0.05 was chosen for statistical comparison.

4.4 Results

4.4.1 Subjects

Forty subjects were randomly allocated into either the Tai Chi group (n=21) or the control group (n=19). Table 4.1 summarizes the relevant demographic data and shows that there were no significant differences between the two groups. The subjects in the Tai Chi and control groups were similar with respect to age, gender, height, weight, MMblind score, vision level and functional ambulation level. After subjects dropped out, there were 6 subjects with low vision and 7 blind subjects remained in Tai Chi group, while there were 6 subjects with low vision and 4 blind subjects in control group. There was no significantly difference in proportions of low vision and blind subjects between two groups after dropping out. The intention to treat with last observation carried forward design achieved higher effect sizes of the outcome measures, therefore the results from such design were reported in the present study.

Table 4.1: Demographic characteristics of the Tai Chi and control groups

Characteristics	**Control Group (n=19)**	**Tai Chi Group (n=21)**	***p***
Age (years)	82.9 ± 7.5	85.5 ± 6.9	0.264
Gender (male/female)	2 /17	1 /20	0.489
Height (cm)	148.3 ± 6.1	144.8 ± 6.5	0.086
Weight (kg)	54.5 ± 9.8	49.2 ± 7.5	0.059
MMblind	15.3 ± 3.9	15.3 ± 3.8	0.954
Vision level			0.301
Low vision	n = 13	n = 11	
Blind	n = 6	n = 10	
FAC			0.675
Category 3	n = 8	n = 7	
Category 4	n = 4	n = 7	
Category 5	n = 7	n = 7	

NOTE. Values are mean ± SD
Abbreviations: MMblind, Mini-Mental Status Examination version for visual impairment; FAC, Functional ambulation classification.

4.4.2 Passive knee joint repositioning test

Figure 4.2 shows that the Tai Chi group members had a significant decrease in the percentage change of absolute angle error (-25.9±28.8%, p = 0.032) that was not evident in the control group (4.2±30.7%).

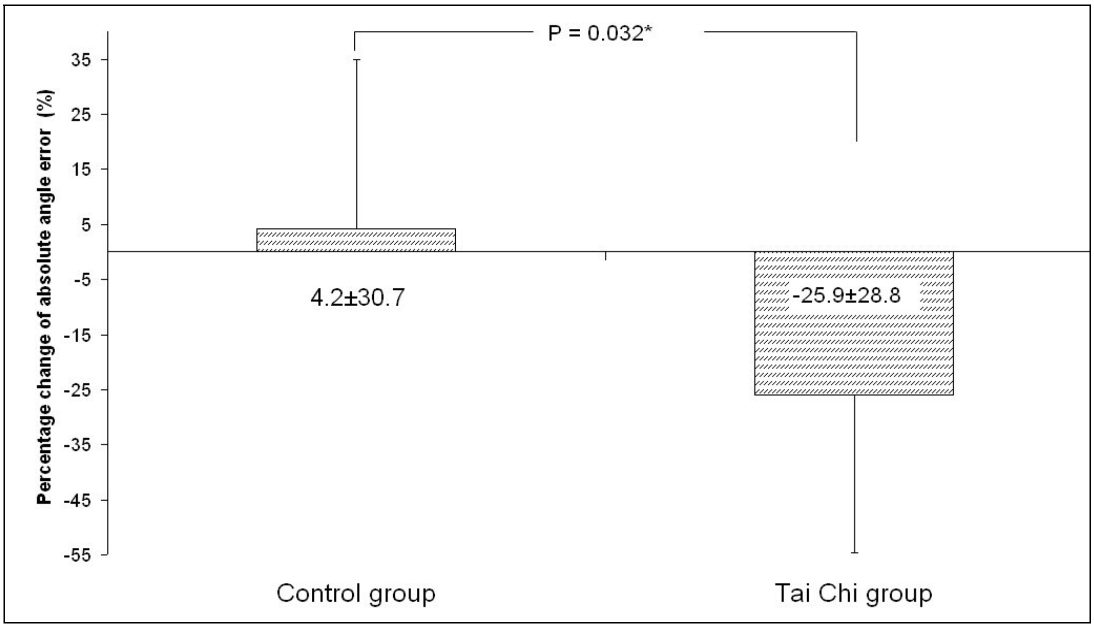

Figure 4.2 Percentage change in absolute angle error of passive knee joint repositioning after training
* Denotes a difference significant at the $p < 0.05$ confidence level

4.4.3 Muscle strength

There was no significant difference between the two groups in terms of the percentage change in the concentric isokinetic knee extensor or flexor strength of their dominant legs (MANOVA $p = 0.379$; Figure 4.3).

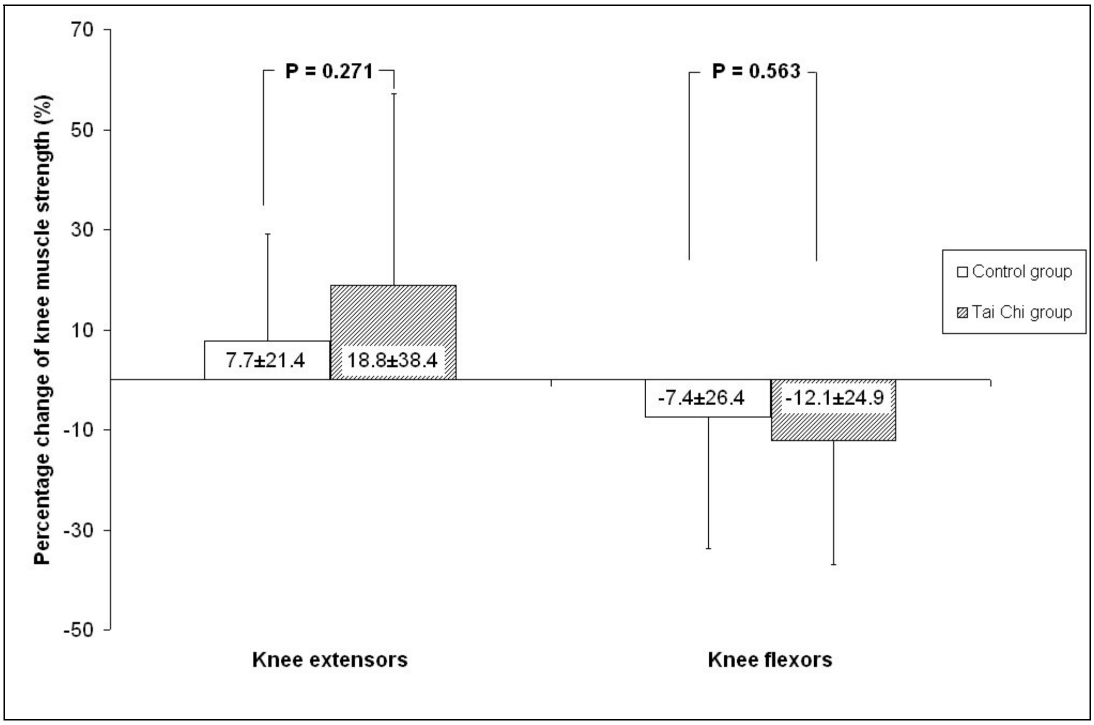

Figure 4.3 Percentage change in knee muscle strength after training

4.4.4 Sensory organization test

The multivariate ANOVA of the SOT results showed an overall significant difference between the two groups (p = 0.024; Figure 4.4). The univariate tests indicated differences in the groups' visual and vestibular ratios. The Tai Chi trainees showed a significantly greater percentage change of the visual ratio (58.1±41.9%) compared to the control group (-1.6±29.4%; p = 0.006). In addition, the Tai Chi group achieved a greater percentage improvement in the vestibular ratio (32.5±40.2%) compared to control group (-17.8±56.8%; p = 0.048).

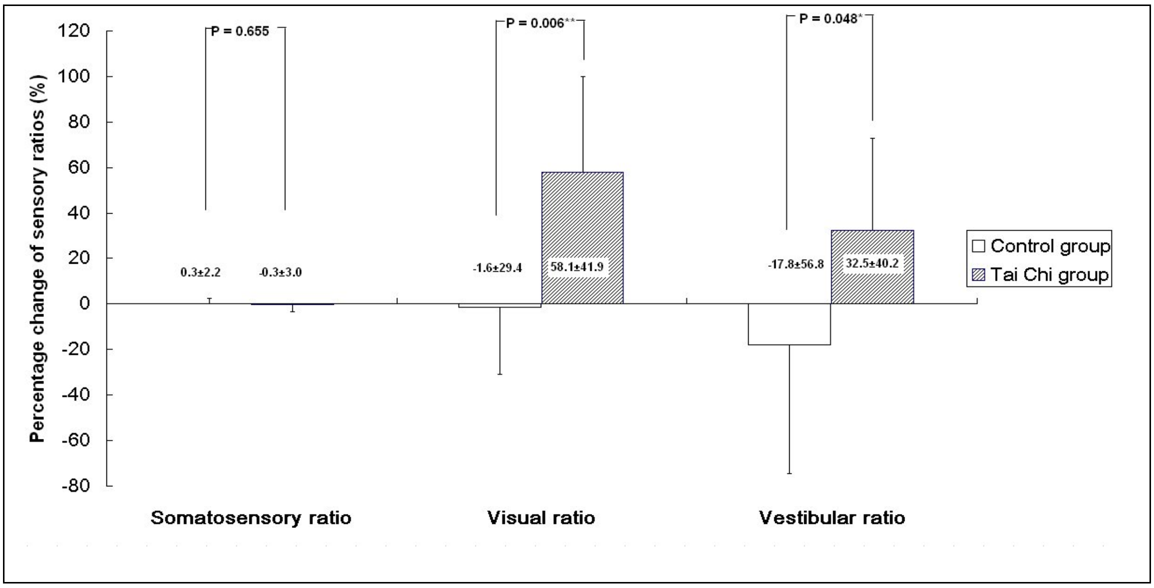

Figure 4.4 Percentage change in sensory ratios after training
* Denotes at difference significant at the $p < 0.05$ (** $p < 0.01$) level of significance

4.4.5 Perturbed double-leg stance test

The multivariate testing of the PDLST results indicated no statistically significant difference between the two groups ($p = 0.077$; Figure 4.5) when the subjects performed the test with their eyes closed.

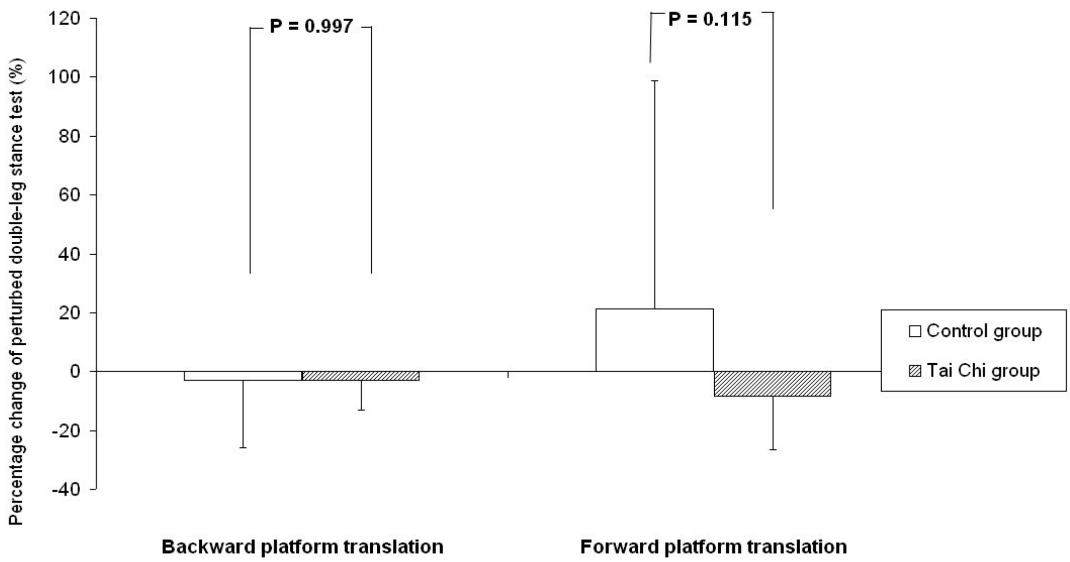

Figure 4.5 Percentage change in perturbed double-leg stance test results after training

4.4.6 Data analysis excluding male subjects

Since the performance of limited number of male subjects may influence the overall group performance, we exclude the data of male subjects in the analysis. However, there was no difference in the results as compared with the results from combined data of male and female subjects.

4.4.7 Comparison of baseline data

There was a significant difference in visual ratio of the sensory organization test when the baseline values of the two groups were compared (p = 0.023; Table 4.2).

Table 4.2: Results of the outcome measures, showing the pre and post intervention data of the two groups, percentage changes, the p values and their effect size.

Outcome measures	Control subjects			Tai Chi subjects				
	pre	post	Percentage change (%)	pre	post	Percentage change (%)	p	Effect size
Knee joint reposition sense error (degree)	4.7±2.9	4.9±3.0	4.2±30.7	3.5±3.2	2.3±2.0	-25.9±28.8	0.032	0.219
Knee muscle strength (N·m/kg)							0.379	
Extensors	0.70±0.40	0.74±0.42	7.7±21.4	0.70±0.34	0.77±0.32	18.8±38.4	0.271	0.032
Flexors	0.34±0.21	0.32±0.23	-7.4±26.4	0.42±0.18	0.38±0.20	-12.1±24.9	0.563	0.009
Sensory organization test							0.024	
Somatosensory ratio	0.99±0.02	0.99±0.02	0.3±2.2	1.00±0.02	1.00±0.02	-0.3±3.0	0.655	0.014
Visual ratio	0.52±0.22	0.59±0.16	-1.6±29.4	0.27±0.25*	0.57±0.20	58.1±41.9	0.006	0.411
Vestibular ratio	0.38±0.29	0.39±0.27	-17.8±56.8	0.38±0.24	0.51±0.22	32.5±40.2	0.048	0.235
PDLST (degree)							0.077	
Backward perturbation	6.2±2.9	6.1±3.3	-2.8±23.0	5.6±3.1	5.5±3.2	-2.8±10.4	0.997	0.000
Forward perturbation	5.9±3.4	6.7±3.8	21.2±77.6	5.7±2.5	5.0±2.2	-8.3±18.1	0.115	0.068

* Denotes significant difference at P<0.05 level when the baseline values of the two groups were compared

4.5 Discussion

Most previous studies of the benefits of Tai Chi exercise have been limited to sighted subjects. The results of this study provide insight into the effect of Tai Chi training on balance control in visually impaired elderly persons. They show that very old persons with visual impairment can improve their knee proprioception and balance control through 16 weeks of Tai Chi practice.

Such practice requires conscious awareness of body position and extremity movements, which may improve joint proprioception. This study's results agree with those of a previous study by Li, Xu, & Hong (2008), who reported that the knee joint proprioception of persons with normal vision could be improved with 16 weeks of Tai Chi training. This study extends those findings to very old visually impaired people. Finding an appropriate activity or exercise to improve joint proprioception is important because it is a key determinant of quantitative balance performance for those older than 80 years (Camicioli, Panzer, & Kaye, 1997).

Tai Chi is performed in a semi-squatting posture that places a substantial load on the leg muscles and has been shown to strengthen them (Tsang & Hui-Chan, 2005; Xu, Li, & Hong, 2006). Previous studies conducted with sighted elderly all concluded that long-term Tai Chi practitioners had better knee muscle strength than matched non-practitioners. This study did not find significant differences in the concentric muscle strength of the knee extensors and flexors between the two groups after training, but 16-weeks of Tai Chi with 8-forms may not be long enough to generate a statistically significant training effect in very old subjects.

A previous study (Tsang et al., 2004) involving sighted elderly subjects reported that long-term Tai Chi practitioners had significantly better balance control under reduced or conflicting sensory conditions than those who did not practice Tai Chi. That study used somatosensory, visual and vestibular ratios as outcome measures and found that Tai Chi practitioners achieved higher visual and vestibular ratios. This study had similar findings with visually impaired very old subjects.

The lack of a significant improvement in somatosensory ratios may be due to a ceiling effect. The somatosensory ratio was calculated using the EQ of conditions 1 and 2 of the SOT to quantify the extent of stability loss when the subject closes their eyes while standing on a fixed support. As we found in our cross-sectional study (Chapter 3), the subjects had high EQ (> 90%; Figure 3.1) and that visual impairment might not influence the postural sway in unchallenging conditions, that is conditions 1 and 2 of the sensory organization test. Thus, lack of change in the EQ of conditions 1 and 2 after intervention, and subsequent change in the somatosensory ratio, could be due to the ceiling effect.

The visual ratio was calculated using the EQ of conditions 1 and 4 to quantify the extent of stability loss when somatosensory input was disrupted with the subjects' eyes open. Although the Tai Chi trainees showed an improvement in their visual ratios, the changes might be due to a gain in their vestibular acuity, because the SOT cannot eliminate its influence in condition 4. Body sway is comparatively great in that condition and the role of vestibular input may be more significant. In addition, the subjects, although having poor or no vision, may still have been able to perceive some visual input and the Tai Chi training, which involves eye and head motion, may have been able to improve their ability to use their remaining vision to control their balance more effectively.

Vestibular ratio was calculated using the EQ of conditions 5 and 1 to reflect the relative reduction in stability when there is no visual help and erroneous somatosensory inputs. This required subjects to rely on their vestibular input alone for balance control. Repeated head movement is one of the important elements in Tai Chi, which can help to stimulate the vestibular system to improve balance control (Tsang & Hui-Chan, 2004).

The Tai Chi trainees tended to perform better than the control group on the PDLST during forward platform perturbations with their eyes closed, but the difference was not statistically significant. It is possible that this finding could be related to the knee muscle strength of the subjects. Performance on the PDLST has been found to correlate with knee muscle strength (Tsang & Hui-Chan, 2005). Subjects require sufficient lower extremity muscle strength to help control the body and counteract the forward/backward platform perturbations (Shumay-Cook & Woollacoot, 2007). There was only a slight improvement in the strength of the knee extensors in the Tai Chi group, so the 16 weeks of Tai Chi training was apparently insufficient to allow very old visually impaired subjects to significantly improve their knee muscle strength. That might in turn explain why there was no statistically significant improvement in balance control in the face of platform perturbations.

Tai Chi was safely practiced by all the visually impaired elderly subjects in the study. All the participants in the Tai Chi group showed interested in practicing Tai Chi. Although some subjects dropped out because they were unwilling to travel to the laboratory for assessments, they continued to attend the Tai Chi classes because they enjoyed the practice. Tai Chi is a moderate exercise in which individuals normally will not exceed 55% of their maximum oxygen intake and 60% of their maximum heart rate (Li et al., 2001). It needs neither much space nor any equipment. This makes it a suitable form of exercise for older people with visual impairment.

The limitations to this study which may restrict the generalisation of its results include the small sample size and its focus primarily on elderly persons living in residential care homes. In the Tai Chi classes the very old subjects with visual impairment required more verbal and physical guidance as well as more time to learn the Tai Chi forms, compromising the comparability of these data with those from other studies. There was also a significant dropout rate attributed to the long distance to the laboratory for assessments and subjects' health problems. Clinical balance assessments that can be carried out at the participants' institutions would help to decrease the dropout rate.

The low vision and blind subjects were grouped together for statistical analysis. Factors such as having different baselines for balance control and degrees of learning Tai Chi could affect the interpretation of the results. Further investigation is warranted. The low baseline value would have influenced the percentage change since the small improvement after intervention could result in a bigger percentage change. Also, this study needs to be extended to involve community dwelling elderly persons, who tend to be more independent and could benefit differently from the training. Additional work might profitably investigate the effect of Tai Chi training on elderly persons with different degrees of visual impairment, particularly its impact on the incidence of falls.

In conclusion, practicing Tai Chi has been shown to improve the balance control of visually impaired elderly persons. After 16 weeks of Tai Chi training, elderly subjects with visual impairment had better knee proprioception and showed improvements in balance control under conditions requiring increased reliance on the visual and vestibular systems.

CHAPTER 5

SUMMARY AND CONCLUSION

5.1 Rationale for the study

Visual impairment is the disability that affects the largest number of people worldwide (WHO, 2008). It is well known to progress rapidly with age (Congdon et al., 2004; Klaver et al., 1998). Good balance is necessary to control body movement, and individuals with vision loss have been shown to have poorer balance (Ray et al., 2008). Some suggest that people with vision loss rely more on their proprioceptive and/or vestibular systems for balance (Di Girolamo et al., 1999; Elliott et al., 1995). However, with aging there is also a deterioration of joint proprioception and vestibular acuity (Baloh et al., 2003; Skinner et al., 1984; Tsang & Hui-Chan, 2004), making balance control a major problem for older individuals, especially those whose visual impairments are relatively serious (Lee & Scudds, 2003; Maeda et al., 1998). Previous studies looking at balance control in the elderly have focused on those with adequate vision, so one of the objectives of this study was to investigate whether the ability to control balance in the elderly differs with varying degrees of visual impairment.

Regular exercise is important for maintaining physical fitness, and it generates the same positive physiological and psychological benefits in individuals with visual impairment as in anyone else (Taylor-Piliae, 2003; Leverenz, 2009). However, older individuals who are visually impaired are less physically active than the sighted elderly (Crews & Campbell, 2001), and as a result have diminished physical functioning and well-being (Chia et al., 2004; Salive et al., 1994). In any attempt to remedy this, the choice of exercise should be safe, easy and convenient enough for such individuals. Tai Chi has been recommended as an appropriate type of exercise that could meet their needs (Miszko et al., 2004). A number of studies with the sighted elderly have proven that the benefits of Tai Chi training include improvements in balance control, increases in muscle strength, and reduced incidence of falls (Hong et al., 2000; Tsang & Hui-Chan, 2005; Wolf et al., 1996). This study, therefore, investigated the effects of Tai Chi on balance control in elderly subjects with visual impairment.

5.2 Summary of results

1) Vision plays an important role in controlling balance in challenging circumstances in that visual information from the environment is an important source of feedback. Having a visual impairment may not, however, influence postural sway in unchallenging conditions.
2) The blind elderly sway significantly more after being perturbed either forward or backward while standing than those with partial or normal visual. According to the 'two-mode' theory of vision, it is possible that the sighted and low vision elderly have adequate ambient cues to react to perturbation, while our blind elderly do not.
3) Visual acuity does not influence performance on the five times sit-to-stand test, since no significant difference among the three groups was found in this study.
4) Having poor vision correlates with fear of falling. The elderly with low vision tested in this study had greater fear of falling than their sighted counterparts.
5) A modified 8-form Yang style Tai Chi routine can be practiced safely by visually impaired elderly persons.

6) Sixteen weeks of Tai Chi training improves the knee proprioception of very old persons with visual impairment.
7) Sixteen weeks of training in this modified 8-form Yang style Tai Chi is not long enough to induce increased leg strength in very old visually impaired persons.
8) After 16 weeks of Tai Chi training, elderly persons with visual impairment showed improved standing balance control in situations demanding an increased reliance on visual and vestibular cues.
9) The Tai Chi trainees tended to perform better than the control group in response to forward perturbations with eyes closed in double-leg stance. However, 16-week of training with the Tai Chi routine used in this study was insufficient for very old visually impaired subjects to improve their knee muscle strength and, as a result, they were unable to show significantly improvements in standing balance control in response to perturbations.

5.3 Recommendations

There are limitations to this study that restrict the generalisation of its results. The sample size was small. Further study of this topic should take steps to involve a larger sample.

In addition, the study focused on persons living in residential care homes where they are well taken care of and do not need to encounter many of the situations asked about in the FES-I questionnaire. For these questions, they were asked to imagine the situation and guess how concerned about falling they would be. It is possible that they overestimated their abilities and were not as concerned about falling as they should have been. This part of the study might profitably be repeated with community dwelling subjects. Such subjects tend to be more independent and perhaps could benefit more from the training.

Although the visual acuity of each subject was verified, other aspects of vision that degrades with aging such as contrast sensitivity, central processing of visual input and visual perception were not tested. These might make important contributions to balance control in the elderly (Lord, Clark, & Webster, 1991; Teasdale, Stelmach, Breunig, & Meeuwsen, 1991).

The subjects with visual impairment required more assistance while performing Tai Chi, in the form of verbal cues and physical guidance. In addition, they needed more time to learn the Tai Chi forms. This differential treatment may have influenced the scientific validity of the control group. Further work in this area needs to pay attention to overcoming this difficulty.

The study had a significant dropout rate that was due mainly to travelling to the laboratory for assessment and the subjects' health problems. Assessments which can be carried out at their institutions would be beneficial to help reduce the dropout rate.

The low vision and blind subjects were grouped together in the statistical analysis of the results. Factors such as their having different baselines for balance control and different degrees of success in learning Tai Chi could have affected the validity of the analysis. Further investigation with protocols which overcome these difficulties is warranted.

Additional work might profitably investigate the effects of Tai Chi practice on elderly persons with more varied degrees of visual impairment and the relationship with fall incidence requires more precise elucidation.

Appendix A

Functional Ambulation Classification[a]

Category		Definition
0	Nonfunctional Ambulation	Patient cannot ambulate, ambulates in parallel bars only, or requires supervision or physical assistance from more than one person to ambulate safely outside of parallel bars.
1	Ambulator - Dependent for Physical Assistance Level II	Patient requires manual contacts of no more than one person during ambulation on level surfaces to prevent falling. Manual contacts are continuous and necessary to support body weight as well as maintain balance and/or assist coordination.
2	Ambulator – Dependent for Physical Assistance Level I	Patient requires manual contact of no more than one person during ambulation on level surfaces to prevent falling. Manual contact consists of continuous or intermittent light touch to assist balance or coordination.
3	Ambulator – Dependent for Supervision	Patient can physically ambulate on level surfaces without manual contact of another person but for safety requires standby guarding of no more than one person because of poor judgment, questionable cardiac status, or the need for verbal cuing to complete the task.
4	Ambulator – Independent Level Surfaces Only	Patient can ambulate independently on level surfaces but requires supervision or physical assistance to negotiate any of the following: stairs, inclines, or non-level surfaces.
5	Ambulator - Independent	Patient can ambulate independently on non-level and level surfaces, stairs, and inclines.

[a] from Holden et al., 1984

Appendix B

香港理工大學
康復治療科學系
<u>同意書</u>

研究題目：太極拳對老年視障人士的平衡控制的研究

研究者： 曾偉男博士
符少娥博士
陳啟明教授
陳瑋小姐
郭清瑩小姐

研究資料：
有研究表明老年視力障礙人士控制平衡的能力低於視力正常的同齡的老人家。而平衡的控制是維持正常功能活動的一個重要能力，如走路，上下樓梯，乘坐電梯等都需要較好的平衡。此外，因為視力障礙，老年人的戶外活動會減少，從而導致肌肉力量的下降，增加跌倒的機率及生活質素的下降。
太極拳是一種身心結合的運動，其動作舒緩，並且不受場地，器械，服裝的局限，不受氣候的影響，受到很多老年人的喜愛。大量研究證實，練習太極能夠提高視力正常的老年人的腿部肌肉力量，改進關節的感覺從而加強平衡的控制能力。但是，現有關太極對老年視障人士效益的研究還沒有結論。因此，通過這項研究，我們希望測試有關太極對老年視障人士的平衡能力，關節感覺及膝部肌肉力量的影響。參與者會被隨機分配到為期三個月的太極班或音樂欣賞班，並與活動班舉行前及完成後進行測試。所有參與者會先填寫相關問卷，以作為鑒別其身體狀況是否適合參與該項研究。

甄選標准：
- 年齡大於70歲。
- 視障人士：以眼科醫師的診斷為准。
- 可獨立的並不需要使用助行器步行。
- 不曾參加太極運動。
- 沒有一下病史: 內耳問題，整形外科（骨科）手術，神經科疾病。

運動班：
參與者會被隨機分配到太極班或音樂欣賞班。太極班的參與者會學習改良的楊式太極拳。在音樂班，參與者主要是坐著學習非洲鼓。兩種活動班都會持續四個月，每周三次課，每次課一個半小時（共48節）。參與者需於活動舉行的四個月間最少出席75%（即36節）的活動班。

測試方法：

參與者將於4個月太極班或音樂班前及完成後參與測試，每次測試需要約90分鐘。所有測試均不會構成任何的危險。測試項目包括：

平衡測試 – 感覺結構測試
關節感覺測試 – 被動膝關節定位測試
肌肉力量的測試 – 向心，離心等速膝關節屈伸力量測試
跌倒評估問卷 – 跌倒機率衡量

同意書：

本人______________已了解此次研究的具體情況。本人願意參加此次研究，本人有權在任何時候、無任何原因放棄參與此次研究，
而此舉不會導致我受到任何懲罰或不公平對待。本人明白參加此研究課題的潛在危險性以及本人的資料將不會洩露給與此研究無關的人員，我的名字或相片不會出現在任何出版物上。

本人可以用電話27666717來聯絡此次研究課題負責人，曾偉男博士或34003957陳瑋小姐。若本人對此研究人員有任何投訴，可以聯系梁女士（部門科研委員會秘書），電話：27665397。本人也明白，參與此研究課題需要本人簽署一份同意書。

參加者簽署：____________________ 日期：____________________

見證人簽署：____________________ 日期：____________________

Appendix C

The Hong Kong Polytechnic University
Department of Rehabilitation Sciences
Consent Form

Project title:
Can Tai Chi improve Balance Control in Elderly Persons with Visual Impairment?

Investigators: Dr. William W. N. Tsang
Dr. Amy S. N. Fu
Prof. K. M. Chan
Ms. Ellen Chen
Ms. Daisy Kwok

Research information:
Previous researches have shown that balance control in older people with visual impairment is poorer when compared to age-matched people without visual impairment. Balance control is an important ability for functional activities like walking, going upstairs or downstairs, taking an elevator and so on. In addition, because of visual impairment, older adults have decreased physical activity which can cause decline in muscle strength, increased falls incidence and reduced quality of life.
Tai Chi is a mind-body exercise with slow, soft and fluid movements. It can be practiced at any time and in any place because it needs neither much space nor equipment. It is popular among elderly persons. A number of studies on elderly persons without visual impairment have proven that Tai Chi can benefit their balance control, lower limb muscle strength, and joint sense. However, the benefits of Tai Chi for visually impaired older adults are not conclusive. Therefore, the objective of the study is to examine the effect of Tai Chi exercise on balance control, joint sense and muscle strength of the knee joint in older adults with visual impairment. Participants will be randomly allocated to either a 3-month Tai Chi or music appreciation class. There will be assessments before and after the whole exercise course. All participants will be screened by questionnaires to ensure there are no medical contraindications.

Inclusion criteria:
- Adults' age ≥70 years old.
- Persons with visual impairment based on diagnosis by an ophthalmologist.
- Able to walk independently.
- No previous Tai Chi experience.
- No history of inner ear problem, orthopaedic operation, neurological disease.

Intervention classes:
Participants will be allocated randomly into either a Tai Chi or a music percussion class. In the Tai Chi group, participants will practice modified Yang style Tai Chi exercise. In the music percussion group, participants will be taught how to play the Djembe which will mostly involve sitting. Both courses will be held for 4 months. Each course will be conducted three sessions per week, 1.5 hour for each session (48 sessions). Participants must attend at least 75% of the sessions (36 sessions) in order to take part in the assessment.

Assessment:
Participants will attend assessment pre- and after the 4-month Tai Chi or music percussion class. Each assessment will take around 90 minutes. There will be no harm caused during the process. Assessments include:

1) Balance test - Sensory Organization Test
2) Joint sense test - Passive knee joint repositioning test
3) Muscle strength test - Concentric and eccentric isokinetic strength of the knee extensors and flexors
4) Fall questionnaire - the Falls Efficacy Scale

Consent

I, ___________________________, have been explained the details of this study. I voluntarily consent to participate in this study. I understand that I can withdraw from this study at any time without giving reasons, and my withdrawal will not lead to any punishment or prejudice against me. I am aware of any potential risk in joining this study. I also understand that my personal information will not be disclosed to people who are not related to this study and my name or photograph will not appear on any publications resulted from this study.

I can contact Dr. William Tsang at telephone 27666717 or Ms. Ellen Chen at 34003957 for any questions about this study. If I have complaints related to the investigators, I can contact Mrs. Michelle Leung, secretary of Departmental Research Committee, at 27665397. I know I will be given a signed copy of this consent form.

Signature (subject): ____________________ Date: _____________

Signature (witness): ____________________ Date: _____________

Appendix D

香港理工大學
康復治療科學系
<u>同意書</u>

研究題目：太極拳對老年視障人士的平衡控制的研究

研究者：曾偉男博士
符少娥博士
陳啟明教授
陳瑋小姐
郭清瑩小姐

研究資料：

有研究表明老年視力障礙人士控制平衡的能力低於視力正常的同齡的老人家。而平衡的控制是維持正常功能活動的一個重要能力，如走路，上下樓梯，乘坐電梯等都需要較好的平衡。此外，因為視力障礙，老年人的戶外活動會減少，從而導致肌肉力量的下降，增加跌倒的機率及生活質素的下降。

太極拳是一種身心結合的運動，其動作舒緩，並且不受場地，器械，服裝的局限，不受氣候的影響，受到很多老年人的喜愛。大量研究證實，練習太極能夠提高視力正常的老年人的腿部肌肉力量，改進關節的感覺從而加強平衡的控制能力。但是，現有關太極對老年視障人士效益的研究還沒有結論。因此，通過這項研究，我們希望測試有關太極對老年視障人士的平衡能力，關節感覺及膝部肌肉力量的影響。參與者會被隨機分配到為期三個月的太極班或音樂欣賞班，並與活動班舉行前及完成後進行測試。所有參與者會先填寫相關問卷，以作為鑒別其身體狀況是否適合參與該項研究。

甄選標准：

- 年齡大於70歲。
- 正常視力
- 可獨立的步行。
- 不曾參加太極運動。
- 沒有一下病史：內耳問題，整形外科（骨科）手術，神經科疾病。

測試方法：

是次研究內的參加者已分為兩組: “上課組” 及 “對照組” 。
此次參加者將獲邀成為 “對照組”(Control group)並進行數項測試,其結果將與”上課組”作比較, 以了解課堂成效。
對照組成員只需接受一次測試。
測試需要約90分鐘。

平衡測試 - 感覺結構測試
關節感覺測試 - 被動膝關節定位測試
肌肉力量的測試 - 向心，離心等速膝關節屈伸力量測試
跌倒評估問卷 – 跌倒機率衡量

同意書：

本人_____________已了解此次研究的具體情況。本人願意參加此次研究,本人有權在任何時候、無任何原因放棄參與此次研究,
而此舉不會導致我受到任何懲罰或不公平對待。本人明白參加此研究課題的潛在危險性以及本人的資料將不會洩露給與此研究無關的人員，我的名字或相片不會出現在任何出版物上。

本人可以用電話27666717來聯絡此次研究課題負責人，曾偉男博士或3400 3957陳瑋小姐。若本人對此研究人員有任何投訴，可以聯系梁女士（部門科研委員會秘書），電話：27665397。本人也明白，參與此研究課題需要本人簽署一份同意書。

參加者簽署：__________________ 日期： __________________

見證人簽署：__________________ 日期： __________________

Appendix E

General health and physical activity questionnaire

Date日期: ___________ Name姓名: _____________
Age年齡: ____________ Gender性別: ____________
Date of birth 出生日期: _____________
Weight 體重: _________ Height 身高: ___________

1) What is your habitual physical activity in the past one year?
   過去一年內空閒時間的活動：
   ____
2) Have you participated in any form of regular formal physical training in recent five years?
   最近五年來有否參與任何正式的運動訓練？
   有 / 否
   如有，是甚麼？ ____
3) What is your education level?
   你的教育程度？ __________________________
4) Do you have the following health problems?
   有否以下的健康問題？
   Cardiopulmonary disease (e.g. COPD) 心肺疾病（慢阻肺）
   有 / 否
   Cardiovascular disease (e.g. HT, DM) 心血管疾病（如高血壓，糖尿病）
   有 / 否
   Middle ear problem or dizziness 頭暈，中耳問題
   有 / 否
   Neck and back pain recently 最近有否頸痛、腰痛
   有 / 否
   Leg pain recently 最近有否腳痛
   有 / 否
   Neurological disease or problems 腦及神經科毛病
   有 / 否
5) Do you have any recent surgery done? 最近有否施行手術?
   有 / 否

6) Are you taking any medication?
   有 / 否
   有否服用任何藥物？
   If yes, indicate type of medication.
   如有，是甚麼藥物？ ________________________
7) Have you had a history of falls?
   有 / 否
   有否跌倒過？
   如有，跌倒次數、經過及治療？ _________________________
8) Do you need any aids for walking? 是否需要輔助工具協助步行？
   有 / 否
   If so, what is it? 如有，是甚麼？ __________________________

Appendix F

Mini-Mental Status Examination version for the Visually Impaired (MMblind)
簡短智能測試

姓名：___________ 性別/年齡：________ 評估日期：________ 評估員：______________

最高分數	分數	
5		**ORIENTATION** 今日係 (星期幾) 今日 (幾號) [接受加減一天] 依家係什麼 (月份) 依家係什麼 (季節) 依家係什麼 (年份)
5		我地依家係邊嗖? [家中 / 老人院 / 老人中心 / 醫院 / 診所] 建築名稱 依嗖係幾樓 依嗖係屬於邊一區，香港 / 九龍 / 新界 依嗖係邊一個地方，例如: 黃大仙、荃灣
3		**REGISTRATION** 依家我會講三樣野既名，講完之後，請你重複一次 --- [蘋果]，[報紙]，[火車] --- 依家請你講番哩三樣野俾我聽。 （以第一次講得計分，一個一分；然後重複物件，直至全部三樣都記得住） 請記住佢地，因為幾分鐘後，我會叫你再講番俾我聽。
5		**ATTENTION & CALCULATION** 請你用一百減七，然後再減七，一路減落去，直到我叫你停為止。 [減5次後便停] 或: 依家我讀幾個數目俾你聽，請你倒轉頭講番出黎 [4 2 7 3 1]
3		**DELAY RECALL** 頭先叫你記住嗰三樣野係咩呀?
1		**LANGUAGE** 請你跟我講句說話 --- “姨丈買魚腸”

總分：_____/ 22

Appendix G

自評跌倒風險量表 (Falls Efficacy Scale International – FES-I)

我們現在要問一些問題, 是關於你關注跌倒可能性的程度

以下每項活動，請想若要是你做這個活動的時候，**關注**自己會因此跌倒的程度。若是說你現在早就已經沒有在做這款活動，請想像你若是現在要你做這款活動，**關注**跌倒的程度。	請選最符合自身情況的選項			
	1 不關注	2 一點關注	3 頗關注	4 極度關注
J1. 家居清潔	□	□	□	□
J2. 穿脫衣服	□	□	□	□
J3. 煮飯	□	□	□	□
J4. 洗澡、淋浴	□	□	□	□
J5. 買東西、購物	□	□	□	□
J6. 從椅子上站起來/坐下	□	□	□	□
J7. 上/落樓梯	□	□	□	□
J8. 在家附近行走	□	□	□	□
J9. 拿高過頭頂/撿地上的東西	□	□	□	□
J10. 趕接電話	□	□	□	□
J11. 走在濕滑的地板	□	□	□	□
J12. 拜訪親友	□	□	□	□
J13. 在人很擠的地方走	□	□	□	□
J14. 走在崎嶇不平(高低、不平)的路上	□	□	□	□
J15. 上/落斜坡	□	□	□	□
J16. 出去參加活動，如去活動中心、教會	□	□	□	□

REFERENCES

1. Al-Abdulwahab SS. The effects of aging on muscle strength and functional ability of healthy Saudi Arabian males. Ann Saudi Med 1999; 19: 211–5.

2. Arfken CL, Lach HW, Birge SJ, Miller JP. The prevalence and correlates of fear of falling in elderly persons living in the community. Am J Public Health 1994; 84: 565–70.

3. Baloh RW, Jacobson KM, Socotch TM. The effect of aging on visual-vestibuloocular responses. Exp Brain Res 1993; 95: 509–16.

4. Baloh RW, Ying SH, Jacobson KM. A longitudinal study of gait and balance dysfunction in normal older people. Arch Neurol 2003; 60: 835–9.

5. Barnett A, Smith B, Lord SR, Williams M, Baumand A. Community-based group exercise improves balance and reduces falls in at-risk older people: A randomized controlled trial. Age Ageing 2003; 32: 407–14.

6. Bulat T, Hart-Hughes S, Ahmed S *et al*. Effect of a group-based exercise program on balance in elderly. Clin Interv Aging 2007; 2: 655–60.

7. Camicioli R, Panzer VP, Kaye J. Balance in the healthy elderly: Posturography and clinical assessment. Arch Neurol 1997; 54: 976–98.

8. Chan KM, Maffulli N, Korkia P, Li RCT, eds. Principles and practice of isokinetics in sports medicine and rehabilitation. Hong Kong: Williams & Wilkins, 1996.

9. Chen EW, Fu ASN, Tsang WWN. Tai chi training improves balance control in subjects with visual impairment. Abstract for the Seventh Pan-Pacific Conference on Rehabilitation. Hong Kong, 2010. P 48.

10. Chia EM, Wang JJ, Rochtchina E, Smith W, Cumming RR, Mitchell P. Impact of bilateral visual impairment on health-related quality of life: The Blue Mountains Eye Study. Invest Ophthalmol Vis Sci 2004 ; 45: 71–6.

11. Chu LW, Chi I, Chiu AYY. Incidence and predictors of falls in the Chinese elderly. Ann Acad Med Singapore 2005; 34: 60–72.

12. Collen FM, Wade DT, Bradshaw CM. Mobility after stroke: Reliability of measures of impairment and disability. Int Disabil Stud 1990; 12: 6–9.

13. Congdon N, O'Colmain B, Klaver CCW *et al.* Causes and prevalence of visual impairment among adults in the United States. Arch Ophthalmol 2004; 122: 477–85.

14. Crews JE, Campbell VA. Health conditions, activity limitations, and participation restrictions among older people with visual impairments. J Vis Impair Blind 2001; 95: 453–67.

15. Csuka M, McCarty DJ. Simple method for measurement of lower extremity muscle strength. Am J Med 1985; 78: 77–81.

16. Di Girolamo S, Di Nardo W, Cosenza A, Ottaviani F, Dickmann A, Savino G. The role of vision on postural strategy evaluated in patients affected by congenital nystagmus as an experimental model. J Vestib Res 1999; 9: 445–51.

17. Dineen BP, Bourne RRA, Ali SM, Huq DMN, Johnson GJ. Prevalence and causes of blindness and visual impairment in Bangladeshi adults: Results of the National Blindness and Low Vision Survey of Bangladesh. Br J Ophthalmol 2003; 87: 820–8.

18. Elliott DB, Patla AE, Flanagan JG *et al.* The Waterloo Vision and Mobility Study: Postural control strategies in subjects with ARM. Ophthalmic Physiol Opt 1995; 15: 553–9.

19. Enrietto JA, Jacobson KM, Baloh RW. Aging effects on auditory and vestibular responses: A longitudinal study. Am J Otolaryngol 1999; 20: 371–8.

20. Fitzpatrick R, McCloskey DI. Proprioceptive, visual and vestibular thresholds for the perception of sway during standing in humans, J Physiol 1994; 478: 173–86.

21. Fletcher PC, Hirdes JP. Restriction in activity associated with fear of falling among community-based seniors using home care services. Age Ageing 2004; 33: 273–9.

22. Folstein MF, Folstein WE, McHugh PR. "Mini-Mental State" A practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res 1975; 12: 189-98.

23. Fong SM, Ng GY. The effects on sensorimotor performance and balance with tai chi training. Arch Phys Med Rehabil 2006; 87: 82–7.

24. Freeman EE, Muñoz B, Rubin G, West SK. Visual field loss increases the risk of falls in older adults: The Salisbury Eye Evaluation. Invest Ophthalmol Vis Sci 2007; 48: 4445–50.

25. Friedman SM, Munoz B, West SK, Rubin GS, Fried LP. Falls and fear of falling: which comes first? A longitudinal prediction model suggests strategies for primary and secondary prevention. J Am Geriatr Soc 2002; 50: 1329–35.

26. Frontera WR, Hughes VA, Lutz KJ, Evans WJ. A cross-sectional study of muscle strength and mass in 45- to 78-yr-old men and women. J Appl Physiol 1991; 71: 644–50.

27. Frontera WR, Hughes VA, Fielding RA, Fiatarone MA, Evans WJ, Roubenoff R. Aging of skeletal muscle: A 12-yr longitudinal study. J Appl Physiol 2000; 88: 1321–6.

28. Harwood RH. Visual problems and falls. Age Ageing 2001; 30-S4, 13–8.

29. Held R. Two modes of processing spatially distributed visual stimulation. In: Schmitt FO, ed. The Neurosciences: Second Study Program. New York: Rockefeller University Press, 1970, 317–23.

30. Ho ST, Mak MKY, Hui-Chan CWY. Balance performance in community-dwelling female elderly fallers and non-fallers in Hong Kong. Abstract for the First Pan Pacific Conference on Rehabilitation. Hong Kong, 1998. P 8.

31. Holden MK, Gill KM, Magliozzi MR, Nathan J, Piehl-Baker L. Clinical gait assessment in the neurologically impaired: Reliability and meaningfulness. Phys Ther 1984; 64: 35–40.

32. Holden MK, Gill KM, Magliozzi MR. Gait assessment for neurologically impaired patients: Standards for outcome assessment. Phys Ther 1986; 66: 1530–9.

33. Hong Kong Blind Union. Epidemiology of visual impairment in Hong Kong. 2001. Retrieved from http://www.hkbu.org.hk/42.0.html

34. Hong Y, Li JX, Robinson PD. Balance control, flexibility, and cardiorespiratory fitness among older tai chi practioners. Br J Sports Med 2000; 34: 29–34.

35. Howe TE, Rochester L, Jackson A, Banks PMH, Blair VA. Exercise for improving balance in older people. Cochrane Database Syst Rev 2007; 4: CD004963.

36. Judge JO, Lindsey C, Underwood M, Winsemius D. Balance improvements in older women: Effects of exercise training. Phys Ther 1993; 73: 254–65.

37. Klaver CCW, Wolfs RCW, Vingerling JR, Hofman A, de Jong PTVM. Age-specific prevalence and causes of blindness and visual impairment in an older population: The Rotterdam Study. Arch Ophthalmol 1998; 116: 653–8.

38. Kollen B, Kwakkel G, Lindeman E. Time dependency of walking classification in stroke. Phys Ther 2006; 86: 618–25.

39. Lan C, Lai JS, Chen SY, Wong MK. 12-month tai chi training in the elderly: Its effect on health fitness. Med Sci Sports Exerc 1998; 30: 345–51.

40. Larsson L, Grimby G, Karlsson J. Muscle strength and speed of movement in relation to age and muscle morphology. J Appl Physiol 1979; 46: 451–6.

41. Laughton CA, Slavin M, Katdare K *et al.* Aging, muscle activity, and balance control: Physiologic changes associated with balance impairment. Gait Posture 2003; 18 : 101–8.

42. Lee HKM, Scudds RJ. Comparison of balance in older people with and without visual impairment. Age Ageing 2003; 32: 643–9.

43. Lee KYT, Jones AYM, Tsang WWN. The kinematics and energy expenditure of sitting tai chi. Am J Chinese Med. (Under review).

44. Legood R, Scuffham P, Cryer C. Are we blind to injuries in the visually impaired? A review of the literature. Inj Prev 2002; 8: 155–60.

45. Leung ESF, Tsang WWN. Comparison of the kinetic characteristics of standing and sitting tai chi forms. Disabil Rehabil 2008; 30: 1891–1900.

46. Leverenz LJ. Visual impairment. In Durstine JL, Moore GE, Painter PL, Robert SO, eds. ACSM's exercise management for persons with chronic diseases and disabilities, 3rd ed. American College of Sports Medicine, 2009. P 393.

47. Li JX, Hong Y, Chan KM. Tai chi: Physiological characteristics and beneficial effects on health. Br J Sports Med 2001; 35: 148–56.

48. Li JX, Xu DQ, Hong Y. Effects of 16-week Tai Chi intervention on postural stability and proprioception of knee and ankle in older people. Age Ageing 2008; 37: 575-8.

49. Lindle RS, Metter EJ, Lynch NA *et al.* Age and gender comparisons of muscle strength in 654 women and men aged 20–93 yr. J Appl Physiol 1997; 83: 1581–7.

50. Lord SR, Clark RD, Webster IW. Postural stability and associated physiological factors in a population of aged persons. J Gerontol 1991; 46: M69–76.

51. Lord SR, Menz HB. Visual contributions to postural stability in older adults. Gerontology 2000; 46: 306–10.

52. Lord SR, Rogers MW, Howland A, Fitzpatrick R. Lateral stability, sensorimotor function and falls in older people. J Am Geriatr Soc 1999; 47: 1077–81.

53. Lord SR, Ward JA. Age-associated differences in sensorimotor function and balance in community-dwelling women. Age Ageing 1994; 23: 452–60.

54. Lord SR, Ward JA. Exercise effect on dynamic stability in older women: A randomized controlled study. Arch Phys Med Rehabil 1996; 77: 232–6.

55. Lundebjerg N, Rubenstein LZ, Kenny RA *et al.* Guideline for the prevention of falls in older persons. J Am Geriatr Soc 2001; 49: 664–72.

56. Maeda AA, Nakamura K, Otomo A, Higuchi S, Motohashi Y. Body support effect on standing balance in the visually impaired elderly. Arch Phys Med Rehabil 1998; 79: 994–7.

57. Martin BJ, Cameron M. Evaluation of walking speed and functional ambulation categories in geriatric day hospital patients. Clin Rehabil 1996; 10: 44–6.

58. Michon JJ, Lau J, Chan WS, Ellwein LB. Prevalence of visual impairment, blindness, and cataract surgery in the Hong Kong elderly. Br J Ophthalmol 2002; 86: 133–9.

59. Miszko TA, Ramsey VK, Blasch BB. Tai chi for people with visual impairments: A pilot study. J Vis Impair Blind 2004; 98: 5–13.

60. Mong Y, Teo TWL, Ng SSM. 5-repetition sit-to-stand test in subjects with chronic stroke: Reliability and validity. Arch Phys Med Rehabil 2010; 91: 407–13.

61. NeuroCom. Smart EquiTest System Operators Manual (Version 7.04). Clackamas, OR: NeuroCom International Inc., 2000, pp. PO 6–7, LOS 5–7.

62. O'Loughlin JL, Robitaille Y, Boivin JF, Suissa S. Incidence of and risk factors for falls and injurious falls among the community-dwelling elderly. Am J Epidemiol 1993; 137: 342–54.

63. Portney LG, Watkins MP. Validity in experimental design. IN: Foundations of clinical research, 3rd edition. Pearson Education Inc., 2009.

64. Ray CT, Horvat M, Croce R, Mason RC, Wolf SL. The impact of vision loss on postural stability and balance strategies in individuals with profound vision loss. Gait Posture 2008; 28: 58–61.

65. Reischies FM, Geiselmann B. Age-related cognitive decline and vision impairment affecting the detection of dementia syndrome in old age. Br J Psychiatry 1997; 171: 449–51.

66. Resnikoff S, Pascolini D, Etya'ale D *et al.* Global data on visual impairment in the year 2002. Bull World Health Organ 2004; 82: 844–51.

67. Rubenstein LZ, Josephson KR. The epidemiology of falls and syncope. Clin Geriatr Med 2002; 18: 141–58.

68. Salive ME, Guralnik J, Glynn RJ, Christen W, Wallace RB, Ostfeld AM. Association of visual impairment with mobility and physical function. J Am Geriatr Soc 1994; 42: 287–92.

69. Sattin RW. Falls among older persons: A public health perspective. Ann Rev Public Health 1992; 13: 489–508.

70. Sattin RW, Easley KA, Wolf SL, Chen Y, Kutner MH. Reduction in fear of falling through intense tai chi exercise training in older, transitionally frail adults. J Am Geriatr Soc 2005; 53: 1168–78.

71. Scheffer AC, Schuurmans MJ, van Dijk N, van der Hooft T, de Rooij SE. Fear of falling: Measurement strategy, prevalence, risk factors and consequences among older persons. Age Ageing 2008; 37: 19–24.

72. Shumay-Cook A, Woollacoot MH. Normal postural control. In: Shumay-Cook A, Woollacoot MH, eds. Motor control: Translating research into clinical practice, 3rd ed. New York: Lippincott William & Wilkins, 2007, P 167.

73. Skinner HB, Barrack RL, Cook SD. Age-related decline in proprioception. Clin Orthop Relat Res 1984; 184: 208–11.

74. Stones MJ, Kozma A. Balance and age in the sighted and blind. Arch Phys Med Rehabil 1987; 68: 85–9.

75. Sturnieks DL, St George R, Lord SR. Balance disorders in the elderly. Neurophysiol Clin 2008; 38: 467–78.

76. Taylor-piliae RE. Tai Chi as an adjunct to cardiac rehabilitation exercise training. J Cardiopulm Rehab 2003; 23: 90–6.

77. Teasdale N, Stelmach G, Breunig A, Meeuwsen H. Age differences in visual sensory intergration. Exp Brain Res 1991; 85:691–6.

78. Tinetti ME, Richman D, Powell L. Falls efficacy as a measure of fear of falling. J Gerontol 1990; 45: 239–43.

79. Tinetti ME, Speechley M, Ginter SF. Risk factors for falls among elderly persons living in the community. New Eng J Med 1988; 319: 1701–7.

80. Tsang WWN, Hui-Chan CWY. Effects of tai chi on joint proprioception and stability limits in elderly subjects. Med Sci Sports Exerc 2003; 35: 1962–71.

81. Tsang WWN, Hui-Chan CWY. Effect of 4- and 8-wk intensive tai chi training on balance control in the elderly. Med Sci Sports Exerc 2004; 36: 648–57.

82. Tsang WWN, Hui-Chan CWY. Effects of exercise on joint sense and balance in elderly men: Tai chi versus golf. Med Sci Sports Exerc 2004; 36: 658–67.

83. Tsang WWN, Hui-Chan CWY. Comparison of muscle torque, balance, and confidence in older tai chi and healthy adults. Med Sci Sports Exerc 2005; 37: 280–9.

84. Tsang WWN, Wong VS, Fu SN, Hui-Chan CWY. Tai chi improves standing balance control under reduced or conflicting sensory conditions. Arch Phys Med Rehabil 2004; 85: 129–37.

85. Tse SK, Bailey DM. Tai chi and postural control in well elderly. Am J Occup Ther 1992; 46: 295–300.

86. Vandervoort AA. Aging of the human neuromuscular system. Muscle Nerve 2002; 25: 17–25.

87. Van Heuvelen MJ, Kempen GI, Ormel J, Rispens P. Physical fitness related to age and physical activity in older persons. Med Sci Sports Exerc 1998; 30: 434–41.

88. Wallmann HW. Comparision of elderly nonfallers and fallers on performance measures of functional reach, sensory organization, and limits of stability. J Gerontol A, Bio Sci Med Sci 2001; 56: M580–3.

89. Watson GR. Low vision in the geriatric population: Rehabilitation and management. J Am Geriatr Soc 2001; 49: 317–30.

90. Whitney SL, Wrisley DM, Marchetti GF, Gee MA, Redfern MS, Furman JM. Clinical measurement of sit-to-stand performance in people with balance disorders : Validity of data for the five-times-sit-to-stand test. Phys Ther 2005; 85: 1034–45.

91. Wolf SL, Barnhart HX, Ellison GL, Coogler CE. The effect of *tai chi quan* and computerized balance training on postural stability in older subjects. Phys Ther 1997; 77: 371–84.

92. Wolf SL, Barnhart HX, Kutner NG, McNeely E, Coogler C, Xu T. Reducing frailty and falls in older persons: An investigation of tai chi and computerized balance training. J Am Geriatr Soc 1996; 44: 489–97.

93. Wong AM, Lin YC, Chou SW, Tang FT, Wong PY. Coordination exercise and postural stability in elderly people: Effect of *tai chi chuan*. Arch Phys Med Rehabil 2001; 82: 608–12.

94. World Health Organization. International statistical classification of disease and related health problems, 10th revision, 2007. Chapter VII. H54. Blindness and low vision. Retrieved from: http://www.who.int/classifications/icd/en/

95. World Health Organization. Global burden of disease, 2004 update. Part 3: Disease incidence, prevalence and disability, 2008, P 5–6. Retrieved from: http://www.who.int/healthinfo/global_burden_disease/2004_report_update/en/index.html

96. Wu G, Liu W, Hitt J, Millon D. Spatial, temporal and muscle action patterns of tai chi gait. J Electromyogr Kinesiol 2004; 14: 343–54.

97. Xu D, Hong Y, Li J, Chan K. Effect of tai chi exercise on proprioception of ankle and knee joints in old people. Br J Sports Med 2004; 38: 50–4.

98. Xu DQ, Li JX, Hong Y. Effect of long-term tai chi practice and jogging exercise on muscle strength and endurance in older people. Br J Sports Med 2006; 40: 50–4.

99. Yardley L, Beyer N, Hauer K, Kempen G, Piot-Ziegler C, Todd C. Development and initial validity of the Falls Efficacy Scale-International (FES-I). Age Ageing 2005; 34: 614–9.